ANTI-ADDL ANTIBODIES AND USES THEREOF

Introduction

This application claims the benefit of priority from U.S. provisional patent application Serial Nos. 60/621,776, filed October 25, 2004, 60/652,538, filed February 14, 2005, 60/695,526 filed June 30, 2005 and 60/695,528 filed June 30, 2005 whose contents are incorporated herein by reference in their entireties.

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Background of the Invention

Alzheimer's Disease is a progressive and degenerative dementia (Terry, et al. (1991) *Ann. Neurol.* 30:572-580; Coyle (1987) In: *Encyclopedia of Neuroscience*, Adelman (ed.), Birkhäuser, Boston-Basel-Stuttgart, pp 29-31,). In its early stages, Alzheimer's Disease manifests primarily as a profound inability to form new memories (Selkoe (2002) *Science* 298:789-791), reportedly due to neurotoxins derived from amyloid beta (Aβ). Aβ is an amphipathic peptide whose abundance is increased by mutations and risk factors linked to Alzheimer's Disease. Fibrils formed from Aβ constitute the core of amyloid plaques, which are hallmarks of an Alzheimer's Disease brain. Analogous fibrils generated *in vitro* are lethal to cultured brain neurons. These findings indicate that memory loss is a consequence of neuron death caused by fibrillar Aβ.

Despite strong experimental support for fibrillar Aβ and memory loss, a poor correlation exists between dementia and amyloid plaque burden (Katzman (1988) *Ann. Neurol.* 23:138-144). Moreover, transgenic hAPP mice (Dodart, et al. (2002) *Nat. Neurosci.* 5:452-457; Kotilinek, et al. (2002)

J. Neurosci. 22:6331-6335), which develop age-dependent amyloid plaques and, most importantly, age-dependent memory dysfunction, show that within 24 hours of vaccination with monoclonal antibodies against Aβ memory loss can be reversed with no change in plaque levels. Such findings are not consistent with a mechanism for memory loss dependent on neuron death caused by amyloid fibrils.

Additional neurologically active molecules formed by Aβ self-assembly have been suggested. These molecules include soluble Aβ oligomers, also referred to as Aβ-derived diffusible ligands or ADDLs. Oligomers are metastable and form at low concentrations of Aβ1-42 (Lambert, et al. (1998) *Proc. Natl. Acad. Sci. USA* 95:6448-6453). Aβ oligomers rapidly inhibit long-term potentiation (LTP), a classic experimental paradigm for memory and synaptic plasticity. As such, memory loss stems from synapse failure, prior to neuron death and synapse failure by Aβ oligomers, not fibrils (Hardy & Selkoe (2002) *Science* 297:353-356). Soluble oligomers have been found in brain tissue and are strikingly elevated in Alzheimer's Disease (Kayed, et al. (2003) *Science* 300:486-489; Gong, et al. (2003) *Proc. Natl. Acad. Sci. USA* 100:10417-10422) and in hAPP transgenic mice Alzheimer's Disease models (Kotilinek, et al. (2002) *J. Neurosci.* 22:6331-6335; Chang, et al. (2003) *J. Mol. Neurosci.* 20:305-313).

A variety of Alzheimer's Disease treatment options have been suggested. Vaccine clinical trials have revealed that persons mounting a vigorous immune response to the vaccine exhibit cognitive benefit (Hock, et al. (2003) *Neuron* 38:547-554); however, frequency of CNS inflammation caused early termination of part of the trial (Birmingham & Frantz (2002) *Nat. Med.* 8: 199-200). As an alternative to a vaccine, therapeutic antibodies that target ADDLs without binding monomers or fibrils have been suggested (Klein (2002) *Neurochem. Int.* 41:345-352). ADDLs are highly

antigenic, generating oligomer-selective polyclonal antibodies in rabbits at concentration of ~50 μg/mL (Lambert, et al. (2001) *J. Neurochem.* 79:595-605). Results from transgenic mice models also suggest that antibodies can be successful in reversing memory decline (Dodart, et al. (2002) *Nat. Neurosci.* 5:452-457). Accordingly, there is a need in the art for ADDL-selective therapeutic antibodies for the prevention and treatment of Alzheimer's Disease. The present invention meets this need.

Summary of the Invention

The present invention is an isolated antibody, or fragment thereof, capable of differentially recognizing a multi-dimensional conformation of one or more Aβ-derived diffusible ligands. In particular embodiments, the antibody of the present invention is in admixture with a pharmaceutically acceptable carrier. In other embodiments, the antibody of the present invention is in a kit.

Methods for preventing binding of Aβ-derived diffusible ligands to a neuron, inhibiting assembly of Aβ-derived diffusible ligands, and blocking the phosphorylation of tau protein at Ser202/Thr205 employing an antibody or antibody fragment which binds a multi-dimensional conformation of one or more Aβ-derived diffusible ligands are also provided.

The present invention further embraces a method for prophylactically or therapeutically treating a disease associated with Aβ-derived diffusible ligands using an antibody of the instant invention. Administration of an antibody of the invention can prevent binding of Aβ-derived diffusible ligands to a neuron thereby preventing or treating the disease associated with Aβ-derived diffusible ligands.

The present invention is also a method for identifying a therapeutic agent that prevents the binding of Aβ-derived

diffusible ligands to a neuron. This method of the invention involves contacting a neuron with Aβ-derived diffusible ligands in the presence of an agent and using an antibody of the present invention to determine binding of the Aβ-derived diffusible ligands to the neuron in the presence of the agent.

The present invention also embraces a method for detecting Aβ-derived diffusible ligands in a sample and a method for diagnosing a disease associated with Aβ-derived diffusible ligands. Such methods involve contacting a sample with an antibody of the instant invention so that the Aβ-derived diffusible ligands can be detected and a disease associated with Aβ-derived diffusible ligands can be diagnosed.

Brief Description of the Drawings

Figure 1 shows the results from an alkaline phosphatase assay, wherein anti-ADDL antibodies differentially block neurons.

Figure 2 shows a summary of bADDL binding when B103 cells are pre-incubated with anti-ADDL antibodies.

Figure 3 shows a summary of binding characteristics of antibodies capable of differentially recognizing multidimensional conformations of ADDLs.

Figure 4 shows a summary of ADDL assembly inhibition of the antibodies disclosed herein.

Figure 5 shows an N2A binding: k_{ADDL} correlation plot.

Figure 6 shows the nucleic acid sequences for the heavy and light chain variable regions, respectively, for murine anti-ADDL antibodies, 20C2 (Figures 6A and 6B), 5F10 (Figures 6C and 6D), 2D6 (Figures 6E and 6F), 2B4 (Figures 6G and 6H), 4E2 (Figures 6I and 6J), 2H4 (Figures 6K and 6L), 2A10 (Figures 6M and 6N), 3B3 (Figures 6O and 6P), 1F6 (Figures 6Q and 6R), 1F4 (Figures 6S and 6T), 2E12 (Figure 6U and 6V) and 4C2 (Figures 6W and 6X). Lower case letters

indicate the antibody leader sequences and uppercase letters indicate antibody variable region sequences. The nucleotides coding for the complementary determining regions (CDRs) are underlined.

Figure 7 shows comparisons of CDR1 (Figure 7A), CDR2 (Figure 7B), CDR3 (Figure 7C) sequences for the heavy chain variable regions and CDR1 (Figure 7D), CDR2 (Figure 7E), CDR3 (Figure 7F) sequences for the light chain variable regions for the mouse anti-ADDL antibodies.

Figure 8 shows the amino acid sequences for the heavy and light chain variable regions, respectively, for humanized anti-ADDL antibodies 20C2 (Figures 8A and 8B), 26D6 (Figures 8C and 8D), 4E2 (Figures 8E and 8F), 3B3 (Figures 8G and 8H), 2H4 (Figures 8I and 8J) and 1F6 (Figures 8K) created by CDR grafting. Sequences are presented as comparisons between the mouse sequence, the most homologous human sequence obtained from the NCBI protein database, the most homologous human genomic sequence and the humanized sequence. Amino acids in the mouse, human and human genomic sequences that differ from the humanized sequences are in bold. CDRs are underlined. Residues important for the maintenance of CDR loop conformation are indicated with an *. Conserved residues found at the VL/VH interface are indicated with a #. Potential glycosylation sites are indicated by italic. For the 20C2 heavy chain two humanized sequences were generated (HCVRA and HCVRB) that differ by one amino acid at position 24. In 20C2 HCVRA the human amino acid was used and in 20C2 HCVRB the mouse amino acid was used. No light chain was designed for 1F6 because it has the same sequence as that of the light chain for 4E2.

Figure 9 shows the amino acid sequences for the heavy and light chain variable regions, respectively, for humanized anti-ADDL antibodies 20C2 (Figures 9A and 9B) and 26D6 (Figures 9C and 9D) created by veneering. Sequences

are presented as comparisons between the mouse sequence, the most homologous human sequence obtained from the NCBI protein database, the most homologous human genomic sequence and the humanized sequence. Amino Acids in the mouse, human and human genomic sequences that differ from the humanized sequences are bold. CDRs are underlined. Residues important for the maintenance of CDR loop conformation are indicated with an asterisk. Conserved residues found at the VL/VH interface are indicated with a pound symbol. Potential glycosylation sites are indicated by italic. For the 20C2 heavy chain, two humanized sequences were generated (HCVRVenA and HCVRVenB) that differ by one amino acid at position 81. In 20C2 HCVRVenA, the mouse amino acid was used and in 20C2 HCVRVenB, the human amino acid was used. For the 26D6 heavy chain, three humanized sequences were designed based on veneering (HCVR Ven1, Ven 2and Ven3) that differ at amino acids 11, 23, 15, 81, 89 and 118. In HCVR Ven1, the mouse amino acid was used at all positions. In Ven2, the mouse amino acid was used for residues 81 and 118 and the human amino acid for residues 11, 13, 15, and 89. In Ven3, the human amino acids were used at all positions. For the 26D6 light chain, two veneered humanized sequences were designed (LCVR Ven1 and Ven2) that differ at amino acids 88 and 105. In LCVR Ven1, the mouse amino acid was used at both positions and in Ven2, the human amino acid was used.

Figure 10 shows nucleic acid sequences for the heavy and light chain variable regions (HCVRs and LCVRs, respectively) for humanized anti-ADDL antibodies. CDR grafted HCVRs and LCVRs for 20C2, 2D6, 4E2, 3B3, 2H4, and IF6, are respectively presented in Figure 10A to Figure 10K. Veneered HCVRs (VenA and VenB) and the LCVR for 20C2 are presented in Figure 10L to Figure 10N, whereas the veneered HCVRs (Ven1, Ven2, Ven3) and LCVRs (Ven1, Ven2) for 26D6 are presented in Figure 10O to Figure 10S.

Uppercase indicates antibody variable region sequences. CDRs are underlined. Variable region sequences were cloned into full heavy and light chain antibody expression vectors.

Figure 11 shows the amino acid sequences for the full IgG1 and IgG2m4 humanized heavy chains and humanized Kappa light chains for anti-ADDL antibodies. Figure 11A, CDR grafted 20C2 HCVRA IgG1; Figure 11B, CDR grafted 20C2 HCVRB IgG1; Figure 11C, CDR grafted 20C2 HCVRA IgG2m4; Figure 11D, CDR grafted 20C2 HCVRB IgG2m4; Figure 11E, CDR grafted 20C2 LCVR Kappa; Figure 11F, CDR grafted 26D6 HCVR IgG1; Figure 11G, CDR grafted 26D6 HCVR IgG2m4; Figure 11H, CDR grafted 26D6 LCVR Kappa; Figure 11I, CDR grafted 4E2 HCVR IgG1; Figure 11J, CDR grafted 4E2 LCVR Kappa; Figure 11K, CDR grafted 3B3 HCVR IgG1; Figure 11L, CDR grafted 3B3 LCVR Kappa; Figure 11M, CDR grafted 2H4 HCVR IgG1; Figure 11N, CDR grafted 2H4 LCVR Kappa; Figure 11O, CDR grafted 1F6 HCVR IgG1; Figure 11P, veneered 20C2 HCVR VenA IgG1; Figure 11Q, veneered 20C2 HCVR VenB IgG1; Figure 11R, veneered 20C2 HCVR VenB IgG2m4; Figure 11S, veneered 20C2 LCVR Kappa; Figure 11T, veneered 26D6 HCVR Ven1 Ig; Figure 11U, veneered 26D6 HCVR Ven1 IgG1; Figure 11V, 26D6 HCVR Ven2 IgG1; Figure 11W, veneered 26D6 HCVR Ven3; Figure 11X, veneered 26D6 LCVR Ven1 Kappa; and Figure 11Y, veneered 26D6 LCVR Ven2 Kappa. Underlining indicates variable region sequences and amino acids corresponding to the CDRs are double-underlined. The remaining amino acid sequences are constant region sequences.

Figure 12 shows a comparison of the amino acid sequence of human antibody constant regions and the sequence of IgG2m4. The asterisk indicates a glycosylation site at Asn297. Regions of FcRn binding are indicated. Sequences in which IgG2m4 is different from IgG2 are underlined.

Figure 13 shows the annotated amino acid sequence for heavy (Figure 13A) and light (Figure 13B) chains of 20C2 humanized antibody in Fab phage-display vector pFab3d.

Figure 14 depicts the design and primers employed in preparing two LC-CDR3 libraries, namely LC3-1 and LC3-2, for generating an affinity matured 20C2 light chain CDR3. Restriction endonuclease recognition sites used for cloning are indicated in italic. Uppercase indicates nucleic acids encoding antibody variable region sequences. Nucleic acids encoding CDRs are underlined.

Detailed Description of the Invention

Monoclonal antibodies, which differentially recognize multi-dimensional conformations of Aβ-derived diffusible ligands (*i.e.*, ADDLs), have now been generated. Advantageously, the instant monoclonal antibodies can distinguish between Alzheimer's Disease and control human brain extracts, and identify endogenous oligomers in Alzheimer's Disease brain slices and in cultured hippocampal cells. Further, the instant antibodies neutralize endogenous and synthetic ADDLs in solution. So-called "synthetic" ADDLs are produced *in vitro* by mixing purified amyloid β1-42 under conditions that generate ADDLs. See U.S. Patent No. 6,218,506. Particular antibodies disclosed herein exhibit a high degree of selectivity for 3-24mers, with minimal detection of monomer Aβ peptides. Further, recognition of ADDLs by selected antibodies of the invention is not blocked by short peptides that encompass the linear sequence of Aβ1-42 or Aβ1-40. However, binding is blocked by Aβ1-28, indicating an epitope based on a conformationally unique structure also found in Aβ1-28. Delineation of epitopes of the instant antibodies indicated that these antibodies recognize similar core linear sequences with similar affinity and specificity characteristics as measured by ELISA. Moreover, the instant

antibodies differentially block the ability of ADDL-containing preparations to bind primary cultures of rat hippocampal neurons and immortalized neuroblastoma cell lines, and also block ADDL assembly. This finding demonstrates that these antibodies possess a differential ability to recognize a multi-dimensional conformation of ADDLs despite similar linear sequence recognition and affinities. Since ADDLs are known to associate with a subset of neurons and disrupt normal neuronal function, one use of this current invention is the development and/or identification of antibodies that prevent the binding of ADDLs to neurons. Such antibodies would be useful in the treatment of ADDL related diseases including Alzheimer's Disease. A refinement of this use would be to specifically use humanized and/or affinity-matured versions of these antibodies for the prevention of ADDL binding to neurons and assembly of ADDLs.

Accordingly, the present invention is an isolated antibody that differentially recognizes one or more multi-dimensional conformations of ADDLs. An antibody of the instant invention is said to be isolated when it is present in the substantial absence of other biological macromolecules of the same type. Thus, an "isolated antibody" refers to an antibody which is substantially free of other antibodies; however, the molecule may include some additional agents or moieties which do not deleteriously affect the basic characteristics of the antibody (*e.g.*, binding specificity, neutralizing activity, etc.).

Antibodies which are capable of specifically binding one or more multi-dimensional conformations of ADDLs, bind particular ADDLs derived from the oligomerization of Aβ1-42, but do not cross-react with other Aβ peptides, namely Aβ1-12, Aβ1-28, Aβ1-40, and Aβ12-28 as determined by western blot analyses as disclosed herein; and preferentially bind ADDLs in solution (see, *e.g.*, Example

21). Specific binding between two entities generally refers to an affinity of at least 10^6, 10^7, 10^8, 10^9, or 10^{10} M^{-1}. Affinities greater than 10^8 M^{-1} are desired to achieve specific binding.

In particular embodiments, an antibody that is capable of specifically binding a multi-dimensional conformation of one or more ADDLs is also raised against (*i.e.*, an animal is immunized with) multi-dimensional conformations of ADDLs. In other embodiments, an antibody that is capable of specifically binding a multi-dimensional conformation of one or more ADDLs is raised against a low n-mer-forming peptide such as Aβ1-42[Nle35-Dpro37].

The term "epitope" refers to a site on an antigen to which B and/or T cells respond or a site on a molecule against which an antibody will be produced and/or to which an antibody will bind. For example, an epitope can be recognized by an antibody defining the epitope.

A linear epitope is an epitope wherein an amino acid primary sequence comprises the epitope recognized. A linear epitope typically includes at least 3, and more usually, at least 5, for example, about 8 to about 10 amino acids in a unique sequence.

A conformational epitope, in contrast to a linear epitope, is an epitope wherein the primary sequence of the amino acids comprising the epitope is not the sole defining component of the epitope recognized (*e.g.*, an epitope wherein the primary sequence of amino acids is not necessarily recognized by the antibody defining the epitope). Typically a conformational epitope encompasses an increased number of amino acids relative to a linear epitope. With regard to recognition of conformational epitopes, the antibody recognizes a three-dimensional structure of the peptide or protein. For example, when a protein molecule folds to form a three-dimensional structure, certain amino acids and/or the polypeptide

backbone forming the conformational epitope become juxtaposed enabling the antibody to recognize the epitope. Methods of determining conformation of epitopes include but are not limited to, for example, x-ray crystallography, two-dimensional nuclear magnetic resonance spectroscopy and site-directed spin labeling and electron paramagnetic resonance spectroscopy. See, for example, Epitope Mapping Protocols in Methods in Molecular Biology (1996) Vol. 66, Morris (Ed.).

Aβ-derived diffusible ligands or ADDLs refer to soluble oligomers of amyloid β1-42 which are desirably composed of aggregates of less than eight or nine amyloid β1-42 peptides and are found associated with Alzheimer's Disease. This is in contrast to high molecular weight aggregation intermediates, which form stings of micelles leading to fibril formation.

As exemplified herein, the instant antibody binds or recognizes at least one multi-dimensional conformation of an ADDL (see, *e.g.*, Figure 3). In particular embodiments, the instant antibody binds at least two, at least three, or at least four multi-dimensional conformations of an ADDL. Multi-dimensional conformations of ADDLs are intended to encompass dimers, trimers, tetramers pentamers, hexamers, heptamers, octamers, nonamers, decamers, etc as defined by analysis via SDS-PAGE. Because trimer, tetramer, etc. designations can vary with the assay method employed (see, *e.g.*, Bitan, et al. (2005) *Amyloid* 12:88-95) the definition of trimer, tetramer, and the like, as used herein, is according to SDS-PAGE analysis. To illustrate the differentially binding capabilities of the instant antibodies, it has been found that certain antibodies will recognize one multi-dimensional conformation, for example, tetramers of ADDLs (*e.g.*, antibody 2D6 or 4E2), while other antibodies recognize several multi-dimensional conformations, for example, trimers and tetramers of ADDLs

(*e.g.*, antibody 2A10, 2B4, 5F10, or 20C2). As such, the antibodies of the instant invention have oligomer-specific characteristics. In particular embodiments, a multi-dimensional conformation of an ADDL is associated with a specific polypeptide structure which results in a conformational epitope that is recognized by an antibody of the present invention. In other embodiments, an antibody of the invention specifically binds a multi-dimensional conformation ADDL having a size range of approximately a trimer or tetramer, which have molecular weights in excess of >50 kDa.

In certain embodiments, in addition to binding to a multi-dimensional conformation, the instant antibody binds to a selected linear epitope of amyloid β1-42. A linear epitope of an ADDLs is intended as a four, five, six or more amino acid residue peptide located in the N-terminal 10, 11, 12, 15 or 20 amino acid residues of amyloid β1-42. In particular embodiments, an antibody of the invention specifically binds to a linear epitope within residues 1-10, 1-8, 3-10, or 3-8 of amyloid β1-42. Exemplary linear epitopes of amyloid β 1-42 include, but are not limited to, amino acid residues EFRHDS (SEQ ID NO:177); DAEFRHDS (SEQ ID NO:178), and EFRHDSGY (SEQ ID NO:179).

While antibodies of the instant invention may have similar linear epitopes, such linear epitopes are not wholly indicative of the binding characteristics of the instant antibodies (*i.e.*, ability to block ADDL binding to neurons, prevent tau phosphorylation and inhibit ADDL assembly) because, as is well known to the skilled artisan, the linear epitope may only correspond to a portion of the antigen's epitope (see, *e.g.*, Breitling and Dübel (1999) *In*: Recombinant Antibodies, John Wiley & Sons, Inc., NY, pg. 115). For example, 20C2 was found to bind assemblies of charge-inverted, truncated Aβ7-42 peptide, which lack the linear epitope for 20C2 (*i.e.*, amino acid residues 3-8) and

contain a very different sequence corresponding to residues 7-16 of Aβ. Therefore 20C2 binds to conformational epitopes that depend upon elements from within residues 17-42 of Aβ, but only when in a multidimensional conformation. The antibodies of the instant invention can be distinguished from those of the art as being capable of differentially recognizing multi-dimensional ADDLs and accordingly differentially blocking ADDL binding to neurons, differentially preventing tau phosphorylation and differentially inhibiting ADDL assembly.

An antibody, as used in accordance with the instant invention includes, but is not be limited to, polyclonal or monoclonal antibodies, and chimeric, human (*e.g.* isolated from B cells), humanized, neutralizing, bispecific or single chain antibodies thereof. In one embodiment, an antibody of the instant invention is monoclonal. For the production of antibodies, various hosts including goats, rabbits, chickens, rats, mice, humans, and others, can be immunized by injection with synthetic or natural ADDLs. Methods for producing antibodies are well-known in the art. See, *e.g.*, Kohler and Milstein ((1975) *Nature* 256:495-497) and Harlow and Lane (Antibodies: A Laboratory Manual (Cold Spring Harbor Laboratory, New York (1988)).

Depending on the host species, various adjuvants can be used to increase the immunological response. Adjuvants used in accordance with the instant invention desirably augment the intrinsic response to ADDLs without causing conformational changes in the immunogen that affect the qualitative form of the response. Particularly suitable adjuvants include 3 De-O-acylated monophosphoryl lipid A (MPL™; RIBI ImmunoChem Research Inc., Hamilton, MT; see GB 2220211) and oil-in-water emulsions, such as squalene or peanut oil, optionally in combination with immune stimulants, such as monophosphoryl lipid A (see Stoute, et al. (1997) *N. Engl. J. Med.* 336:86-91), muramyl peptides

(*e.g.*, N-acetylmuramyl-L-threonyl-D-isoglutamine (thr-MDP), N-acetyl-normuramyl-L-alanyl-D-isoglutamine (nor-MDP), N-acetylmuramyl-L-alanyl-D-isoglutaminyl-L-alanine-2-(1'-2'dipalmitoyl-sn-glycero-3-hydroxyphosphoryloxy)-ethylamine (E-PE), N-acetylglucsaminyl-N-acetylmuramyl-L-Al-D-isoglu-L-Ala-dipalmitoxy propylamide (DTP-DPP)), or other bacterial cell wall components. Specific examples of oil-in-water emulsions include MF59 (WO 90/14837), containing 5% Squalene, 0.5% TWEEN™ 80, and 0.5% SPAN 85 (optionally containing various amounts of MTP-PE) formulated into submicron particles using a microfluidizer such as Model 110Y microfluidizer (Microfluidics, Newton, MA); SAF containing 10% Squalene, 0.4% TWEEN™ 80, 5% PLURONIC®-blocked polymer L121, and thr-MDP, either microfluidized into a submicron emulsion or vortexed to generate a larger particle size emulsion; and RIBI™ adjuvant system (RAS) (Ribi ImmunoChem, Hamilton, MT) containing 2% squalene, 0.2% TWEEN™ 80, and one or more bacterial cell wall components such as monophosphoryllipid A, trehalose dimycolate (TDM), and cell wall skeleton (CWS).

Another class of adjuvants is saponin adjuvants, such as STIMULON™ (QS-21, Aquila, Framingham, MA) or particles generated therefrom such as ISCOMs (immunostimulating complexes) and ISCOMATRIX® (CSL Ltd., Parkville, Australia). Other suitable adjuvants include Complete Freund's Adjuvant (CFA), Incomplete Freund's Adjuvant (IFA), mineral gels such as aluminum hydroxide, and surface-active substances such as lysolecithin, PLURONIC® polyols, polyanions, peptides, CpG (WO 98/40100), keyhole limpet hemocyanin, dinitrophenol, and cytokines such as interleukins (IL-1, IL-2, and IL-12), macrophage colony stimulating factor (M-CSF), and tumor necrosis factor (TNF). Among adjuvants used in humans, BCG (bacilli Calmette-Guerin) and *Corynebacterium parvum* are particularly suitable.

An antibody to a multi-dimensional conformation ADDL is generated by immunizing an animal with ADDLs. Generally, ADDLs can be generated synthetically or by recombinant fragment expression and purification. Synthetic ADDLs can be prepared as disclosed herein or in accordance with the methods disclosed in U.S. Patent No. 6,218,506 or in co-pending applications USSN 60/621,776, 60/652,538, 60/695,526 and 60/695,528. Further, ADDLs can be fused with another protein such as keyhole limpet hemocyanin to generate an antibody against the chimeric molecule. The ADDLs can be conformationally constrained to form an epitope useful as described herein and furthermore can be associated with a surface for example, physically attached or chemically bonded to a surface in such a manner so as to allow for the production of a conformation which is recognized by the antibodies of the present invention.

Monoclonal antibodies to multi-dimensional conformations of ADDLs can be prepared using any technique which provides for the production of antibody molecules by continuous cell lines in culture. These include, but are not limited to, the hybridoma technique, the human B-cell hybridoma technique, and the EBV-hybridoma technique (Kohler, et al. (1975) *Nature* 256:495-497; Kozbor, et al. (1985) *J. Immunol. Methods* 81:31-42; Cote, et al. (1983) *Proc. Natl. Acad. Sci.* 80:2026-2030; Cole, et al. (1984) *Mol. Cell Biol.* 62:109-120). Exemplary monoclonal antibodies include murine antibodies designated 2A10, 4C2, 2D6, 4E2, 20C2, 2B4, 5F10, 2H4, 2E12, 1F6, 1F4, 3B3, 5G12, 6B7, 6B11, 11B4, 11B5, 14A11, 15G6, 17G4, 20C2, 3B7, 1E3, 1A9, 1G3, 1A7 and 1E5.

In addition, humanized and chimeric antibodies can be produced by splicing of mouse antibody genes to human antibody genes to obtain a molecule with appropriate antigen specificity and biological activity (see Morrison, et al. (1984) *Proc. Natl. Acad. Sci.* 81, 6851-6855;

Neuberger, et al. (1984) *Nature* 312:604-608; Takeda, et al. (1985) *Nature* 314:452-454; Queen, et al. (1989) *Proc. Natl. Acad. Sci. USA* 86:10029-10033; WO 90/07861). For example, a mouse antibody is expressed as the Fv or Fab fragment in a phage selection vector. The gene for the light chain (and in a parallel experiment, the gene for the heavy chain) is exchanged for a library of human antibody genes. Phage antibodies, which still bind the antigen, are then identified. This method, commonly known as chain shuffling, provided humanized antibodies that should bind the same epitope as the mouse antibody from which it descends (Jespers, et al. (1994) *Biotechnology NY* 12:899-903). As an alternative, chain shuffling can be performed at the protein level (see, Figini, et al. (1994) *J. Mol. Biol.* 239:68-78).

Human antibodies can also be obtained using phage-display methods. See, *e.g.*, WO 91/17271 and WO 92/01047. In these methods, libraries of phage are produced in which members display different antibodies on their outer surfaces. Antibodies are usually displayed as Fv or Fab fragments. Phage displaying antibodies with a desired specificity are selected by affinity enrichment to ADDLs. Human antibodies against ADDLs can also be produced from non-human transgenic mammals having transgenes encoding at least a segment of the human immunoglobulin locus and an inactivated endogenous immunoglobulin locus. See, *e.g.*, WO 93/12227 and WO 91/10741, each incorporated herein by reference. Human antibodies can be selected by competitive binding experiments, or otherwise, to have the same epitope specificity as a particular mouse antibody. Such antibodies are particularly likely to share the useful functional properties of the mouse antibodies. Human polyclonal antibodies can also be provided in the form of serum from humans immunized with an immunogenic agent. Optionally,

such polyclonal antibodies can be concentrated by affinity purification using ADDLs as an affinity reagent.

Humanized antibodies can also be produced by veneering or resurfacing of murine antibodies. Veneering involves replacing only the surface fixed region amino acids in the mouse heavy and light variable regions with those of a homologous human antibody sequence. Replacing mouse surface amino acids with human residues in the same position from a homologous human sequence has been shown to reduce the immunogenicity of the mouse antibody while preserving its ligand binding. The replacement of exterior residues generally has little, or no, effect on the interior domains, or on the interdomain contacts. (See, *e.g.*, U.S. Patent No. 6,797,492).

Human or humanized antibodies can be designed to have IgG, IgD, IgA, IgM or IgE constant regions, and any isotype, including IgG1, IgG2, IgG3 and IgG4. In particular embodiments, an antibody of the invention is IgG or IgM, or a combination thereof. A particular combination embraces a constant region formed by selective incorporation of human IgG4 sequences into a standard human IgG2 constant region. An exemplary mutant IgG2 Fc is IgG2m4, set forth herein as SEQ ID NO:254. Antibodies can be expressed as tetramers containing two light and two heavy chains, as separate heavy chains and light chains or as single chain antibodies in which heavy and light chain variable domains are linked through a spacer. Techniques for the production of single chain antibodies are well-known in the art.

Exemplary humanized antibodies produced by CDR grafting and veneering are disclosed herein for antibodies designated 4E2, 26D6, 20C2, 3B3, 2H4, and 1F6. Amino acid sequences for IgG1 and IgG2M4 heavy chain variable regions, as well as kappa light chain variable regions for humanized 4E2, 26D6, 20C2, 3B3, 2H4, and 1F6 generated by CDR

grafting and veneering are presented in Figures 11A to 11Y and set forth herein as SEQ ID NOs:152 to 176.

Diabodies are also contemplated. A diabody refers to an engineered antibody construct prepared by isolating the binding domains (both heavy and light chain) of a binding antibody, and supplying a linking moiety which joins or operably links the heavy and light chains on the same polypeptide chain thereby preserving the binding function (see, Holliger et al. (1993) *Proc. Natl. Acad. Sci. USA* 90:6444; Poljak (1994) *Structure* 2:1121-1123). This forms, in essence, a radically abbreviated antibody, having only the variable domain necessary for binding the antigen. By using a linker that is too short to allow pairing between the two domains on the same chain, the domains are forced to pair with the complementary domains of another chain and create two antigen-binding sites. These dimeric antibody fragments, or diabodies, are bivalent and bispecific. The skilled artisan will appreciate that any method to generate diabodies can be used. Suitable methods are described by Holliger, et al. (1993) *supra*, Poljak (1994) *supra*, Zhu, et al. (1996) *Biotechnology* 14:192-196, and U.S. Patent No. 6,492,123, incorporated herein by reference.

Fragments of an isolated antibody of the invention are also expressly encompassed by the instant invention. Fragments are intended to include Fab fragments, $F(ab')_2$ fragments, F(ab') fragments, bispecific scFv fragments, Fd fragments and fragments produced by a Fab expression library, as well as peptide aptamers. For example, $F(ab')_2$ fragments are produced by pepsin digestion of the antibody molecule of the invention, whereas Fab fragments are generated by reducing the disulfide bridges of the $F(ab')_2$ fragments. Alternatively, Fab expression libraries can be constructed to allow rapid and easy identification of monoclonal Fab fragments with the desired specificity (see Huse, et al. (1989) *Science* 254:1275-1281). In particular

embodiments, antibody fragments of the present invention are fragments of neutralizing antibodies which retain the variable region binding site thereof. Exemplary are $F(ab')_2$ fragments, F(ab') fragments, and Fab fragments. See generally Immunology: Basic Processes (1985) 2nd edition, J. Bellanti (Ed.) pp. 95-97.

Peptide aptamers which differentially recognize multi-dimensional conformations of ADDLs can be rationally designed or screened for in a library of aptamers (*e.g.*, provided by Aptanomics SA, Lyon, France). In general, peptide aptamers are synthetic recognition molecules whose design is based on the structure of antibodies. Peptide aptamers consist of a variable peptide loop attached at both ends to a protein scaffold. This double structural constraint greatly increases the binding affinity of the peptide aptamer to levels comparable to that of an antibody (nanomolar range).

Exemplary nucleic acid sequences encoding heavy and light chain variable regions for use in producing antibody and antibody fragments of the instant invention are disclosed herein in Figures 6 and 10 (*i.e.*, SEQ ID NOs:1-24 and SEQ ID NOs:132-151). As will be appreciated by the skilled artisan, the heavy chain variable regions disclosed herein can be used in combination with any one of the light chain variable regions disclosed herein to generate antibodies with modified affinities, dissociate constants, epitopes and the like. For example, combining the light chain variable region of 2H4 (encoded by SEQ ID NO:12) with the heavy chain variable region of 2A10 (encoded by SEQ ID NO:13) may provide for recognition of a larger linear epitope.

Exemplary heavy and light chain CDRs for use in producing an antibody or antibody fragment of the instant invention are disclosed in Figures 7A-7F and have amino acid sequences set forth in SEQ ID NOs:25, 26, and 28

(heavy chain CDR1); SEQ ID NOs: 29, 30, 31, 33, 34, 35, and 36 (heavy chain CDR2); SEQ ID NOs:38, 39, 40, 41, 43, 44, 45, 46, 47 and 48 (heavy chain CDR3); SEQ ID NOs:49, 50, 51 and 53 (light chain CDR1); SEQ ID NOs:54, 55, 56, and 58 (light chain CDR2); and SEQ ID NOs:59, 60, 61, 62, 63, 64, and 66 (light chain CDR3). Particular embodiments of the heavy and light chains of the antibody or antibody fragments of the instant invention are as follows. A heavy chain CDR1 having an amino acid sequence of Ser-Phe-Gly-Met-His (SEQ ID NO:28) or Thr-Ser-Gly-Met-Gly-Val-Xaa (SEQ ID NO:27), wherein Xaa is an amino acid with no side chain or a small side chain (*e.g.*, Ser, Gly, or Ala). A heavy chain CDR2 having an amino acid sequence of His-Ile-Xaa_1-Trp-Asp-Asp-Asp-Lys-Xaa_2-Tyr-Asn-Pro-Ser-Leu-Lys-Ser (SEQ ID NO:32), wherein Xaa_1 is an amino acid with an aromatic side chain group (*e.g.*, Phe, Tyr or Trp) and Xaa_2 is Ser, Arg or Tyr; or a heavy chain CDR2 having an amino acid sequence of Tyr-Ile-Xaa_1-Xaa_2-Xaa_3-Ser-Xaa_4-Thr-Ile-Tyr-Tyr-Ala-Asp-Thr-Val-Lys-Arg (SEQ ID NO:37), wherein Xaa_1 and Xaa_2 are amino acids with a polar side chain group (*e.g.*, Arg, Ser, Gly, Thr, Cys, Tyr, Asn, Gln, Lys, or His); Xaa_3 is Gly or Val; and Xaa_4 is an amino acid with a polar and uncharged side group (*e.g.*, Gly, Ser, Thr, Cys, Tyr, Asn, or Gln). A heavy chain CDR3 having an amino acid sequence of Arg-Ser-Ile-Xaa_1-Xaa_2-Xaa_3-Xaa_4-Pro-Glu-Asp-Tyr-Phe-Xaa_5-Tyr (SEQ ID NO:42), wherein Xaa_1 is an amino acid with a polar and uncharged side group (*e.g.*, Gly, Ser, Thr, Cys, Tyr, Asn, or Gln); Xaa_2 is an amino acid with hyroxyl side chain group (*e.g.*, Ser or Thr); Xaa_3 and Xaa_4 are amino acids with an aliphatic side chain group (*e.g.*, Ala, Val, Leu, Ile, or Pro); and Xaa_5 is Asp or Ala. A light chain CDR1 having an amino acid sequence of Arg-Ser-Ser-Gln-Ser-Xaa_1-Xaa_2-His-Ser-Asn-Gly-Asn-Thr-Tyr-Leu-Xaa_3 (SEQ ID NO:52), wherein Xaa_1 and Xaa_2 are amino acids with an aliphatic side chain group (*e.g.*, Ala, Val, Leu, Ile, or Pro) and Xaa_3 is an

amino acid with a charged side chain group (*e.g.*, Asp, Glu, Arg, His, or Lys). A light chain CDR2 having an amino acid sequence of Lys-Xaa_1-Ser-Asn-Arg-Phe-Xaa_2 (SEQ ID NO:57), wherein Xaa_1 is an amino acid with an aliphatic side chain group (*e.g.*, Ala, Val, Leu, Ile, or Pro) and Xaa_2 is Ser or Phe. A light chain CDR3 having an amino acid sequence of Xaa_1-Gln-Xaa_2-Xaa_3-Xaa_4-Val-Pro-Xaa_5-Thr (SEQ ID NO:65), wherein Xaa_1 is Ser or Phe; Xaa_2 is an amino acid with no side chain (*e.g.*, gly) or hyroxyl side chain group (*e.g.*, Ser or Thr); Xaa_3 is an amino acid with a hyroxyl side chain group (*e.g.*, Ser or Thr); Xaa_4 is His, Tyr or Leu; and Xaa_5 is an amino acid with an aliphatic side chain group (*e.g.*, Ala, Val, Leu, Ile, or Pro). As will be appreciated by the skilled artisan, one or more of the CDRs within the heavy and light chain variable regions of an antibody can be replaced with one or more CDRs from another antibody to generate a wholly new antibody or antibody fragment. For example, replacing CDR3 of the heavy chain of 5F10 with the CDR3 of the heavy chain from 4E2 (SEQ ID NO:41) may enhance that ability of 5F10 to block binding of ADDLs to neuronal cells.

Antibodies with particular characteristics are contemplated. In one embodiment, an antibody which binds the 3-8 amino acid epitope of Aβ1-42 has a heavy chain CDR1 amino acid sequence of Thr-Ser-Gly-Met-Gly-Val-Xaa (SEQ ID NO:27), wherein Xaa is an amino acid with no side chain or a small side chain (*e.g.*, Ser, Gly, or Ala); or a heavy chain CDR2 amino acid sequence of His-Ile-Xaa_1-Trp-Asp-Asp-Asp-Lys-Xaa_2-Tyr-Asn-Pro-Ser-Leu-Lys-Ser (SEQ ID NO:32), wherein Xaa_1 is an amino acid with an aromatic side chain group (*e.g.*, Phe, Tyr or Trp) and Xaa_2 is Ser, Arg or Tyr. In another embodiment, an antibody with a moderate affinity for large (>50 kDa) ADDL aggregates over small (<30 kDa) aggregates (*i.e.* SEC Peak 1 and Peak 2, respectively), has a heavy chain CDR3 amino acid sequence of Arg-Ser-Ile-Xaa_1-

Xaa_2-Xaa_3-Xaa_4-Pro-Glu-Asp-Tyr-Phe-Xaa_5-Tyr (SEQ ID NO:42), wherein Xaa_1 is an amino acid with a polar and uncharged side group (*e.g.*, Gly, Ser, Thr, Cys, Tyr, Asn, or Gln), Xaa_2 is an amino acid with hyroxyl side chain group (*e.g.*, Ser or Thr), Xaa_3 and Xaa_4 are amino acids with an aliphatic side chain group (*e.g.*, Ala, Val, Leu, Ile, or Pro), and Xaa_5 is Asp or Ala.

Antibodies or antibody fragments of the present invention can have additional moieties attached thereto. For example, a microsphere or microparticle can be attached to the antibody or antibody fragment, as described in U.S. Patent No. 4,493,825, the disclosure of which is incorporated herein by reference.

Moreover, antibody or antibody fragments of the invention can be mutated and selected for increased antigen affinity, neutralizing activity (*i.e.*, the ability to block binding of ADDLs to neuronal cells or the ability to block ADDL assembly), or a modified dissociation constant. Mutator strains of *E. coli* (Low, et al. (1996) *J. Mol. Biol.* 260:359-368), chain shuffling (Figini, et al. (1994) *supra*), and PCR mutagenesis are established methods for mutating nucleic acid molecules encoding antibodies. By way of illustration, increased affinity can be selected for by contacting a large number of phage antibodies with a low amount of biotinylated antigen so that the antibodies compete for binding. In this case, the number of antigen molecules should exceed the number of phage antibodies, but the concentration of antigen should be somewhat below the dissociation constant. Thus, predominantly mutated phage antibodies with increased affinity bind to the biotinylated antigen, while the larger part of the weaker affinity phage antibodies remains unbound. Streptavidin can then assist in the enrichment of the higher affinity, mutated phage antibodies from the mixture (Schier, et al. (1996) *J. Mol. Biol.* 255:28-43). Exemplary affinity-maturated light chain

CDR3 amino acid sequences are disclosed herein (see Tables 11 and 12), with particular embodiments embracing a light chain CDR3 amino acid sequence of Xaa_1-Gln-Xaa_2-Thr-Arg-Val-Pro-Leu-Thr (SEQ ID NO:316), wherein Xaa_1 is Phe or Leu, and Xaa_1 is Ala or Thr.

For some therapeutic applications it may be desirable to reduce the dissociation of the antibody from the antigen. To achieve this, the phage antibodies are bound to biotinylated antigen and an excess of unbiotinylated antigen is added. After a period of time, predominantly the phage antibodies with the lower dissociation constant can be harvested with streptavidin (Hawkins, et al. (1992) *J. Mol. Biol.* 226:889-96).

Various immunoassays including those disclosed herein can be used for screening to identify antibodies, or fragments thereof, having the desired specificity for multi-dimensional conformations of ADDLs. Numerous protocols for competitive binding (*e.g*, ELISA), latex agglutination assays, immunoradiometric assays, kinetics (*e.g.*, BIACORE™ analysis) using either polyclonal or monoclonal antibodies, or fragments thereof, are well-known in the art. Such immunoassays typically involve the measurement of complex formation between a specific antibody and its cognate antigen. A two-site, monoclonal-based immunoassay utilizing monoclonal antibodies reactive to two non-interfering epitopes is suitable, but a competitive binding assay can also be employed. Such assays can also be used in the detection of multi-dimensional conformations of ADDLs in a sample.

An antibody or antibody fragment can also be subjected to other biological activity assays, *e.g.*, displacement of ADDL binding to neurons or cultured hippocampal cells or blockade of ADDL assembly, in order to evaluate neutralizing or pharmacological activity and potential

efficacy as a prophylactic or therapeutic agent. Such assays are described herein and are well-known in the art.

Antibodies and fragments of antibodies can be produced and maintained as hydridomas or alternatively recombinantly produced in any well-established expression system including, but not limited to, *E. coli*, yeast (*e.g.*, *Saccharomyces* spp. and *Pichia* spp.), baculovirus, mammalian cells (*e.g.*, myeloma, CHO, COS), plants, or transgenic animals (Breitling and Dübel (1999) *In*: Recombinant Antibodies, John Wiley & Sons, Inc., NY, pp. 119-132). Exemplary nucleic acid sequences of IgG1 and IgG2m4 heavy chain variable regions, as well as kappa light chain variable regions for humanized 4E2, 26D6, 20C2, 3B3, 2H4, and 1F6 generated by CDR grafting and veneering are presented in Figures 10A to 10S and set forth herein as SEQ ID NOs:132 to 151. For antibodies and fragments of antibodies can be isolated using any appropriate methods including, but not limited to, affinity chromatography, immunoglobulins-binding molecules (*e.g.*, proteins A, L, G or H), tags operatively linked to the antibody or antibody fragment (*e.g.*, His-tag, FLAG®-tag, Strep tag, c-myc tag) and the like. See, Breitling and Dübel (1999) *supra*.

Antibodies and antibody fragments of the instant invention have a variety of uses including, diagnosis of diseases associated with accumulation of ADDLs, blocking or inhibiting binding of ADDLs to neuronal cells, blocking ADDL assembly, prophylactically or therapeutically treating a disease associated with ADDLs, identifying therapeutic agents that prevent binding of ADDLs to neurons, and preventing the phosphorylation of tau protein at Ser202/Thr205.

Antibody and antibody fragments of the instant invention are also useful in a method for blocking or inhibiting binding of ADDLs to neuronal cells. This method of the invention is carried out by contacting a neuron, *in*

vitro or *in vivo,* with an antibody or antibody fragment of the present invention so that binding of ADDLs to the neuron is blocked. In particular embodiments, an antibody or antibody fragment of the instant invention achieves at least a 15%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, or 97% decrease in the binding of ADDLs as compared to binding of ADDLs in the absence of the antibody or antibody fragment. The degree to which an antibody can block the binding of ADDLs to a neuron can be determined in accordance with the methods disclosed herein, *i.e.,* immunocytochemistry or cell-based alkaline phosphatase assay or any other suitable assay. Antibodies particularly useful for decreasing binding of ADDLs to neuronal cells include the exemplary 20C2, 3B3, 1F4, 1F6, 4E2, 2B4, 2D6, and 2H4 monoclonal antibodies.

Antibody and antibody fragments of the instant invention are further useful in a method for blocking or inhibiting assembly of ADDLs. This method involves contacting a sample containing amyloid β 1-42 peptides with an antibody or antibody fragment of the instant invention so that ADDL assembly is inhibited. The degree to which an antibody can block the assembly of ADDLs can be determined in accordance with the methods disclosed herein, *i.e.,* FRET or fluorescence polarization or any other suitable assay. Antibodies particularly useful for blocking the assembly of ADDLs include the exemplary 1F4, 20C2, 4C2, 1F6, 2B4, 5F10, 2A10, and 2D6 antibodies.

Antibodies disclosed herein are also useful in methods for preventing the phosphorylation of tau protein at Ser202/Thr205. This method involves contacting a sample containing tau protein with an antibody or antibody fragment of the instant invention so that binding of ADDLs to neurons is blocked thereby preventing phosphorylation of tau protein. The degree to which an antibody can prevent the phosphorylation of tau protein at Ser202/Thr205 can be

determined in accordance with the methods disclosed herein or any other suitable assay.

Blocking or decreasing binding of ADDLs to neurons, inhibiting assembly of ADDLs, and preventing the phosphorylation of tau protein at Ser202/Thr205 all find application in methods of prophylactically or therapeutically treating a disease associated with the accumulation of ADDLs. Accordingly, the present invention also embraces the use of an antibody or antibody fragment of the instant invention to prevent or treat a disease associated with the accumulation of ADDLs (*e.g.* Alzheimer's or similar memory-related disorders). Patients amenable to treatment include individuals at risk of disease but not exhibiting symptoms, as well as patients presently exhibiting symptoms. In the case of Alzheimer's Disease, virtually anyone is at risk of suffering from Alzheimer's Disease if he or she lives long enough. Therefore, the antibody or antibody fragments of the present invention can be administered prophylactically to the general population without the need for any assessment of the risk of the subject patient. The present methods are especially useful for individuals who have a known genetic risk of Alzheimer's Disease. Such individuals include those having relatives who have been diagnosed with the disease, and those whose risk is determined by analysis of genetic or biochemical markers. Genetic markers of risk for Alzheimer's Disease include mutations in the APP gene, particularly mutations at position 717 and positions 670 and 671 referred to as the Hardy and Swedish mutations respectively. Other markers of risk are mutations in the presenilin genes, PS1 and PS2, and ApoE4, family history of Alzheimer's Disease, hypercholesterolemia or atherosclerosis. Individuals presently suffering from Alzheimer's Disease can be recognized from characteristic dementia, as well as the presence of risk factors described

above. In addition, a number of diagnostic tests are available for identifying individuals who have Alzheimer's Disease. These include measurement of CSF tau and Aβ1-42 levels. Individuals suffering from Alzheimer's Disease can also be diagnosed by ADRDA criteria or the method disclosed herein.

In asymptomatic patients, treatment can begin at any age (*e.g.*, 10, 20, 30 years of age). Usually, however, it is not necessary to begin treatment until a patient reaches 40, 50, 60 or 70 years of age. Treatment typically entails multiple dosages over a period of time. Treatment can be monitored by assaying for the presence of ADDLs over time.

In therapeutic applications, a pharmaceutical composition or medicament containing an antibody or antibody fragment of the invention is administered to a patient suspected of, or already suffering from such a disease associated with the accumulation of ADDLs in an amount sufficient to cure, or at least partially arrest, the symptoms of the disease (biochemical, histologic and/or behavioral), including its complications and intermediate pathological phenotypes in development of the disease. In prophylactic applications, a pharmaceutical composition or medicament containing an antibody or antibody fragment of the invention is administered to a patient susceptible to, or otherwise at risk of, a disease associated with the accumulation of ADDLs in an amount sufficient to achieve passive immunity in the patient thereby eliminating or reducing the risk, lessening the severity, or delaying the outset of the disease, including biochemical, histologic and/or behavioral symptoms of the disease, its complications and intermediate pathological phenotypes presenting during development of the disease. In some methods, administration of agent reduces or eliminates myocognitive impairment in patients that have not yet developed characteristic Alzheimer's pathology. In

particular embodiments, an effective amount of an antibody or antibody fragment of the invention is an amount which achieves at least a 15%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, or 97% decrease in the binding of ADDLs to neurons in the patient as compared to binding of ADDLs in the absence of treatment. As such, impairment of long-term potentiation/memory formation is decreased.

Effective doses of the compositions of the present invention, for the treatment of the above described conditions vary depending upon many different factors, including means of administration, physiological state of the patient, whether the patient is human or an animal, other medications administered, and whether treatment is prophylactic or therapeutic. Usually, the patient is a human but nonhuman mammals such as dogs or transgenic mammals can also be treated.

Treatment dosages are generally titrated to optimize safety and efficacy. For passive immunization with an antibody or antibody fragment, dosage ranges from about 0.0001 to 100 mg/kg, and more usually 0.01 to 5 mg/kg, of the host body weight are suitable. For example, dosages can be 1 mg/kg body weight or 10 mg/kg body weight or within the range of 1-10 mg/kg. An exemplary treatment regime entails administration once per every two weeks or once a month or once every 3 to 6 months. In some methods, two or more antibodies of the invention with different binding specificities are administered simultaneously, in which case the dosage of each antibody administered falls within the ranges indicated. Antibodies are usually administered on multiple occasions, wherein intervals between single dosages can be weekly, monthly or yearly. Intervals can also be irregular as indicated by measuring blood levels of antibody to ADDLs in the patient. In some methods, dosage is adjusted to achieve a plasma antibody concentration of 1-1000 µg/mL and in some methods 25-300 µg/mL.

Alternatively, the antibody or antibody fragment can be administered as a sustained-release formulation, in which case less frequent administration is required. Dosage and frequency vary depending on the half-life of the antibody in the patient. In general, human and humanized antibodies have longer half-lives than chimeric antibodies and nonhuman antibodies. As indicated above, dosage and frequency of administration can vary depending on whether the treatment is prophylactic or therapeutic. In prophylactic applications, a relatively low dosage is administered at relatively infrequent intervals over a long period of time. Some patients continue to receive treatment for the rest of their lives. In therapeutic applications, a relatively high dosage at relatively short intervals is sometimes required until progression of the disease is reduced or terminated, and preferably until the patient shows partial or complete amelioration of symptoms of disease. Thereafter, the patient can be administered a prophylactic regime.

Antibody and antibody fragments of the instant invention can be administered as a component of a pharmaceutical composition or medicament. Pharmaceutical compositions or medicaments generally contain the active therapeutic agent and a variety of other pharmaceutically acceptable components. See Remington: The Science and Practice of Pharmacy, Alfonso R. Gennaro, editor, 20th ed. Lippincott Williams & Wilkins: Philadelphia, PA, 2000. The preferred form depends on the intended mode of administration and therapeutic application. Pharmaceutical compositions can contain, depending on the formulation desired, pharmaceutically-acceptable, non-toxic carriers or diluents, which are defined as vehicles commonly used to formulate pharmaceutical compositions for animal or human administration. Diluents are selected so as not to affect the biological activity of the combination. Examples of

such diluents are distilled water, physiological phosphate-buffered saline, Ringer's solutions, dextrose solution, and Hank's solution.

Pharmaceutical compositions can also contain large, slowly metabolized macromolecules such as proteins, polysaccharides such as chitosan, polylactic acids, polyglycolic acids and copolymers (such as latex-functionalized SEPHAROSE™, agarose, cellulose, and the like), polymeric amino acids, amino acid copolymers, and lipid aggregates (such as oil droplets or liposomes).

Administration of a pharmaceutical composition or medicament of the invention can be carried out via a variety of routes including, but not limited to, oral, topical, pulmonary, rectal, subcutaneous, intradermal, intranasal, intracranial, intramuscular, intraocular, or intra-articular injection, and the like. The most typical route of administration is intravenous followed by subcutaneous, although other routes can be equally effective. Intramuscular injection can also be performed in the arm or leg muscles. In some methods, agents are injected directly into a particular tissue where deposits have accumulated, for example, intracranial injection. In some embodiments, an antibody or antibody fragment is injected directly into the cranium. In other embodiments, antibody or antibody fragment is administered as a sustained-release composition or device, such as a MEDIPAD™ device.

For parenteral administration, antibody or antibody fragments of the invention can be administered as injectable dosages of a solution or suspension of the substance in a physiologically acceptable diluent with a pharmaceutical carrier that can be a sterile liquid such as water, oils, saline, glycerol, or ethanol. Additionally, auxiliary substances, such as wetting or emulsifying agents, surfactants, pH buffering substances and the like

can be present in compositions. Other components of pharmaceutical compositions are those of petroleum, animal, vegetable, or synthetic origin, for example, peanut oil, soybean oil, and mineral oil. In general, glycols such as propylene glycol or polyethylene glycol are suitable liquid carriers, particularly for injectable solutions. Antibodies can be administered in the form of a depot injection or implant preparation which can be formulated in such a manner as to permit a sustained-release of the active ingredient An exemplary composition contains an antibody at 5 mg/mL, formulated in aqueous buffer composed of 50 mM L-histidine, 150 mM NaCl, adjusted to pH 6.0 with HCl.

Typically, compositions are prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid vehicles prior to injection can also be prepared. The preparation also can be emulsified or encapsulated in liposomes or micro particles such as polylactide, polyglycolide, or copolymer for enhanced delivery.

For suppositories, binders and carriers include, for example, polyalkylene glycols or triglycerides; such suppositories can be formed from mixtures containing the active ingredient in the range of 0.5% to 10%, or more desirably 1%-2%.

Oral formulations include excipients, such as pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, and magnesium carbonate. These compositions take the form of solutions, suspensions, tablets, pills, capsules, sustained-release formulations or powders and contain 10%-95% of active ingredient, or more suitably 25%-70%.

Topical application can result in transdermal or intradermal delivery. Topical administration can be facilitated by co-administration of the agent with cholera toxin or detoxified derivatives or subunits thereof or

other similar bacterial toxins (see Glenn, et al. (1998) *Nature* 391:851). Co-administration can be achieved by using the components as a mixture or as linked molecules obtained by chemical crosslinking or expression as a fusion protein.

Alternatively, transdermal delivery can be achieved using a skin path or using transferosomes (Paul, et al. (1995) *Eur. J. Immunol.* 25:3521-24; Cevc, et al. (1998) *Biochem. Biophys. Acta* 1368:201-15).

An antibody or antibody fragment of the invention can optionally be administered in combination with other agents that are at least partly effective in treatment of amyloidogenic disease.

Antibody and antibody fragments of the instant invention also find application in the identification of therapeutic agents that prevent the binding of ADDLs to neurons (*e.g.* a hippocampal cell) thereby preventing downstream events attributed to ADDLs. Such an assay is carried out by contacting a neuron with ADDLs in the presence of an agent and using an antibody of antibody fragment of the invention to determine binding of the ADDLs to the neuron in the presence of the agent. As will be appreciated by the skilled artisan, an agent that blocks binding of ADDLs to a neuron will decrease the amount of ADDLs bound to the neuron as compared to a neuron which has not been contacted with the agent; an amount which is detectable in an immunoassay employing an antibody or antibody fragment of the instant invention. Suitable immunoassays for detecting neuronal-bound ADDLs are disclosed herein.

Agents which can be screened using the method provided herein encompass numerous chemical classes, although typically they are organic molecules, preferably small organic compounds having a molecular weight of more than 100 and less than about 2,500 daltons. Agents encompass functional groups necessary for structural interaction with

proteins, particularly hydrogen bonding, and typically include at least an amine, carbonyl, hydroxyl or carboxyl group, preferably at least two of the functional chemical groups. The agents often contain cyclical carbon or heterocyclic structures and/or aromatic or polyaromatic structures substituted with one or more of the above functional groups. Agents can also be found among biomolecules including peptides, antibodies, saccharides, fatty acids, steroids, purines, pyrimidines, derivatives, structural analogs or combinations thereof. Agents are obtained from a wide variety of sources including libraries of natural or synthetic compounds.

A variety of other reagents such as salts and neutral proteins can be included in the screening assays. Also, reagents that otherwise improve the efficiency of the assay, such as protease inhibitors, nuclease inhibitors, anti-microbial agents, and the like can be used. The mixture of components can be added in any order that provides for the requisite binding.

Agents identified by the screening assay of the present invention will be beneficial for the treatment of amyloidogenic diseases and/or tauopathies. In addition, it is contemplated that the experimental systems used to exemplify these concepts represent research tools for the evaluation, identification and screening of novel drug targets associated with amyloid beta induction of tau phosphorylation.

The present invention also provides methods for detecting ADDLs and diagnosing a disease associated with accumulation of ADDLs using an antibody or antibody fragment of the instant invention. A disease associated with accumulation of ADDLs is intended to include any disease wherein the accumulation of ADDLs results in physiological impairment of long-term potentiation/memory formation. Diseases of this type include, but are not

limited to, Alzheimer's Disease and similar memory-related disorders.

In accordance with these methods, a sample from a patient is contacted with an antibody or antibody fragment of the invention and binding of the antibody or antibody fragment to the sample is indicative of the presence of ADDLs in the sample. As used in the context of the present invention, a sample is intended to mean any bodily fluid or tissue which is amenable to analysis using immunoassays. Suitable samples which can be analyzed in accordance with the methods of the invention include, but are not limited to, biopsy samples and fluid samples of the brain from a patient (*e.g.*, a mammal such as a human). For *in vitro* purposes (*e.g.*, in assays monitoring oligomer formation), a sample can be a neuronal cell line or tissue sample. For diagnostic purposes, it is contemplated that the sample can be from an individual suspected of having a disease associated with accumulation of ADDLs or from an individual at risk of having a disease associated with accumulation of ADDLs, *e.g.*, an individual with a family history which predisposes the individual to a disease associated with accumulation of ADDLs.

Detection of binding of the antibody or antibody fragment to ADDLs in the sample can be carried out using any standard immunoassay (*e.g.*, as disclosed herein), or alternatively when the antibody fragment is, *e.g.*, a peptide aptamer, binding can be directly detected by, for example, a detectable marker protein (*e.g.*, β-galactosidase, GFP or luciferase) fused to the aptamer. Subsequently, the presence or absence of the ADDL-antibody complex is correlated with the presence or absence, respectively, of ADDLs in the sample and therefore the presence or absence, respectively, of a disease associated with accumulation of ADDLs. It is contemplated that one or more antibodies or antibody fragments of the present

invention can be used in conjunction with current non-invasive immuno-based imaging techniques to greatly enhance detection and early diagnosis of a disease associated with accumulation of ADDLs.

To facilitate diagnosis the present invention also pertains to a kit for containing an antibody or antibody fragment of the instant invention. The kit includes a container holding one or more antibody or antibody fragments which recognizes multi-dimensional conformation of ADDLs and instructions for using the antibody for the purpose of binding to ADDLs to form an antibody-antigen complex and detecting the formation of the antibody-antigen complex such that the presence or absence of the antibody-antigen complex correlates with presence or absence of ADDLs in the sample. Examples of containers include multiwell plates which allow simultaneous detection of ADDLs in multiple samples.

The invention is described in greater detail by the following non-limiting examples.

Example 1: General Materials and Methods

ADDL Preparation. ADDLs in F12 medium (Biosource, Camarillo, CA) were prepared from Aβ1-42 in accordance with established methods (Lambert, et al. (2001) *supra*). Briefly, Aβ1-42 peptide (American Peptide Co., Sunnyvale, CA or California Peptide Research, Inc., Napa, CA) was weighed and placed in a glass vial capable of holding a sufficient quantity of HFIP (1,1,1,3,3,3-hexafluoro-2-propanol) to achieve a peptide concentration of 10 mg/mL. HFIP was added to the dry peptide, the vial was capped and gently swirl to mix, and the peptide/HFIP solution was stored at room temperature for at least one hour. Aliquots (50 or 100 µL, 0.5 or 1.0 mg, respectively) of peptide solution was dispensed into a series of 1.5 mL conical centrifuge tubes. The tubes were placed in a speedvac

overnight to remove the HFIP. Tubes containing the dried peptide film were capped and stored at -70°C in a sealed container with dessicant.

Prior to use, the Aβ1-42 peptide film was removed from -70°C storage and allowed to warm to room temperature. Fresh DMSO (44 µL/mg of peptide film; 5 mM) was added and the peptide/DMSO mixture was incubated on a vortex mixer at the lowest possible speed for ten minutes. F12 media (2 mL/mg peptide) was dispensed into each tube of DMSO/peptide and the tube was capped and mixed by inversion. The 100 µM preparation was stored at 2-8°C for eighteen to twenty four hours. The samples were centrifuged at 14,000 x g for ten minutes at 2-8°C. The supernatant was transferred to a fresh tube and stored at 2-8°C until used.

Biotinylated ADDL preparations (bADDLs) were prepared in the same manner as described above for ADDL preparations using 100% *N*-terminal biotinylated amyloid beta peptide (American Peptide Company, Sunnyvale, CA).

ADDL Fibril Preparation. To room temperature ADDL peptide film was added 2 mL of 10 mM hydrochloric acid per mg peptide. The solution was mixed on a vortex mixer at the lowest possible speed for five to ten minutes and the resulting preparation was stored at 37°C for eighteen to twenty four hours before use.

Monomer Preparation. HFIP dry down preparations of amyloid beta (1-40) peptide (Aβ1-40) were prepared as outlined for Aβ(1-42) peptide. The peptide film was dissolved in 2 mL of 25 mM borate buffer (pH 8.5) per mg of peptide, divided into aliquots, and frozen at -70°C until used.

Human Fibril Preparation. Samples obtained from frozen human cortex were homogenized in 20X cold F12 medium with protease inhibitors (COMPLETE®, Roche Diagnostics Corporation, Indianapolis, IN) for 1 minute. The sample was then centrifuged at 10,000 x g for 1 hour at 4°C. After

washing twice with F12, the pellet was resuspended in 2% SDS/F12 and incubated on ice for 30 minutes. The sample was subsequently centrifuged at 220,000 x g for 1 hour at 4°C. The pellet was resuspended in cold F12 and sonicated for 1 minute in 15-second bursts. Protein was determined using COOMASSIE PLUS™ kit (Pierce Biotechnology, Rockford, IL).

Immunization. The resulting soluble Aβ oligomers, referred to herein as "synthetic" ADDLs, were mixed 1:1 with complete Freund's adjuvant (first and second vaccination) or incomplete Freund's adjuvant (all subsequent vaccinations) and injected subcutaneously (first two vaccinations) or intraperitoneally into three mice in a total volume of ~1 mL/mouse. Each injection consisted of purified ADDLs equivalent to 194 ± 25 µg total protein. Mice were injected approximately every three weeks. After six injections, one mouse died and its spleen was frozen. The spleen from the mouse with the highest titer serum was then fused with SP2/0 myeloma cells in the presence of polyethylene glycol and plated out into six 96-well plates. The cells were cultured at 37°C with 5% CO_2 for ten days in 200 µL of HAT selection medium, which is composed of ISCOV medium supplemented with 10% fetal bovine serum (FBS), 1 µg/mL HYBRIMAX® (azaserine-hypoxanthine; Sigma-Aldrich, St. Louis, MO), and 30% conditioned media collected from SP2/0 cell culture. The cultures were fed once with ISCOV medium supplemented with 10% FBS on day 10, and the culture supernatants were removed on day 14 to screen for positive wells in ELISA. The positive cultures were further cloned by limiting dilutions with probability of 0.3 cells per well. The positive clones were confirmed in ELISA and further expanded.

Screening of supernates involved five assays: a dot blot and western immunoblot (Lambert, et al. (2001) *supra*), a native immunoblot using synthetic ADDLs, and a dot blot and western blot using endogenous fibrils obtained from

human tissue. These assays tested the binding of antibodies to ADDLs (the dot blot) and identified the oligomer(s) that had the greatest affinity (western). All antibodies were tested in the dot blot using 5 pmole ADDLs (576 supernates in the first fusion and 1920 supernates in the second). Those supernatants that tested positive were then screened further using western blot at 10-20 pmole ADDLs. The screen was repeated to identify low positives or false positives. Ten wells supernatants expanded for the first mouse and forty-five wells were expanded for the second mouse. The expanded cells were then frozen or subcloned.

Monoclonal antibody-containing ascites were produced in female balb/c mice using standard protocols (Current Protocol of Molecular Biology). Briefly, mice were primed by intraperitoneal injection of 0.5 mL of pristane. One week after the priming, mice were injected intraperitoneally with approximately 5 x 10^6 hybridoma cells in 1 mL phosphate-buffered saline (PBS). Ascites were collected ten to fourteen days later. IgG purification was carried out by using BIO-RAD® AFFI-GEL® Protein A MAPS® II kit, according to manufacturer's protocol. For each run, 3 mL ascites were desalted by passage through a desalting column and elution in 4 mL binding buffer. The sample was then applied to the Protein A column. After washing with 40 mL binding buffer, the column was eluted with elution buffer and the 5 mL fractions were collected. Samples were neutralized by addition of 60 µL of 10 N NaOH. To exchange the buffer to PBS, the samples were applied to a second desalting column and eluted with PBS.

Control Antibodies. Polyclonal antibodies M71/2 and M90/1 were obtained from Bethyl Laboratories, Inc. (Montgomery, TX). Anti-Aβ monoclonal antibodies 6E10 (raised against residues 1-17) and 4G8 (raised against residues 17-24) were obtained from Signet Labs (Dedham, MA). Monoclonal antibody WO-2 is known in the art for its

ability to recognize both 1-40 and 1-42 via western blot analysis (Ida, et al. (1996) *J. Biol. Chem.* 271: 22908-22914. Monoclonal antibody BAM-10 (raised against Aβ1-40) was obtained from ABCAM® (Cambridge, MA). Monoclonal antibody 26D6 is well-known in the art for its ability to recognize amino acids 1-12 of Aβ sequence (Lu, et al. (2000) *Nat. Med.* 6:397-404).

Immunoblot Analysis. Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) was performed using established methods (Lambert, et al. (2001) *supra*), except that 10-20% Tris-Tricine gels (BIO-RAD®, Hercules, CA) were used and the separation was performed at 120 V. Gels were transferred according to standard methods and secondary antibody was routinely used at a 1:40,000 dilution.

For initial screening, 2.7 µg ADDLs, equivalent to ~16-20 pmol/lane, were separated on two-dimensional (2D) 4-20% gels. Electrophoresis and transfer were as above. Using the tracking dye as a guide, the nitrocellulose was placed into a Surf-blot apparatus (Idea Scientific, Minneapolis, MN) and 200 µL of hybridoma supernate mixed with blocking buffer, composed of 5% nonfat dry milk in tris-buffered saline with TWEEN™ 20 (TBS-T; Lambert et al. (2001) *supra*), was added to each of 20-21 wells. After incubation at room temperature for 1.5 hour with rocking, the supernatants were removed and the wells were washed with 200 µL blocking buffer. The membrane was then removed from the Surf-blot apparatus and washed 3 x 15 minutes in TBS-T. The secondary antibody (anti-mouse, IgG conjugated-HRP, 1:40,000; Molecular Probes, Eugene, OR) was then incubated with the membrane for 1 hour at room temperature. After washing (3 x 15 minutes), the oligomers were visualized with half-strength SUPERSIGNAL® (Pierce, Rockland, IL). The western immunoblot using human fibrils was performed in the same

manner using approximately 64 µg of human fibrillar tissue in each 2D SDS-PAGE immunoblot.

Native polyacrylamide gel electrophoresis was performed according established methods (Chromy, et al. (2003) *Biochemistry* 42:12749-12760) except that the separation was performed at 120 V.

Western Blot. Separated proteins were transferred to nitrocellulose. Blots were blocked with 5% non-fat dry milk or 1% bovine serum albumin (BSA) in TBS-T (TBS with 0.1% TWEEN™ 20) overnight, incubated with primary antibody(ies) for 1.5 hours, washed, and incubated the horseradish peroxidase (HRP)-conjugated secondary antibody (Amersham Biosciences Corp., Piscataway, NJ) for 1 hour. After final washing, proteins were visualized with a West Femto chemiluminescence kit (Pierce Biotechnology, Rockford, IL) and a KODAK® Image Station 440 CF or with film (HYPERFILM™, Amersham Biosciences Corp., Piscataway, NJ).

Hippocampal Cultures. Cultures were prepared from E18 embryos according to standard methods (Brewer (1997) *J. Neurosci. Methods* 71:143-155; Stevens, et al. (1996) *J. Neurosci. Res.* 46:445-455). Viable cells were counted and plated on coverslips coated with polylysine (200 µg/mL) at densities from 1.5 x 10^4-10^6 cells/cm^2. The medium was changed by removing half of the medium and replacing it with supplemented NEUROBASAL™ media.

Primary Neurons. Primary hippocampal cultures were prepared from frozen, dissociated neonatal rat hippocampal cells (Cambrex, Corp., East Rutherford, NJ) that were thawed and plated in 96-well COSTAR® plates at a concentration of 20,000 cells per well. The cells were maintained in NEUROBASAL™ media without L-glutamine (GIBCO-BRL™, Gaithersburg, MD) and supplemented with B27 (GIBCO-BRL™, Gaithersburg, MD) for a period of two weeks and then used for binding studies.

B103 Cells. The B103 neuroblastoma cell line (Schubert and Behl (1993) *Brain Res*. 629:275-82) was grown in DMEM without phenol red (GIBCO-BRL™, Gaithersburg, MD), in the presence of 10% FBS (Hyclone, Logan, UT) and 1% Pen-Strep (GIBCO-BRL™, Gaithersburg, MD). Exponentially growing B103 cells were dissociated and plated in 96-well CORNING® plates at a concentration of 5,000 cells/well. Twenty-four hours after plating, the cells were used to assess ADDL and bADDL binding as well as characterize commercial and novel anti-ADDL monoclonal antibodies.

Dot Blot Analysis. Dot blots were performed according to Lambert, et al. ((2001) *supra*) applying either ADDLs (5 pmole/dot) or fibrils to the nitrocellulose. For later dot blots, ADDLs were applied to dry nitrocellulose in duplicate at various pmolar concentrations in 0.5 µL using a template derived from the Surf-blot apparatus. Samples were then dried for 15 minutes, blocked with blocking buffer for 1 hour, and incubated for 1.5 hour with antibody plus or minus peptide, which had been pre-incubated for at least 1 hour at room temperature. The solution was removed from the Surf-blot apparatus, the wells were washed with blocking buffer, and the membrane was removed from the apparatus. The nitrocellulose was washed, treated with secondary antibody, and visualized as indicated above.

Immunocytochemistry. Immunocytochemistry was performed according to established methods (Lambert, et al. (2001) *supra*), except the secondary antibodies were conjugated to ALEXAFLUOR® 588 (Molecular Probes, Eugene, OR). Antibodies and ADDLs were preincubated for 1 hour at room temperature, at a molar ratio of 1:4 antibody:ADDL before application to the 21-day hippocampal cell culture. For endogenous ADDLs, human brain protein (prepared as in Lambert, et al. (2001) *supra*) was incubated with cells for 1 hour before the cells were washed, fixed, and visualized as above.

Lightly fixed frozen sections (4% paraformaldehyde at 4°C for 30 hours and cryoprotected in 40 µm sucrose) from Alzheimer's Disease and control hippocampus were incubated with antibody (1:1000 in phosphate-buffered saline (PBS)) overnight at 4°C. After removal of antibody, sections were washed 3 times with PBS and incubated with secondary antibody at room temperature. Binding was then visualized with DAB (SIGMA™, St. Louis, MO). Sections were then counterstained with hematoxylin, mounted, and imaged on a NIKON® ECLIPSE® E600 light microscope with a SPOT™ INSIGHT™ digital video camera (v. 3.2).

Quantitative Immunocytochemistry. Cultured hippcampal cells were incubated with 500 nM ADDLs for 1 hour at 37°C. ADDLs were removed by washing and cells were fixed with 3.7% formaldehyde. Cells were incubated with 0.1% TRITON™ X-100 in PBS-NGS (PBS with 10% normal goat serum) for 30 minutes, washed once, and incubated with the desired primary antibody(ies) (diluted in PBS-NGS) overnight at 4°C. Samples were washed and incubated with the appropriate secondary antibody(ies), *e.g.*, ALEXAFLUOR® 488 or 594 anti-mouse and anti-rabbit IgGs (Molecular Probes, Inc., Eugene, OR), for 2 hours at 37°C. Coverslips were washed and mounted in PROLONG® anti-fade mounting medium (Molecular Probes, Inc., Eugene, OR) and imaged using a LEICA® TCS SP2 confocal Scanner DMRXE7 microscope.

ELISA. Polyclonal anti-ADDLs IgG (M90/1; Bethyl Laboratories, Inc., Montgomery, TX) was plated at 0.25 mg/well on IMMULON™ 3 REMOVAWELL™ strips (Dynatech Labs, Chantilly, VA) for 2 hours at room temperature and the wells blocked with 2% BSA in TBS. Samples diluted with 1% BSA in F12 were added to the wells, allowed to bind for 2 hours at 4°C, and washed 3X with BSA/TBS at room temperature. Monoclonal antibodies diluted in BSA/TBS were incubated for 90 minutes at room temperature and detected with a VECTASTAIN® ABC kit to mouse IgG. The HRP label was

visualized with BIO-RAD® peroxidase substrate and read at 405 nm on a Dynex MRX-TC microplate reader.

Example 2: Development and Characterization of Anti-ADDL Antibodies

Three mice were inoculated with ADDLs (194 ± 25 µg protein/injection) every three weeks for a total of six inoculations. Hybridomas made from the fusion of these mice spleens with SP2 cells were grown in 96-well plates. Supernates from these wells were screened in dot blots with synthetic ADDLs to identify positive clones, which were compared with dot blots of endogenous fibrils to identify differences. Hybridomas that bound only synthetic ADDLs and not endogenous fibrils were sought. To further refine what the products of the hybridomas bound to and under what conditions binding occurred, three western blots of each positive clone were performed: SDS-PAGE of ADDLs, native gels of ADDLs, and SDS-PAGE with endogenous fibrils. Approximately 40 clones were selected for further examination. Each clone was tested for recognition of soluble Alzheimer's Disease brain extract, for identification of ADDLs bound to cultured hippocampal cells, and for the ability to block ADDL binding under various conditions. Selected antibodies were collected from culture medium and further purified using Protein G SEPHAROSE™.

Each time a set of hybridomas was screened via dot blot, approximately ~30% yielded positive supernates. Of these, only one or two hybridomas bound synthetic ADDLs and not endogenous fibrils. Approximately 2% of the original number of clones bound synthetic ADDLs and not monomer at low ADDL concentrations, as determined by western blot analysis. Clone 3B7, which bound synthetic ADDLs and not fibrils on western blots, was kept for further analysis.

One to two clones were identified that bound higher molecular weight material (12-24 mer) better than trimer/tetramer oligomers. Two to three clones were identified which could bind to native ADDLs under native conditions, but failed to bind ADDLs in the presence of SDS.

The results of this analysis indicated that ADDLs are good antigens in mice and monoclonal antibodies can be developed that bind to synthetic ADDLs with much greater affinity than to monomers.

Example 3: Immunohistochemical Analysis of Endogenous and Synthetic ADDLs Bound to Cultured Hippocampal Cells

Cultured hippocampal cells were also analyzed to determine whether monoclonal antibodies that distinguish between Alzheimer's Disease and control brain extracts could identify ADDLs (either endogenous or synthetic) bound to cultured cells. Hippocampal cultures were prepared according to established protocols and allowed to grow for 3-4 weeks. Synthetic ADDLs were prepared according to standard protocols (*e.g.*, U.S. Patent No. 6,218,506). Endogenous ADDLs were extracted from Alzheimer's Disease brain according to Gong, et al. ((2003) *supra*). ADDLs (100 nM in F12, or 2 mg total protein in F12) were incubated with the cells for 1 hour and then washed and fixed according to standard methods. Following washing, the cells were incubated with 20C2, 3B7, M94, 2A10, 4E2, 2D6, 4C2, 2B4, 5F10, or 5G12 monoclonal antibody and subsequently with anti-mouse secondary conjugated to ALEXAFLUOR® 488. Images were taken on a NIKON® DIAPHOT™ epifluorescent microscope with COOLSNAP™ HQ camera and analyzed using METAMORPH™ software (Universal Imaging, Downingtown, PA).

Both endogenous and synthetic ADDLs exhibited the standard hot spot pattern in cultured cells when visualized by 20C2. Thus, monoclonal antibody 20C2 identifies both

synthetic and endogenous ADDLs bound to cultured hippocampal cells. As 3B7 did not bind to fibrils, higher molecular weight oligomers, and monomers, hot spot binding of ADDLs by 3B7 was attributed to oligomeric ADDLs. The other antibodies appeared to recognize a variety of epitopes on ADDLs bound to cells, ranging from hot spots on processes (M94, 2A10) to cell body specific attachment (4E2) and other states in between (2D6, 4C2, 2B4, 5F10, 5G12).

Example 4: Inhibition of ADDL Binding to Neurons Using Murine Anti-ADDL Antibodies

To determine whether monoclonal antibodies that distinguish between Alzheimer's Disease and control brain extracts could also block binding of ADDLs to cultured cells, cultured hippocampal cells were preincubated with 20C2 antibody and ADDL binding was determined by immunocytochemistry. Hippocampal cultures were prepared according to established methods and allowed to grow for 3-4 weeks. Synthetic ADDLs were prepared according to standard protocols (*e.g.*, see U.S. Patent No. 6,218,506 and the like). Endogenous ADDLs were extracted from Alzheimer's Disease brain according to Gong, et al. ((2003) *supra*). ADDLs (100 nM in F12, or 2 mg total protein in F12) were preincubated with 20C2 antibody for 1 hour and subsequently added to cells for 1 hour at 37°C. Cells were washed, fixed, and incubated with anti-mouse secondary conjugated to ALEXAFLUOR® 488.

Both endogenous and synthetic ADDL binding to cultured cells was blocked by preincubation with 20C2. Vehicle and no-secondary antibody control images were black.

Example 5: Detection of ADDL Binding to Neurons Using Biotinylated ADDLs

The binding of ADDLs or bADDLs (biotinylated ADDLs) to neurons was detected using standard immunofluorescence procedures. Primary hippocampal neurons (cultured for fourteen days) or B103 cells (plated for twenty-four hours) were incubated with 5-25 μm ADDLs or bADDLs for one hour at 37°C and the cells were subsequently washed three to four times with warm culture medium to remove unbound ADDLs or bADDLs. The cells were then fixed for ten minutes at room temperature with 4% paraformaldehyde prepared from 16% paraformaldehyde (Electron Microscopy Sciences, Fort Washington, PA) diluted in PBS. Subsequently, the solution was removed and fresh fixative added for an additional ten minutes at room temperature. The cells were permeabilized (4% paraformaldehyde solution with 0.1% TRITON™-X 100; SIGMA, St. Louis, MO) for ten minutes, washed six times with PBS and incubated for one hour at 37°C with blocking buffer (PBS with 10% BSA; Sigma, St. Louis, MO). At this point, the protocols for the detection of bound ADDLs and bADDLs diverge. To detect ADDL binding, the cells were incubated overnight at 37°C with 4G8 (diluted 1:1,000 in PBS containing 1% BSA; Signet Labs, Dedham, MA), 6E10 (1:1,000; Signet Labs, Dedham, MA), or one of the anti-ADDL monoclonal antibodies disclosed herein (diluted 1:1,000). In addition, a polyclonal antiserum raised against tau (1:1,000; Sigma, St. Louis, MO) was used to visualize the cell processes. The next day, the cells were washed three times with PBS, incubated for one hour at room temperature with an ALEXA® 594-labeled anti-mouse secondary (diluted 1:500 in PBS with 1% BSA; Molecular Probes, Eugene, OR,) and an ALEXA® 488-labeled anti-rabbit secondary (diluted 1:1,000; Molecular Probes, Eugene, OR), washed three times in PBS and the binding observed using a microscope with fluorescence capabilities. For the detection of bADDL

binding, the cells were incubated overnight with the tau antibody. Subsequently, the cells were washed three times with PBS, incubated for one hour at room temperature with an ALEXA® 488-labeled anti-rabbit secondary (as above) and an ALEXA® 594-labeled streptavidin, 1:500 dilution (Molecular Probes, Eugene, OR), washed 5-6 times in PBS and the binding visualized with a fluorescence microscope. If the staining of the cell nuclei was desired, the nuclei were labeled with DAPI (1:1000) according to standard protocols.

For immunocytochemical analysis of ADDLs using an ADDL-specific monoclonal antibody, cells were washed, fixed, permeabilized and blocked after incubation with ADDLs. To detect the bound bADDLs with monoclonal antibodies, the cells were incubated overnight with 4G8, 6E10 or one of the instant anti-ADDL monoclonal antibodies and immunoreactivity was subsequently detected with an ALEXA® 488-labeled anti-mouse secondary antibody. The bound bADDLs were visualized with an ALEXA® 594-labeled streptavidin and the nuclei stained with DAPI. After staining, the colocalization of bADDL binding and ADDL immunoreactivity was detected with a fluorescence microscope.

Specific immunoreactivity with primary hippocampal cells incubated with ADDLs was seen with each of the monoclonal antibodies evaluated (*i.e.*, 20C2, 2H4, 2B4, and 2A10). The bound ADDLs appeared as punctate staining along the neuronal processes and cell soma. This pattern was only seen on a subset of neurons, a pattern that is consistent with previous reports describing ADDL binding to primary neurons using both commercial and non-commercial antibodies. The pattern of staining and the results of a number of control studies demonstrated the specificity of these antibodies.

The use of bADDLs offered a simplified method to detect bound ADDLs and evaluate the blockade of ADDL binding with the monoclonal antibodies. When bADDLs were added to primary hippocampal cells and the binding evaluated with a fluorescent-labeled streptavidin, specific binding was seen along the neuronal processes of a subset of cells in culture. If the cells were then fixed, processed for immunocytochemistry and an anti-ADDL antibody used to visualize binding, a similar pattern of staining was observed. Furthermore, the superimposition of these staining patterns revealed a perfect overlap of the antibody staining and bound bADDLs, thus demonstrating that bADDLs and ADDLs are functionally equivalent and the use of bADDLs in binding assays.

Example 6: Detecting and Measuring Murine anti-ADDL Monoclonal Antibody Differential Displacement of bADDL Binding to Neurons

The ability of antibodies to block the binding of ADDLs or bADDLs to neuronal cultures (primary neurons or B103 cells) was characterized using the immunocytochemical methods described herein with a few modifications. Monoclonal antibodies were mixed with 1-10 μm bADDLs at a molar ratio of 1:1, 1:5 or 1:10 (antibody:bADDLs) and incubated in a siliconized microcentrifuge tube for one hour at 37°C on a slow rotator (Miltenyi Biotec, Auburn, CA). Subsequently, the antibody/bADDL mixture was added to cells and allowed to further incubate for one hour at 37°C. After incubation, the cells were washed, fixed, permeabilized, blocked and incubated overnight with a polyclonal antiserum raised against tau to visualize the cell processes. The next day, the cells were washed, incubated with an ALEXA® 488-labeled anti-rabbit secondary antibody and an ALEXA® 594-labeled streptavidin and the cells were stained with DAPI to allow detection of nuclei.

Once stained, the degree of binding was assessed visually with a fluorescence microscope.

To quantitatively assess the degree of bADDL binding and the ability of anti-ADDL antibodies to abate this interaction, a cell-based alkaline phosphatase assay was developed. Monoclonal antibodies or PBS were mixed at a 1:1 (B103 cells) or 1:5 (primary neurons) molar ratio with 2.5-10 μm (final concentration) of bADDLs and incubated for one hour at 37°C on a slow rotator. After preincubation, the antibody/bADDL preparations were added to the B103 or primary neuron cultures and incubated for an additional one hour at 37°C. At the end of the incubation period, the bADDLs/antibody mixture was removed and the plates washed six times with media. The cells were fixed in 4% paraformaldehyde for ten minutes at room temperature, the solution removed, fresh fixative added and the cells fixed for an additional ten minutes. The cells were permeabilized with 4% paraformaldehyde containing 0.1% TRITON™ X-100 (2 times, each for ten minutes at room temperature), washed six times in PBS and treated with 10% BSA in PBS for one hour at 37°C. Alkaline phosphatase-conjugated streptavidin (1:1,500 in 1% BSA; Molecular Probes, Eugene, OR) was added to the cells for one hour at room temperature. The cells were rinsed six times with PBS, the alkaline phosphatase substrate (CDP-STAR® with SAPPHIRE-II™; Applied Biosystems, Foster City, CA) added to the cells and incubated for thirty minutes prior to determining the luminescence on a LJL Luminometer (Analyst AD; LJL BioSystems, Sunnyvale, CA).

When the binding of bADDLs to the neurons was evaluated, an antibody-dependant pattern of staining was observed. Some of the antibodies investigated markedly reduced the binding of bADDLs, while others were less effective. Unexpectedly, a third group of antibodies appeared to enhance the binding of bADDLs to neurons. While

the results of these studies were qualitative and not quantitative in nature, they indicated that the antibodies differentially blocked bADDL binding to neurons. Quantitative assessment demonstrated a similar trend (Figure 1). That is, some antibodies abated the binding of bADDLs to neurons, some were weak or had little effect and a few enhanced the binding (*i.e.*, 5F10 and 4C2). Moreover, a mouse Fab was unable to block the binding of bADDLs, further demonstrating the specificity of the monoclonal antibodies in this assay.

Analysis of bADDL binding and blockade with monoclonal antibodies in the neuroblastoma cell line B103 demonstrated specific bADDL binding to B103 cells, but not to an ovarian cell line (CHO). Moreover, the binding was dramatically attenuated when bADDLs were pre-incubated with an anti-ADDL monoclonal antibody prior to the addition to B103 cells. Quantitative assessment of the blockade of bADDL binding to B103 cells with monoclonal antibodies indicated that the monoclonal antibodies were not equal in their ability to block bADDL binding to cells (Figure 2). As seen with the primary hippocampal cells, some antibodies were quite good at blocking binding, while others were less effective. Furthermore, the antibody 4C2 also enhanced the ability of bADDLs to bind to B103 cells in culture.

To show that bADDLs also bind to regions of the hippocampus that are involved in learning and memory, a series of binding studies were conducted using rat hippocampal slice cultures. Binding studies showed that neurons in the CA1-3 and dentate gyrus regions of the hippocampus were capable of binding bADDLs, while neurons in other regions did not. When the bADDLs were pre-incubated with an anti-ADDL monoclonal antibody, the degree of bADDL binding was attenuated in a dose-dependant manner. These results showed that monoclonal antibodies can also

abate the binding of bADDLs to a subset of hippocampal neurons, neurons that a critical for learning and memory.

Example 7: Binding of Anti-ADDL Antibodies to Endogenous ADDLs from Alzheimer's and Control Brain

To further characterize the monoclonal antibodies disclosed herein, it was determined whether the monoclonal antibodies could identify ADDLs from soluble extracts of human Alzheimer's Disease brain (endogenous ADDLs) and distinguish that from extracts of control brain. Synthetic ADDLs and human brain extracts prepared in F12 were diluted in F12 and spotted (1 pmole ADDLs; 0.5 µg brain extract) in duplicate onto dry HYBOND™ ECL™ nitrocellulose. Brain tissue, with corresponding CERAD grades (Consortium to Establish a Registry for Alzheimer's Disease) and Braak stages, was obtained from NU Brain Bank Core. The blot was allowed to dry 20 minutes and then incubated in 3% H_2O_2 in TBS (20 mM Tris-HCl, pH 7.5, 0.8% NaCl) for 20 minutes at room temperature. The blot was cut into strips and blocked with 5% milk in TBS-T (0.1% TWEEN™-20 in TBS) for 1 hour at room temperature. Rabbit polyclonal antibody M71/2 (1:2500, 0.4 µg; Bethyl Laboratories, Inc., Montgomery, TX); monoclonal antibody 6E10 (1:500, 3 µg; Signet Labs, Dedham, MA); and monoclonal antibodies 20C2 (1.52 mg/mL, 5 µg), 11B5 (2.54 mg/ml, 5 µg), 2B4 (1.71 mg/mL, 5 µg), and 2A10 (1.93 mg/mL, 7.5 µg) as disclosed herein (Figure 3) were diluted in 1.5 mL of milk/TBS-T and incubated for 1 hour at room temperature. The blots were washed 3 x 10 minutes with TBS-T. The blots were incubated with horseradish peroxidase (HRP)-linked secondary antibody (1:40,000 in milk/TBS-T; Amersham Life Science, Inc., Arlington Heights, IL) for 1 hour at room temperature. The blots were washed 3 x 10 minutes with TBS-T, rinsed 3 times with dH_2O, developed with SUPERSIGNAL™ substrate (1:1 dilution with ddH_2O; Pierce,

Rockland, IL) and exposed to HYPERFILM™ ECL™ (Amersham Life Science, Inc., Arlington Heights, IL).

All antibodies tested identified synthetic ADDLs with robust binding, except 2A10, which had weaker binding, even though it was tested at higher protein concentration. Polyclonal antibody M71/2 and monoclonal antibodies 20C2 and 11B5 bound strongly to both Alzheimer's Disease samples, but showed only very faint binding, similar to background in control brain. In contrast, monoclonal antibodies 6E10, 2B4, and 2A10 showed weak binding to Alzheimer's Disease brain.

The results of this analysis indicated that two of the monoclonal antibodies tested could distinguish between Alzheimer's Disease and control brain, wherein binding to endogenous oligomers was with a high degree of specificity. In addition, these data indicate that detection can be accomplished in early stages of Alzheimer's Disease.

Example 8: Immunohistochemical Analysis of Alzheimer's Disease and Control Brain Slices

Immunohistochemical analysis using the monoclonal antibodies disclosed herein was carried out to determine whether ADDLs can be visualized in brain slices using monoclonal antibodies that distinguish between Alzheimer's Disease and control brain extracts, and to demonstrate the nature of ADDL labeling (*e.g.*, diffuse, perineuronal, plaque-like, etc.) and its distribution in human tissue. Sections (40 μm) of fixed Alzheimer's Disease and control brain were prepared in accordance with standard methods. The slices were labeled with several monoclonal and one polyclonal antibody and subsequently counterstained with hematoxylin to identify cell nuclei. Images were obtained using a NIKON® ECLIPSE® E600 light microscope with a SPOT™ INSIGHT™ digital video camera (v. 3.2).

Immunohistochemical analysis indicated that ADDL staining was manifest in Alzheimer's Disease brain in the hippocampus, entorhinal cortex, and middle frontal gyrus. In a severe Alzheimer's Disease case, there was abundant light ADDLs staining in what appeared predominantly as a plaque-type distribution. Some light ADDL staining was observed as peri-neuronal in one Alzheimer's Disease case. In contrast, there is no staining using either antibody in any regions of control samples, not even a rare neuron surrounded by dot-like immunostaining.

These data indicate that polyclonal and monoclonal antibodies can be used to identify ADDLs in fixed human tissue, wherein labeling is varied, consisting of plaque-like regions, vascular regions, and peri-neuronal labeling of individual cells and some clusters. Further, labeling of ADDLs in Alzheimer's Disease, but not control, brain was observed in at least three brain regions: hippocampus, entorhinal cortex, and middle frontal gyrus.

Example 9: Immunostaining of Aβ1-40 Monomer-Like Control

Aβ1-40 oligomerizes slowly in DMSO/F12 compared to ADDLs. Thus, it was determined whether Aβ1-40 could serve as a monomer-like control. ADDLs were subjected to size exclusion chromatography (SEC) on a SUPERDEX® 75 column (ADDL063), which resolved into two peaks. Aβ1-40 was prepared in DMSO/F12 (45.5 mM), frozen and thawed. Samples were diluted with F12 and mixed ~2:1 with Tricine sample buffer (BIO-RAD®, Waltham, MA). SDS-PAGE was carried out on 10-20% Tris-Tricine gels (BIO-RAD®, Waltham, MA) with Tris/Tricine/SDS buffer (BIO-RAD®, Waltham, MA) at 120V at room temperature for 80 minutes. The gel was silver stained (60 pmoles Aβ1-40 or ADDLs; 40 pmoles Peaks 1 or 2) with SILVERXPRESS™ (INVITROGEN™, Carlsbad, CA). Alternatively, the gels (20 pmoles Aβ1-40 or ADDLs; 30 pmoles Peaks 1 or 2) were electroblotted onto HYBOND™ ECL™ nitrocellulose

using 25 mM Tris-192 mM glycine, 20% v/v methanol, pH 8.3, 0.02% SDS at 100V for 1 hour at 8°C. The blots were blocked with 5% milk in TBS-T (0.1% TWEEN™-20 in 20 mM Tris-HCl, pH 7.5, 0.8% NaCl) overnight at 8°C. Monoclonal antibody 6E10 (1:2000; Signet Labs, Dedham, MA), monoclonal antibody 20C2 (1.52 mg/mL, 1:2000; Figure 3), or polyclonal antibody M71/2 (1:4000, Bethyl Laboratories, Inc., Montgomery, TX) was diluted in milk/TBS-T and incubated with the blots for 90 minutes at room temperature. The blots were washed 3 x 10 minutes with TBS-T and subsequently incubated with HRP-conjugated secondary antibody (1:40,000 in TBS-T; Amersham Life Science, Inc., Arlington Heights, IL) for 1 hour at room temperature. After three washes with TBS-T, 10 minutes per wash, the blots were rinsed 3X with dH_2O, developed with SUPERSIGNAL® West Femto Maximum Sensitivity substrate (1:1 dilution with ddH_2O; Pierce, Rockland, IL) and exposed to HYPERFILM™ ECL™ (Amersham Life Science, Inc., Arlington Heights, IL).

Silver stain analysis showed Aβ1-40 as a heavy monomer band. In contrast, ADDLs and Peak 1 showed monomer, trimer and tetramer, although there was less tetramer. Silver stain analysis of Peak 2 showed heavy monomer with a lighter trimer and very light tetramer band.

Immunostaining of Aβ1-40 with 6E10 showed only a light monomer band. Immunostaining of ADDLs and Peak 1 with 6E10 showed monomer, trimer, tetramer and 12-24mer. Peak 2 showed heavy monomer staining with 6E10 and some light trimer and tetramer with no 12-24mer. There was no monomer staining of Aβ1-40 with 20C2 or M71/2. While both 20C2 and M71/2 showed minimal or no monomer staining of ADDLs and Peak 1, these samples had trimer, tetramer, and 12-24mer staining with 20C2 and M71/2. Peak 2 immunostaining with 20C2 and M71/2 showed light monomer, trimer and tetramer with no 12-24mer observed. Aβ1-40 immunostained lighter

with 6E10 than did the ADDL monomer, despite heavier silver staining.

These results indicated that, in contrast to the 6E10 antibody which shows good recognition of monomer, gels transferred with 0.02% SDS in the transfer buffer showed minimal monomer detection with the oligomer-specific antibodies. Immunostaining of SEC fractions showed Peak 2 composed mostly of monomer with small amounts of trimer and tetramer and no 12-24mer, while Peak 1 has monomer, trimer, tetramer and the 12-24mers.

To further characterize the monoclonal antibodies with respect to binding to Peak 1 and Peak 2, a sandwich ELISA was developed using polyclonal antibody M90 to ADDLs as the capture antibody. SEC peak 1 and peak 2 fractions referred to herein are the two major peaks of ADDLs that were fractionated on a SEPHADEX™ 75 column to distinguish between potentially bioactive and inactive oligomers. Non-denaturing gel electrophoresis confirmed the separation into large (>50 kDa) and small (<30 kDa) aggregates that were stable at 37°C. These peaks were used separately as the detection substance for clone supernates. Binding was visualized with a VECTASTAIN® kit. Differences between recognition of the two peaks was observed for all antibodies. For example, compare the ratio of peak 1 to peak 2 for antibodies 2B4 and 20C2 (Figure 3). Only one antibody reflects the control antibody (6E10) preference for peak 2.

Example 10: Detection of ADDL Formation from Aβ1-42

Polyclonal antibodies have been used in dot-blots to show time-dependent ADDL formation from Aβ1-42. Thus, it was demonstrated that monoclonal 20C2 antibody, which preferentially binds to oligomers, could also show increased signal with time as ADDLs form from Aβ1-42. Aβ1-42, ~750 pmoles HFIP film, was dissolved in 1.5 mL DMSO

(0.5 mM) and 2 µL aliquots diluted to a final volume of 100 µL with F12 (10 nM) and incubated on ice. Two µL (20 fmol) of reaction mixture was spotted on dry HYBOND™ ECL™ nitrocellulose (Amersham Life Science, Inc., Arlington Heights, IL) at specified time points. The nitrocellulose was blocked with 5% non-fat dry milk in TBS-T (20 mM Tris-HCl, pH 7.5, 0.8% NaCl, 0.1% TWEEN™-20) for 1 hour at room temperature. Polyclonal antibody M90/1 (Bethyl Laboratories, Inc., Montgomery, TX) or monoclonal antibody 20C2 (1.52 mg/mL) was diluted 1:2000 in milk/TBS-T and incubated with the blot for 90 minutes at room temperature followed by washing 3 x 10 minutes with TBS-T. HRP-conjugated secondary antibodies (Amersham Life Science, Inc., Arlington Heights, IL) were diluted 1:40,000 in milk/TBS-T and the blot incubated for 60 minutes at room temperature followed by washing as above. After a brief rinse with dH_2O, the blot was incubated for 60 seconds with SUPERSIGNAL® West Femto Maximum Sensitivity substrate (diluted 1:1 with ddH_2O; Pierce, Rockland, IL) and exposed to HYPERFILM™ ECL™ (Amersham Life Science, Inc., Arlington Heights, IL). Dot blots were scanned and intensity of spots was determined with ADOBE® PHOTOSHOP®.

Both antibodies detected time-dependent ADDL formation from Aβ1-42, wherein the results for 20C2 showed better signal and consistency. Neither antibody could detect Aβ1-40 at a concentration equivalent to ADDLs. These data further demonstrate the oligomer-specificity of this antibody, since monomers are present all the time and oligomers form with time. In addition, both M90/1 and 20C2 showed minimal recognition of Aβ1-40 monomers even at a 100-fold higher concentration than ADDLs.

Example 11: Competition Dot Blot Assays

To determine whether the monoclonal antibodies disclosed herein could bind monomers, a competition dot

blot assay was performed with synthetic ADDLs, 20C2, and Aβ1-40. ADDLs were applied to dry nitrocellulose at 10 pmol/0.5 µL. While the nitrocellulose was being blocked in 5% NDM/TBS-T for one hour, ADDLs and fresh Aβ1-40 at various concentrations were incubated with 200 µL each of 20C2 (1.5 µg/mL final concentration) in 5% NDM/TBS-T for 1 hour. These solutions were then applied to the nitrocellulose using the SURF-BLOT apparatus and incubated at room temperature for 1.5 hours with rocking. The blot was subsequently visualized with anti-mouse IgG-HRP and chemiluminescence. Quantitation was performed using the KODAK® IMAGESTATION® 440 and EXCEL®.

Results of this analysis indicated that synthetic ADDLs in solution could effectively and specifically block 20C2 binding to ADDLs immobilized on nitrocellulose with a half maximal inhibition observed at <50 nM for ADDLs. In contrast, Aβ1-40 in solution did not block binding of 20C2 to immobilized ADDLs.

To determine which portions constitute the binding epitope of the Aβ1-42 molecule, a competition dot blot assay was performed with ADDLs, 20C2, and peptides. ADDLs were spotted on nitrocellulose at four concentrations (1, 0.5, 0.25, and 0.125 pmole) each in 0.5 µL. While the nitrocellulose was being blocked in 5% NDM/TBS-T for two hours, the peptides at 50, 100 and 200 pmol were added to 200 µL of 20C2 (1.52 µg/mL final concentration = 1.9 pmol, in 5% NDM/TBS-T) and rocked at room temperature. The solutions were subsequently incubated with the nitrocellulose using the SURF-BLOT apparatus for 1.5 hours at room temperature. Binding was visualized with anti-mouse IgG-HRP using chemiluminescence.

The results of this analysis indicated that binding to ADDLs was blocked by the ADDLs themselves and by Aβ1-28, but no other combination of peptides. Thus, the binding epitope required some conformation that Aβ1-28 could

attain, but that was not available on Aβ1-12 and Aβ12-28 or their combination. Alternatively, Aβ1-28 forms a dimer that blocks binding of ADDLs by steric hindrance.

To determine whether Aβ1-28 aggregates (similar to Aβ1-42) or folds such that it blocks the binding epitope for 20C2, SDS-PAGE gels were silver stained and western blot analysis was performed. ADDLs and Aβ1-28 (60 pmol in each of two lanes used for silver stain and 20 pmol otherwise) were separated using a 10-20% Tris-Tricine SDS-PAGE. The 60 pmol lanes were excised and stained with SILVERXPRESS™ (INVITROGEN™, Carlsbad, CA); alternatively, the gels (20 pmoles ADDLs and Aβ1-28) were electroblotted onto HYBOND™ ECL™ nitrocellulose using 25 mM Tris-192 mM glycine, 20% v/v methanol, pH 8.3, 0.02% SDS at 100V for 1 hour at 8°C. The blots were blocked with 5% milk in TBS-T (0.1% TWEEN™-20 in 20 mM Tris-HCl, pH 7.5, 0.8% NaCl). Samples were incubated with 20C2 (1:1000, 1.52 mg/mL) or 20C2 + Aβ1-28 (2 nmol, preincubated for 2 hour) for 1.5 hour at room temperature in the above blocking buffer. Binding was visualized with anti-mouse IgG-HRP (1:40,000 in TBS-T) and chemiluminescence.

Silver staining showed monomer, trimer and tetramer in the ADDL lane, whereas the Aβ1-28 lane had one species, which ran at about a dimer. ADDLs, but not Aβ1-28, were visualized by 20C2 and binding to all ADDL species by 20C2 was blocked by Aβ1-28. Moreover, while the 20C2 binding epitope is blocked by Aβ1-28, 20C2 does not recognize the Aβ1-28 peptide in a western blot.

Example 12: Isotype Analysis of Anti-ADDL Antibodies

To further characterize the monoclonal antibodies disclosed herein, isotype analysis was performed using the SIGMA IMMUNOTYPE™ Kit with the Mouse Monoclonal Antibody Isotyping Reagents, following the manufacturer's directions

(Sigma-Aldrich Co., St. Louis, MO). Results of this analysis are presented in Figure 3.

Example 13: Core Linear Epitope Mapping of Anti-ADDL Antibodies

Specific interaction of the anti-ADDL monoclonal antibodies with amyloid beta peptide was detected in standard ELISA assays. Briefly, synthetic peptides, or ADDL or fibril in some cases, were used as antigen to coat on NUNC™ MAXISORB™ plate at concentration of 4 µg/mL (about 800 to 1200 nM). Unless specified, the peptides were coated in 5 mM sodium bicarbonate buffer, pH 9.6, overnight at 4°C. After blocking the plates with PBS containing 0.05% TWEEN™ 20 and 3% (w/v) nonfat dry milk for one hour, the monoclonal antibody was titrated in blocking buffer at a determined concentration and the plates were incubated for one hour at ambient temperature with gentle rocking. After washing, HRP-conjugated goat anti-mouse IgG (H+L), diluted in blocking buffer, was added to the plates. The colorimetric substrate, TMB, was added to the plates after extensive washes to remove unbound HRP-conjugate. The absorbance was measured at wavelength of 450 nm on a plate reader.

To map the core linear epitope for the anti-ADDL monoclonal antibodies, a set of overlapping, ten amino acid peptides was synthesized to cover Aβ1-42 (Table 1). Three peptides of fourteen amino acids, with reversed amino acid sequence of Aβ1-42 were also synthesized as nonspecific control peptides.

TABLE 1

N-	C-	Peptide Sequence	Mol. Wt.	SEQ ID NO:
1	42	DAEFRHDSGYEVHHQKLVFFAEDVGSNKGAIIGLMVGGVVIA		180
1	7	DAEFRHD	929.8	181
1	8	DAEFRHDS	975.4	178
1	9	DAEFRHDSG	10352.5	182

1	10	DAEFRHDSGY	1195.4	183
2	11	AEFRHDSGYE	1209.3	184
3	12	EFRHDSGYEV	1237.4	185
4	13	FRHDSGYEVH	1245.2	186
5	14	RHDSGYEVHH	1235.7	187
6	15	HDSGYEVHHQ	1207.4	188
7	16	DSGYEVHHQK	1198.5	189
8	17	SGYEVHHQKL	1196.8	190
9	18	GYEVHHQKLV	1208.3	191
10	19	YEVHHQKLVF	1298.6	192
11	20	EVHHQKLVFF	1282.9	193
12	21	VHHQKLVFFA	1224.4	194
13	22	HHQKLVFFAE	1254.5	195
14	23	HQKLVFFAED	1232.5	196
15	24	QKLVFFAEDV	1177.3	197
16	25	KLVFFAEDVG	1123.8	198
17	26	LVFFAEDVGS	1082.3	199
18	27	VFFAEDVGSN	1083.0	200
19	28	FFAEDVGSNK	1112.2	201
20	29	FAEDVGSNKG	1022.6	202
21	30	AEDVGSNKGA	946.5	203
22	31	EDVGSNKGAI	988.1	204
23	32	DVGSNKGAII	972.2	205
24	33	VGSNKGAIIG	914.4	206
25	34	GSNKGAIIGL	928.5	207
26	35	SNKGAIIGLM	1002.2	208
27	36	NKGAIIGLMV	1014.7	209
28	37	KGAIIGLMVG	957.4	210
29	38	GAIIGLMVGG	886.3	211
30	39	AIIGLMVGGV	928.3	212
31	40	IIGLMVGGVV	956.5	213
32	41	IGLMVGGVVI	956.4	214
33	42	GLMVGGVVIA	914.2	215
14	1	HHVEYGSDHRFEAD	1923.8	216
28	15	KNSGVDEAFFVLKQ	1806.9	217
42	29	AIVVGGVMLGIIAGKK	1751.5	218

All peptides were dissolved in DMSO at about 400 to 500 µM (1 mg/mL) and stored in multiple aliquots at -20°C. The peptides were used in an ELISA assay for determination of the core epitope of the anti-ADDL monoclonal antibodies. Each monoclonal antibody was tested at four concentrations (3, 1, 0.3 and 0.1 µg/mL) against either an N-terminal peptide set (from residues 1 to 25) or a C-terminal peptide set (from residues 17 to 42), with control peptides. The core linear epitopes for the panel of monoclonal antibodies are listed in Table 2. Several commercial monoclonal antibodies (6E10, BAM-10, 4G8 and WO-2) were included in the experiment to validate the assay format, and the results confirmed their core linear epitopes as reported in published literature.

TABLE 2

Antibody	Core Epitope*	Epitope Sequence within Aβ1-42	SEQ ID NO:
		DAEFRHDSGYEVHHQKLVFFAEDVGSNKGAIIGLMVGGVVIA	180
6E10	5-11	RHDSGYE	219
BAM-10	3-8	EFRHDS	220
4G8	xx-21	EVHHQKLVFFA	221
WO-2	3-8	EFRHDS	220
26D6	3-8	EFRHDS	220
2A10[a]	3-8	EFRHDS	220
2B4[b]	3-8	EFRHDS	220
4C2[a]	3-8	EFRHDS	220
4E2[a]	3-8	EFRHDS	220
2H4[c]	1-8	DAEFRHDS	178
20C2[a]	3-8	EFRHDS	220
2D6[a]	3-8	EFRHDS	220
5F10[c]	3-8	EFRHDS	220
1F4[a]	nd		
1F6[a]	nd		
2E12[a]	3-10	EFRHDSGY	222
3B3[a]	nd		

*Position within Aβ1-42. [a]IgG1, [b]IgG2b, [c]IgG2a. nd, not determined.

Nine out of twelve ADDL-specific monoclonal antibodies evaluated were mapped to the N-terminal region of Aβ1-42, and seven of these mapped to amino acid residues 3 to 8. Two monoclonal antibodies, 2H4 and 2E12, prefer slightly bigger epitopes. Three monoclonal antibodies, 1F4, 1F6 and 3B3, failed to bind the overlapping peptide set, even at high concentration of 3 μg/mL, but their epitopes were estimated to be located at the N-terminus of Aβ1-42, as they could bind to Aβ1-20 peptide, which was used as a positive control in the experiments.

Example 14: Affinity and Specificity of Mouse Anti-ADDL Antibodies

A solution-based binding assay was developed to determine the specificity and affinity of anti-ADDL antibodies to different amyloid beta peptide preparations (ADDL, fibril, Aβ1-40, Aβ1-20). A quantitative ELISA was established that was capable of capturing the linear range of dose-response of monoclonal antibodies against ADDL

coated on NUNC™ plates. Based on this information, a fixed concentration of monoclonal antibody was selected that could give consistent OD signals in ELISA just above assay noise (OD 450 nm reading around 0.2 to 0.5). IgG at this fixed concentration was then incubated with different amyloid beta peptide substrates (ADDL, fibril, Aβ1-40, Aβ1-20) in 20 point titrations in solution at room temperature overnight to reach equilibrium. The quantity of free IgG within the mixture was determined the next day in a quantitative ELISA with a one hour incubation on regular ELISA plates. The fraction of bound IgG was calculated and the correlations of bound IgG to titration of free ligand (substrates) were used to derive K_D, using the GraFit program (Erithacus Software, Surrey, UK). Thus, the substrate preference for each antibody to different amyloid beta peptide preparations was presented as the intrinsic affinity values (K_D).

There were several advantages of using this assay format. First, the interaction of the antibody and substrate was in solution phase, thus, there was no constraint from any solid surface such as in regular ELISA assay or BIACORE™ experiment, where potential influence of solid surface from ELISA plates or sensor chip on monoclonal antibody and substrate interaction has to be taken into consideration for interpretation of data. Second, the interactions were allowed to reach equilibrium. Therefore, the interaction of IgG and substrate occurred at limiting concentrations of both components with no concerns for precipitation of IgG or additional amyloid beta peptide oligomerization due to high experimental concentration. Third, the assay readout was independent of antigen in the solution; thus, any heterology of amyloid beta in different peptide preparations (*e.g.*, ADDL or fibril) would not interfere with data interpretation and mathematical modeling. The assay sensitivity was limited to ELISA assay

detection limits which allowed this assay to evaluate monoclonal antibodies with K_D values in the nanomolar range. Alternative substrates such fluorescent reagents are contemplated to improve the sensitivity range. It is believed that the immune complex was minimally disrupted during the one hour incubation to capture the free IgG in quantitative ELISA.

The quantities of free IgG were determined by a standard curve and plotted against titrations of different substrate. The quantities of bound IgG with different substrates were plotted and the information was used in GraFit for curve fitting with appropriate mathematic models. The summary of K_D, expressed in nM ranges, for the panel of monoclonal antibodies disclosed herein is presented in Table 3.

TABLE 3

Antibody*	ADDL		Fibril		Aβ1-40		Aβ1-20	
	K_D	SE	K_D	SE	K_D	SE	K_D	SE
20C2	0.92	0.09	3.62	0.47	30.48	5.05	*71.35*	*24.41*
2A10	2.29	0.25	6.72	0.99	14.69	2.64	22.40	2.43
2B4	2.09	0.24	10.50	1.26	27.57	4.88	*1.63*	*0.26*
2D6	5.05	0.52	14.41	2.40	*25.66*	*5.84*	*30.17*	*7.07*
5F10	11.90	1.63	*28.95*	*5.78*	*23.54*	*6.21*	*6.10*	*4.39*
4E2	4.26	0.42	9.40	1.60	20.24	2.07	28.40	3.23
4C2	8.08	1.03	19.17	3.69	21.89	4.14	28.40	3.23
1F4	9.24	0.84	12.52	1.66	IC	IC	IC	IC
1F6	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T
3B3	10.02	0.74	7.21	0.59	*104.68*	*21.86*	IC	IC
2E12	IC	IC	IC	IC	IC	IC	IC	IC
WO-2	0.57	0.042	1.15	0.12	6.15	0.62	*19.26*	*3.53*

*All antibodies were IgG.
Values listed in italic are high SE and poor fitting.
IC: inconclusive data
N/T: not tested.

Example 15: Detecting and Measuring tau Phosphorylation

Hyperphosporylated Tau (pTau) is a hallmark of Alzheimer's Disease, although little is known about the events that cause this hyperphosphorylation. Without wishing to be bound by any theory, it is believed that

ADDLs may play a role in this phosphorylation event. To investigate this, neuronal cultures (primary neurons and B103 cells) were grown as described above, 1 μm bADDLs or vehicle was added to the media and the cultures were maintained for an additional one, six or twenty four hours. At the end of each incubation, the cells were washed, fixed, permeabilized, blocked and incubated overnight with a monoclonal antiserum raised against pTau (AT8, 1:500; Pierce, Rockland, IL). The next day, the cells were washed, incubated with an ALEXA® 488-labeled anti-mouse secondary antibody and an ALEXA® 594-labeled streptavidin and the cells were stained with DAPI to allow detection of nuclei. The cells were then assessed using a fluorescence microscope, with the degree of pTau staining and correlation with bADDL binding being noted at each time-point.

The results of this analysis indicated that bADDL binding to B103 cells increased the level of pTau in the cellular processes, when compared with vehicle-treated cells. A similar change was also noted in primary hippocampal cells. When cells were exposed to bADDLs for six hours, an increase in pTau staining was observed in a subpopulation of cells, cells that also bound bADDL. A time-course study with B103 cells further investigated the modulation of pTau by bADDLs. The addition of bADDLs resulted in a marginal increase in pTau at one hour. However, pTau staining was dramatically increased six hours after the addition of bADDLs and remained elevated up to 24 hours later. Thus, these data indicate that ADDL binding to neurons can initiate a cascade of intracellular events that results in the hyperphosphorylation of tau, the accumulation of neurofibrillary tangles and eventual cell death. To this end, one skilled in the art can appreciate that blocking the binding of ADDLs to neurons, would in turn prevent such downstream events and be beneficial for

the treatment of amyloidogenic diseases and/or tauopathies. Moreover, a better understanding of the signaling events that are triggered by ADDL binding and result in pTau production may also elucidate additional pathways that are suitable targets for the development of novel therapeutics.

Example 16: Aβ Peptide/ADDL-Antibody Interaction and Assembly Inhibition

Changes in ADDL assembly kinetics and oligomeric size, in the presence of selected monoclonal antibodies disclosed herein were observed by fluorescence resonance energy transfer (FRET) and fluorescence polarization (FP) using a 1:4 mixture of fluorescein-labeled Aβ1-42 monomers to native peptide monomers. The auto-quenching of flourescein emission upon monomer incorporation into ADDLs results in a three- to five-fold reduction of fluorescence intensity over the short hour timescale due to FRET. In addition, the increase in size when monomers assemble into oligomeric ADDL species results in a two-fold FP increase. The FRET and FP kinetic progress curves of ADDL assembly, in the presence of various novel and commercial anti-ADDL and anti-Aβ peptide antibodies, showed differences in the ability of the antibodies to inhibit ADDL assembly and/or bind peptide oligomers (Figure 4).

Assays were performed in 384-well CORNING® Non-Binding Surface black, opaque microtiter plates. The assay buffer was composed of 50 mM MOPS-Tris (pH 8.0) with 100 mM $MgCl_2$. The assay volume, containing 0.2 μM FITC-Aβ1-42 and 0.8 μM Aβ1-42, was 50 μL and the assay temperature was 37°C. ADDL assembly was monitored with a Tecan GENios Pro plate reader, exciting at a wavelength of 485 nm and detecting emission at a wavelength of 515 nm. Kinetic traces were collected by recording fluorescence intensity and polarization readings every five minutes over a six-hour time course. Negative control reactions, which did not

appreciably assemble into ADDLs during this time, lacked $MgCl_2$ but contained all other buffer and peptide components. Positive control reactions contained all buffer components in the absence of added monoclonal antibody reagents. To test for ADDL binding and assembly inhibition, antibodies were incubated with the peptide mixture at eight concentrations from 500 nM decreasing to 5 nM.

This assay was useful for classifying different profiles of ADDL binding behavior and ADDL assembly inhibition. The binding and neutralization of larger ADDL species, through interaction with ADDL-specific and/or conformational epitopes, serves as a viable therapeutic strategy. In addition, the inhibition of oligomerization into large ADDLs by binding an ADDL-specific and/or conformational epitope present in transient, intermediate ADDL assembly species (non-monomer) provides an alternative strategy for anti-ADDL therapy. The FP progress curves, which demonstrated striking differences between antibodies, denotes such intermediate or stable species binding. Correlating the FP/FRET behavior of monoclonal antibodies with other functional, cellular and *in vivo* effects allows for the selection of desired immunotherapy modes of action.

The results of the analyses disclosed herein indicates that 1F6, 2A10, 5F10, 2D6, and 2B4 exhibit potent assembly inhibition, whereas 20C2, 1F4, and 4C2 exhibit intermediate assembly inhibition and 2H4, 3B3 and 4E2 show weak assembly inhibition (Figure 4). As summarized in Table 4 and illustrated in Figure 5, 20C2, 4E2, 3B3 and 5F10 show a variety of biochemical behaviors.

TABLE 4

	Potent Assembly Inhibition by FP/FRET	Weak or no Assembly Inhibition by FP/FRET
FP laddering at 30 minutes	20C2	4E2
Low or no FP	5F10, 1A9	3B3

laddering at 30 minutes		

Further, antibody 1A9, one of five purified antibodies (*i.e.*, 1A9, 1E3, 1G3, 1A7, and 1E5) generated against a low n-mer-forming peptide Aβ1-42[Nle35-Dpro37], segregates with 5F10 in terms of its assembly inhibition and FP behavior.

Moreover, 20C2 was found to bind to assemblies of charge-inverted, truncated Aβ7-42 peptide assemblies as determined by SEC/ICC, indicating a lack of conventional linear epitope binding to the Aβ7-42 charge-inverted peptide, which has a very different sequence corresponding to residues 7-16 of Aβ, *i.e.*, Aβ(7-42)[$Orn_7Orn_{11}D_{13}D_{14}E_{16}Nle_{35}$]. Therefore, 20C2 binds to conformational epitopes that depend upon elements from within residues 17-42 of Aβ, but only when assembled.

Example 17: Isolation of Mouse Antibody Variable Region Sequences

The cDNAs coding for the variable domains of the mouse antibody were cloned and sequenced following a polymerase chain reaction (PCR) using specially designed primers that hybridize to the 5'-ends of the mouse constant regions and to the murine leader sequences upstream of the V regions. This ensured that the mouse variable region sequences obtained were complete and accurate. In short, mRNA was extracted from mouse hybridoma cell lines using the QIAGEN® OLIGOTEX® Direct mRNA Mini Kit and subsequently converted to cDNA using a first-strand cDNA synthesis kit. The cDNA was then used as template in PCR reactions to obtain the antibody variable region sequences.

To obtain the light chain variable region sequence, eleven independent PCR reactions were set up using each of the eleven light chain 5′ PCR primers (MKV-1 to MKV-11) and the 3′ PCR primer MKC-1 (Table 5).

TABLE 5

5′ Primer	Sequence	SEQ ID NO:
MKV-1	GAT CTC TAG **ATG AAG ATT GCC TGT TAG GCT GTT GGT GCT G**	223
MKV-2	GAT CTC TAG **ATG GAG WCA GAC ACA CTC CTG YTA TGG GTG**	224
MKV-3	GAT CTC TAG **ATG AGT GTG CTC ACT CAG GTC CTG GSG TTG**	225
MKV-4	GAT CTC TAG **ATG AGG RCC CCT GCT CAG WTT YTT GGM WTC TTG**	226
MKV-5	GAT CTC TAG **ATG GAT TTW CAG GTG CAG ATT WTC AGC TTC**	227
MKV-6	GAT CTC TAG **ATG AGG TKC YYT GYT SAY CTY CTC TGR GG**	228
MKV-7	GAT CTC TAG **ATG GGC WTC AAA GAT GGA GTC ACA KWY YCW GG**	229
MKV-8	GAT CTC TAG **ATG TGG GGA YCT KTT TYC MMT TTT TCA ATG**	230
MKV-9	GAT CTC TAG **ATG GTR TCC WCA SCT CAG TTC CTT G**	231
MKV-10	GAT CTC TAG **ATG TAT ATA TGT TTG TTG TCT ATT TCT**	232
MKV-11	GAT CTC TAG **ATG GAA GCC CCA GCT CAG CTT CTC TTC C**	333
3′ Primer	Sequence	SEQ ID NO:
MKC-1	GAT CGA GCT C**AC TGG ATG GTG GGA AGA TGG**	234

Underlined and italic sequences denote *Xba*I and *Sac*I restriction sites, respectively. W = A or T, M = A or C, K = G or T, Y = C or T, and R = A or G.

To obtain the heavy chain variable region sequences twelve independent PCR reactions were set up using each of the twelve heavy chain 5′ PCR primers (MHV-1 to MHV-12) and the appropriate isotype specific 3′ primer (MHCG-1, MHCG-2A, MHCG-2B, MHCG-3) (Table 6).

TABLE 6

5′ Primer	Sequence	SEQ ID NO:
MHV-1	GAT CTC TAG **ATG AAA TGC AGC TGG GGC ATS TTC TTC**	235
MHV-2	GAT CTC TAG **ATG GGA TGG AGC TRT ATC ATS YTC TT**	236
MHV-3	GAT CTC TAG **ATG AAG WTG TGG TTA AAC TGG GTT TTT**	237
MHV-4	GAT CTC TAG **ATG RAC TTT GGG YTC AGC TTG RTT T**	238
MHV-5	GAT CTC TAG **ATG GGA CTC CAG GCT TCA ATT TAG TTT TCC TT**	239
MHV-6	GAT CTC TAG **ATG GCT TGT CYT TRG SGC TRC TCT TCT GC**	240
MHV-7	GAT CTC TAG **ATG GRA TGG AGC KGG RGT CTT TMT CTT**	241
MHV-8	GAT CTC TAG **ATG AGA GTG CTG ATT CTT TTG TG**	242
MHV-9	GAT CTC TAG **ATG GMT TGG GTG TGG AMC TTG CTT ATT CCT G**	243
MHV-10	GAT CTC TAG **ATG GGC AGA CTT ACC ATT CTC ATT CCT G**	244
MHV-11	GAT CTC TAG **ATG GAT TTT GGG CTG ATT TTT TTT ATT G**	245
MHV-12	GAT CTC TAG **ATG ATG GTG TTA AGT CTT CTG TAC CTG**	246
3′ Primer	Sequence	SEQ ID NO:
MHCG-1	GCATC *GAG CTC* **CAG TGG ATA GAC AGA TGG GGG**	247
MHCG-2A	GCATC *GAG CTC* **CAG TGG ATA GAC CGA TGG GGG**	248
MHCG-2B	GCATC GAG CTC **CAG TGG ATG AGC TGA TGG GGG**	249
MHCG-3	GCATC *GAG CTC* **CAA GGG ATA GAC AGA TGG GGC**	250

Underlined and italic sequences denote *Xba*I and *Sac*I restriction sites, respectively. W = A or T, M = A or C, K = G or T, Y = C or T, and R = A or G.

Each of the light chain PCR reactions contained 46 µL INVITROGEN™ PLATINUM® PCR Super Mix, 1.0 µL of one of the 100 µM 5′ primers (MKV-1 to MKV-11), 1.0 µL of the 100 µM 3′ primer (MKC-1), and 2.0 µL of hybridoma cDNA. Similar PCR reactions were employed to clone the mouse heavy chain variable region sequences. Reactions were placed in a DNA thermal cycler and, after an initial denaturation step at 97°C for 2.0 minutes, subjected to 30 cycles of: 95°C for 30 seconds, 55°C for 45 seconds, and 72°C for 90 seconds. Following the last cycle, a final extension step at 72°C for 10 minutes was employed. To determine which PCR reactions yielded product, 5 µL aliquots from each reaction were separated on 1.5% (w/v) agarose/1X TAE buffer gels, containing 0.5 µg/mL ethidium bromide. PCR products from reactions that produced fragments of the expected size (420 to 500 bp) were then gel purified, digested with *Xba*I and *Sac*I and ligated into the *Xba*I and *Sac*I sites in the multicloning region of plasmid pNEB193 (New England Biolabs, Beverly, MA). Alternatively, PCR products were ligated directly into plasmid pCR®2.1 using the INVITROGEN™ TA CLONING® kit. Ligation products were then transformed into XL-1 cells and aliquots of the transformed *E. coli* were plated onto LB agar plates containing 50 µg/mL ampicillin and overlaid with 40 µL of X-Gal stock (50 mg/mL) and 40 µL IPTG (100 mM) solution for blue/white selection. Plates were incubated overnight at 37°C and potential clones were identified as white colonies. DNA from at least 24 independent clones for each PCR product were sequenced on both strands using universal forward and reverse primers for pNEB193 and pCR®2.1. The resulting sequences were then assembled into a contig to generate a consensus sequence for each antibody light and heavy chain variable region. Using this approach the sequences were determined for the light and heavy antibody variable

regions of hybridoma's 20C2, 5F10, 2D6, 2B4, 4E2, 2H4, 2A10, 3B3, 1F6, 1F4, 2E12 and 4C2 (Figures 6A-6X).

The six complementarity-determining regions (CDRs), which form the structure complementary to the antigen, are underlined in Figures 6A-6X. Upon analysis of the CDRs and corresponding antigen epitopes (Table 2), sequence similarities were observed. Antibodies sharing the 3-8 amino acid epitope of Aβ1-42 (*i.e.*, 2A10, 4C2, 2D6, 4E2, 20C2, 2B4, and 5F10) shared highly homologous CDR1 (Figure 7A) and CDR2 (Figure 7B) sequences of the heavy chain. Antibody 2H4, which was found to recognize the 1-8 amino acid epitope of Aβ1-42, appeared to have unique CDR3 (Figure 7C) sequences of the heavy chain and unique CDR1 (Figure 7D), CDR2 (Figure 7E), and CDR3 (Figure 7F) sequences of the light chain. Similarly, antibody 2E12, which was found to recognize the 3-10 amino acid epitope of Aβ1-42, had unique CDR3 sequences of the heavy chain (Figure 7C). Further, antibodies 2A10, 2B4, 4C2 and 4E2, having similar affinities for SEC Peak 1 and Peak 2 ADDLs (see Figure 3), shared highly homologous CDR3 sequences of the heavy chain (Figure 7C). Moreover, amino acid substitutions in CDR3 of the heavy chain of antibody 4E2 appeared to enhance blockage of binding of ADDLs to neuronal cells, as 4E2 is more effective than antibody 2D6 at blocking ADDL binding to neurons and the sequences of the heavy and light chains of 4E2 and 2D6 were identical except for three amino acid residues of CDR3 of the heavy chain; Ser vs. Asn, Thr vs. Ser, and Ile vs. Val for 2D6 and 4E2, respectively (Figure 7C).

Example 18: Humanization of Mouse Anti-ADDL Antibody Variable Region Sequences

Mouse antibody heavy and light variable domains nucleic acids obtained from mouse hybridoma cell lines 20C2, 26D6, 4E2, 3B3, 2H4 and 1F6 were humanized using a

CDR grafting approach and in the case of 20C2 and 26D6 a veneering strategy. It will be appreciated by those skilled in the art that humanization of mouse antibody sequences can maximize the therapeutic potential of an antibody by improving its serum half-life and Fc effector functions thereby reducing the anti-globulin response.

Humanization by CDR grafting was carried out by selecting the human light and heavy chain variable regions from the NCBI protein database with the highest homology to the mouse variable domains. The mouse variable region sequences were compared to all human variable region sequences in the database using the protein-protein Basic Local Alignment Search Tool (BLAST). Subsequently, mouse CDRs were joined to the human framework regions and the preliminary amino acid sequence was analyzed. All differences between the mouse and human sequences in the framework regions were evaluated particularly if they were part of the canonical sequences for loop structure or were residues located at the VL/VH interface (O'Brien and Jones (2001) *In*: Antibody Engineering, Kontermann and Dubel (Eds.), Springer Laboratory Manuals). Framework regions were also scanned for unusual or rare amino acids in comparison to the consensus sequences for the human subgroup and for potential glycosylation sites. Wherein amino acid sequence differences existed between the mouse and human framework region sequences that were not found to be involved in canonical sequences, or located at the VL/VH interface, the human residue was selected at that position. Wherein a difference in a key residue existed, two versions of the variable region sequence were generated for evaluation. The CDR grafting strategy made the minimum number of changes to the human framework region so that good antigen binding was achieved while maintaining human framework regions that closely matched the sequence from a

natural human antibody. The design of humanized amino acid sequences using CDR grafting is shown in Figure 8.

Humanized sequences for 20C2 and 26D6 were also designed using a veneering strategy (See, *e.g.*, U.S. Patent No. 6,797,492). Humanization was carried out by selecting the human light and heavy chain variable regions from the NCBI protein database with the highest homology to the mouse variable domains, as well as to the closest human antibody germline family or families (see, Kabat, eta l. (1991) Sequences of proteins of immunological interest, 5th ed., U.S. Dept. Health and Human Services, NIH, Washington DC). The mouse variable region sequences were compared to all human variable region sequences in the database using protein-protein BLAST. The murine variable sequences and their closest human homologues were modeled to the closest crystallized human antibody as determined by computer modeling as practiced in the art. From the model of the murine VH and VL sequences, a surface area map was constructed, which dictated the solvent accessibility of the amino acids in the mouse heavy and light variable regions. To confirm the modeling, these exposed residues were compared position-by-position with known surface accessible residues (see, *e.g.*, Padlan (1994) *Mol. Immunol.* 31(3):169-217). A score was assigned for each residue in the sequence designating it as exposed, mostly exposed, partly buried, mostly buried and buried according to established methods (see, U.S. Patent No. 6,797,492). Mouse framework residues that scored as exposed or mostly exposed and differed from the homologous human sequence were changed to the human residue at that position. The designed veneered sequences retained the mouse CDRs, residues neighboring the CDRs, residues known be involved in canonical sequences, residues located at the VL/VH interface, and residues at the N-terminal sequences of the mouse heavy and light chain. The N-terminal sequences are known to be contiguous

with the CDR surface and are potentially involved in ligand binding. Likewise, care was taken to limit changes in Pro, Gly, or charged residues. Once the veneered sequences were finalized they were remodeled to look for are any potential obvious structural issues. In some instances, more then one veneered sequence was generated for analysis. The design of humanized amino acid sequences using the veneering approach is shown in Figure 9.

Once the humanized amino acid sequences were selected the sequences were reverse-translated to obtain the corresponding DNA sequence. The DNA sequences were codon-optimized using art-established methods (Lathe (1985) *J. Mol. Biol.* 183(1):1-12) and designed with flanking restriction enzyme sites for cloning into human antibody expression vectors. The DNA sequences synthesized are presented in Figures 10A-10S. For the 20C2 humanized antibodies designed by CDR grafting and veneering, both human IgG1/kappa and IgG2m4/kappa versions were constructed, wherein IgG2m4 represents selective incorporation of human IgG4 sequences into a standard human IgG2 constant region. IgG1/kappa and IgG2m4/kappa versions were also made for the 26D6 CDR grafted antibody. For all other antibodies only the IgG1/kappa versions were made. The complete amino acid sequence of the resulting antibodies is shown in Figures 11A-11Y.

Antibodies were expressed by co-transient transfection of separate light and heavy chain expression plasmids into 293 EBNA cells. In cases where more then one humanized heavy or light chain sequence was designed for a given antibody, all combinations of heavy and light chains were combined to generate the corresponding antibodies. Antibodies were purified from culture supernatant 7-10 days post-transfection using protein A columns and used in subsequent analysis.

Example 19: Generation of IgG2m4 Antibodies

IgG2m4 antibody derivatives were prepared to decrease Fc receptor engagement, C1q binding, unwanted cytotoxicity or immunocomplex formation while maintaining both the long half-life and pharmacokinetic properties of a typical human antibody. The basic antibody format of IgG2m4 is that of IgG2, which has been shown to possess a superior half-life in experimental models (Zuckier, et al. (1994) *Cancer Suppl.* 73:794-799). The structure of IgG2 was modified to eliminate C1q binding, through selective incorporation of IgG4 sequences, while maintaining the typical low level of FcγR binding (Canfield and Morrison (1991) *J. Exp. Med.* 173:1483-1491). This was achieved by using cross-over points wherein sequences of IgG2 and IgG4 were identical, thereby producing an antibody containing natural Fc sequences rather than any artificial mutational sequences.

The IgG2m4 form of the human antibody constant region was formed by selective incorporation of human IgG4 sequences into a standard human IgG2 constant region, as shown in Figure 12. Conceptually, IgG2m4 resulted from a pair of chain-swaps within the CH2 domain as shown in Figure 12. Four single mutations were made corresponding to sequences from IgG4. The Fc residues mutated in IgG2 included His268Gln, Val309Leu, Ala330Ser, and Pro331Ser, which minimized the potential for neoepitopes. The specific IgG4 amino acid residues placed into the IgG2 constant region are shown in Table 7, along with other alternatives from the basic structure.

TABLE 7

Residue (Kabat numbering)	Residue in IgG2	Residue in IgG4	Residue in IgG2m4	Alternative residue in IgG2m4	Comment
189	Pro or Thr*	Pro	Thr	Pro	Key polymorphism of IgG2; Pro residue present in *IGHG*01* allotype and Thr residue present in *IGHG2*02* allotype[a,b].
268	His	Gln	Gln	--	Change in the B/C loop

					known to be involved in FcγRII binding[c].
309	Val	Leu or Val	Leu	Val	FcRn binding domain
330	Ala	Ser	Ser	--	Key residue for C1q binding[d]; also potentially involved in binding FcγRII and FcγRIII[e].
331	Pro	Ser	Ser	--	Key residue for C1q binding[d,f] and FcγRI binding[g]; also potentially involved in binding FcγRII and FcγRIII[e].
397	Met or Val*	Val	Met	Val	Val residue present in *IGHG*01* allotype and Met residue present in *IGHG2*02* allotype[a].

*Positions marked with an asterisk are subject to allelic variations.

[a]Hougs, et al. (2001) *Immunogenetics* 52(3-4):242-8.

[b]WO 97/11971.

[c]Medgyesi, et al. (2004) *Eur. J. Immunol.* 34:1127-1135.

[d]Tao, et al. (1991) *J. Exp. Med.* 173:1025-1028.

[e]Armour, et al. (1999) *Eur. J. Immunol.* 29:2613.

[f]Xu, et al. (1994) *J. Biol. Chem.* 269:3469-3474.

[g]Canfield and Morrison (1991) *J. Exp. Med.* 173:1483.

Example 20: Binding Affinity of Humanized Anti-ADDL Antibodies

To evaluate ADDL binding affinity of the humanized antibodies, titration ELISAs were conducted as disclosed herein. Streptavidin-coated, 96-well microtiter plates (Sigma, St. Louis, MO) were coated with 10% biotinylated ADDL antigen (1 μM). A series of 2-fold dilutions of purified antibody, starting at 500 ng/mL was added to the ADDL captured plates and the plates were incubated for 2 hours at 25°C. After washing five times with PBS solution using a plate washer (Bio-Tek, Winooski, VA), polyclonal goat anti-human kappa light chain antibody (Biomeda, Foster City, CA) was added at a 1/2000 dilution in 3% non-fat milk blocker and incubated at room temperature for 1 hour. A rabbit anti-goat IgG (H+L) HRP-conjugated (Bethyl Laboratories, Inc., Montgomery, TX) detection antibody was then added at a 1/ 2000 dilution in blocking solution and

incubated for 1 hour at room temperature. After washing with PBS, HRP substrate, 3,3',5'5-tetramethylbenzidine (ready-to-use TMB; Sigma, St. Louis, MO) was added and the reaction was stopped after 10 minutes with 0.5 N H_2SO_4. Absorbance at wavelength of 450 nm was read in a plate reader (model VICTOR V; Perkin Elmer, Boston, MA) and data were processed using EXCEL® work sheet. Assay variations between plates were estimated within 20%.

Different groups of humanized antibodies were compared in different experiments. A comparison of IgG1 antibodies 20C2A, 20C2B, 3B3, 4E2, 1F6 and 2H4 humanized by CDR grafting indicated that all antibodies could bind to ADDLs, wherein binding with 1F6 was weaker than the majority and 20C2A was the strongest. The four different humanized versions of 20C2 IgG1 antibodies (two CDR grafted versions and two veneered versions) were also compared and found to exhibit very similar ADDL binding curves with all binding slightly better then a chimeric 20C2 antibody. The seven different humanized versions of 26D6 IgG1 (one CDR grafted versions and six veneered versions) were also compared. All were found to have ADDL binding curves similar to the chimeric form of 26D6. The IgG1 and IgG2m4 antibodies for the two 20C2 versions humanized by CDR grafting were also analyzed and found to have comparable binding curves as did the IgG1 and IgG2m4 isotypes of 26D6 humanized by CDR grafting.

Example 21: Inhibition of ADDL Binding to Neurons Using Humanized Anti-ADDL Antibodies

The humanized anti-ADDL antibodies were further evaluated for their ability to block ADDL binding to primary hippocampal neurons using the methods disclosed herein. The relevant antibodies, or PBS as a control, were mixed at a 1:1 (B103 neuroblastoma cells) or 1:5 (primary hippocampal neurons) molar ratio with 2.5-10 μm (final

concentration) of bADDLs and incubated for one hour at 37°C on a slow rotator. After the preincubation, the antibody/bADDL preparations were added to the B103 or primary neuron cultures and incubated for an additional hour at 37°C. At the end of the incubation period, the bADDLs/antibody mixture was removed and the plates washed six times with media. The cells were then fixed in 4% paraformaldehyde for ten minutes at room temperature, the solution removed, fresh fixative added, and the cells fixed for an additional ten minutes. The cells were permeabilized with 4% paraformaldehyde containing 0.1% TRITON™ X-100 (2 times, each for ten minutes at room temperature), washed six times in PBS and then treated with 10% BSA in PBS for one hour at 37°C. Alkaline phosphatase-conjugated streptavidin (1:1,500 in 1% BSA; Molecular Probes, Eugene, OR) was then added to the cells for one hour at room temperature. The cells were rinsed six times with PBS, the alkaline phosphatase substrate (CDP-STAR® with SAPPHIRE-II™; Applied Biosystems, Foster City, CA) added to the cells and incubated for thirty minutes prior to determining the luminescence on a LJL Luminometer (Analyst AD; LJL Biosystems, Sunnyvale, CA). As with the murine antibodies, the humanized versions of 26D6, 20C2, 4E2, 3B3, 2H4 and 1F6 were capable of inhibiting the binding of ADDL preparations to B103 neuroblastoma cells and to primary neurons.

Example 22: Affinity Maturation of a Humanized Anti-ADDL Antibody

Nucleic acid molecules encoding humanized 20C2 version A variable heavy chain only, light chain only, or heavy chain and light chain together were cloned in the Fab phage-display vector pFab3d. Nucleic acid sequence analysis confirmed sequence and orientation in pFab3d. The annotated 20C2 Fab sequences in pFab3d are presented in Figure 13 and set forth herein as SEQ ID NO:255 for the heavy chain and

SEQ ID NO:256 for the light chain. The three constructs were used in the 20C2 maturation program using art-established phage-displayed Fab library methods.

Briefly, two libraries were designed to mutate the nine wild-type amino acids of CDR3 of the light (kappa) chain of 20C2 (*i.e.*, Phe-Gln-Gly-Ser-Leu-Val-Pro-Leu-Thr; SEQ ID NO:60). These libraries were designated LC3-1 and LC3-2 representing light chain CDR3 sequences of Xaa-Xaa-Xaa-Xaa-Xaa-Val-Pro-Leu-Thr (SEQ ID NO:257) and Phe-Gln-Gly-Ser-Xaa-Xaa-Xaa-Xaa-Xaa (SEQ ID NO:258), respectively. Biotinylated reverse primers, 20C2LC3-1 (SEQ ID NO:259) and 20C2LC3-2 (SEQ ID NO:260), were used in combination with forward primer 20C2LC3F (SEQ ID NO:261) to generate the LC3-1 and LC3-2 libraries (see Figure 14). Primers were purified by polyacrylamide gel electrophoresis, whereas the vector DNA was purified by gel electrophoresis and electroelution. The two light chain libraries were designed to be randomly mutated. The final diversities of the three 10G5H6 LC_3 libraries were 4.76×10^8 and 7.45×10^8, respectively (Table 8). Sequence analysis of approximately 100 clones from the libraries showed 100% diversity of mutant clones at the designed amino acid positions.

TABLE 8

Characteristic	20C2 Library	
	LC3-1	LC3-2
Vector	pFab3d20C2HS	pFab3d20C2HS
Number of Transformants	4.76×10^8	7.45×10^8
Library Diversity	$4.76 \times 10^8 \times 0.89 = 4.24\ 10^8$	$7.45 \times 10^8 \times 0.90 = 6.71\ 10^8$
Primary Library Volume	2 mL	2 mL
Primary Library Titer	2.13×10^{11}	$*9.3 \times 10^{10}$

*Higher titers are achieved by concentration or phage rescue.

Soluble panning of the two 20C2 light chain libraries against high molecular weight bADDL was completed. Briefly, four rounds of panning were carried out using biotinylated high molecular weight ADDL (bADDL). The first three rounds were carried out using approximately 1.5 μM antigen concentration (input = 1 x 10^{10} to 1 x 10^{11}). Upon completion of the third round, the outputs of the two libraries were combined and divided into three groups for analysis with 10 nM, 100 nM and approximately 1.5 μM antigen to increase panning stringency. As such, a total of 58 output plates were tested in phage ELISA assays, *i.e.*, two plates per library in the first round (a total of four plates), six plates per library in the second round (a total of 12 plates), eight plates for LC3-1 and 10 plates for LC3-2 libraries in the third round (a total of 18 plates) and eight plates for each antigen concentration in the fourth round (a total of 24 plates).

Panning resulted in 1000 hits, 436 of which were sequenced (Table 9).

TABLE 9

Round	Antigen	Input	Output	% Recovery	ELISA Screen*	Sequenced
1[a]	1.6 μM	$2.13x10^{10}$	$7.3x10^{4}$	$3.42x10^{-6}$	0% (0/176)	0
2[a]	2.0 μM	$1.55x10^{11}$	$1.88x10^{5}$	$1.21x10^{-6}$	1.5% (8/528)	8
3[a]	1.1 μM	$1.80x10^{10}$	$7.8x10^{4}$	$4.3x10^{-6}$	5.8% (41/704)	41
1[b]	1.6 μM	$9.30x10^{9}$	$5.7x10^{4}$	$6.13x10^{-6}$	2.3% (7/176)	4
2[b]	2.0 μM	$1.23x10^{11}$	$1.07x10^{5}$	$8.7x10^{-7}$	4.5% (24/528)	24
3[b]	1.1 μM	$1.37x10^{10}$	$3.32x10^{5}$	$2.42x10^{-5}$	15% (134/880)	134
4[c]	1.1 μM	$3.0x10^{11}$	$1.37x10^{5}$	$4.6x10^{-7}$	39% (274/704)	-
4[c]	100 nM	$3.0x10^{11}$	$3.88x10^{5}$	$1.29x10^{-6}$	41% (290/704)	-
4[c]	10 nM	$3.0x10^{11}$	$1.6x10^{5}$	$5.3x10^{-7}$	32% (225/704)	225
				Total	1000/5104	436

[a]20C2 LC3-1 versus high molecular weight 10% bADDL.
[b]20C2 LC3-2 versus high molecular weight 10% bADDL.

[c]20C2 LC3-1 + 20C2 LC3-2 versus high molecular weight 10% bADDL.
*Hits per total number of colonies.

Sequence and frequency of highly enriched clones are presented in Table 10.

TABLE 10

Clone Designation	CDR3	SEQ ID NO:	Round 2	Round 3	Round 4	Total
Hu20C2LC	FQGSLVPLT	60	6	15	14	35
SJ-p1-31	ADTTHVPLT	262		1	2	3
SJ-p1-14	AHSTFVPLT	263	1	1	2	4
4P2-12-E3	AQASFVPLT	264			2	2
SJ-p1-38	AQATKVPLT	265		1	1	2
4P3-59	AQSSKVPLT	266			2	2
SJ-p2-14	AQSTLVPLT	267		1	2	3
4P3-11	FAASSVPLT	268			2	2
4P3-1	FESTYVPLT	269			2	2
SJ-p2-10	FESSRVPLT	270		1	1	2
SJ-p2-11	FNATWVPLT	271		2		2
SJ-p2-60	FQASRVPLT	272		1	5	6
SJ-p1-18	FQATRVPLT	273		1	5	6
SJ-p3-51	FQGSFIGLS	274	1		1	2
SJ-p3-16	FQGSFIPGT	275		2	3	5
SJ-p8-8F	FQGSFLPPS	276		1	1	2
SJ-p3-26	FQGSFLPQL	277	1	2		3
SJ-p3-15	FQGSLFPPV	278	1	2		3
SJ-p2-70	FQGSLFSPS	279	1	5		6
SJ-p3-24	FQGSRIPIS	280		1	1	2
SJ-p3-33	FQGSRLPVS	281		2	3	5
SJ-p3-14	FQGSRVPLV	282		2	1	3
SJ-p2-1F	FQSSFVPLT	283		6	8	14
4P1-22	FQSSRVPLT	284			15	15
SJ-p2-44	GQTTLVPLT	285		1	3	4
SJ-p1-56	HESTLVPLT	286		2	1	3
4P1-40	HQSSKVPLT	287			4	4
SJ-p2-20	IQTSLVPLT	288		2		2
SJ-p1-41	IQAALVPLT	289		1	1	2
SJ-p2-13	LQSSFVPLT	290	1	4		5
4P1-26	LETSRVPLT	291			3	3
SJ-p1-33	LASSHVPLT	292		2	1	3
SJ-p2-27	LNSTTVPLT	293		2	4	6
SJ-p2-62	LQSKSVPLT	294		2		2
4P2-26-E5	LQSVRVPLT	295			3	3
4P1-32	LQSSLVPLT	296			5	5
SJ-p2-37	LQTGRVPLT	297		2	2	4
SJ-p2-64	LQTSFVPLT	298		3		3
4P1-20	LQTSNVPLT	299			5	5
SJ-p2-39	LQTTRVPLT	300		2	6	8
SJ-p2-52	LSSTFVPLT	301		3	1	4
SJ-p2-6L	LSSTHVPLT	302		2	1	3
4P1-77	LTSSAVPLT	303			2	2
SJ-p1-59	LVSSLVPLT	304		2		2
SJ-p2-23	METANVPLT	305		2		2

SJ-p1-9M	MQSSFVPLT	306		1	3	4
SJ-p2-28	MQSSLVPLT	307		1	2	3
SJ-p1-21	MQTSKVPLT	308		1	1	2
4P1-17	SQARMVPLT	309			3	3
SJ-p2-66	SQASRVPLT	310		1	2	3
SJ-p1-49	TQSTQVPLT	311		2	1	3
SJ-p2-24	VCATFVPLT	312		1	1	2
4P1-41	VQSSAVPLT	313			2	2
SJ-p2-51	VQTSLVPLT	314		12	31	43
4P1-64	VQTSVVPLT	315			3	3
SJ-p2-55	VQTTAVPLT	316		2		2
SJ-p1-25	LQTARVPLT	317		1	3	4

Fab fragments from the 10 top clones based on enrichment frequency were prepared and a total of 15 clones were converted into IgG1 humanized A version and two clones, 20C2-6 and 20C2-8, were converted to IgG1 humanized B version. KD values for these clones were measured by BIACORE™ using biotin-Aβ1-20 (Table 11) and bADDL (Table 12) as antigens. Dramatic improvements in affinity were observed as compared to parental humanized 20C2A and 20C2B, as well as mouse 20C2 antibodies. In particular, low nanomolar to sub-picomolar KDs were achieved with a light chain CDR3 of the sequence Xaa_1-Gln-Xaa_2-Thr-Arg-Val-Pro-Leu-Thr (SEQ ID NO:318), wherein Xaa_1 is Phe or Leu, and Xaa_1 is Ala or Thr. Moreover, a comparison between KD values obtained with BIACORE™ using biotin-Aβ1-20 and bADDL further demonstrates that anti-ADDL antibodies such as 20C2 preferentially bind multi-dimensional conformations of ADDLs over monomeric Aβ peptides.

TABLE 11

Name	Clone	LC-CDR3	SEQ ID NO:	KD (Biotin-Aβ1-20)		
				Fab	IgG1#1	IgG1#2
20C2-1A	SJ-p2-60	FQASRVPLT	262	91 nM	1.2 nM	--
20C2-2A	SJ-p1-18	FQATRVPLT	273	28 nM	686 pM	2 nM
20C2-3A	SJ-p3-16	FQGSFIPGT	275	--	1.7 nM	--
20C2-5A	SJ-p2-1F	FQSSFVPLT	283	41 nM	912 pM	1.5 nM
20C2-6A	4P1-22	FQSSRVPLT	284	18 nM	544 pM	714 pM
20C2-6B	4P1-22	FQSSRVPLT	284	--	53 pM	--
20C2-7A	SJ-p2-27	LNSTTVPLT	293	128 nM	--	--
20C2-8A	SJ-p2-39	LQTTRVPLT	300	14 nM	140 pM	376 pM
20C2-8B	SJ-p2-39	LQTTRVPLT	300	--	46 pM	64 pM
20C2-9A	SJ-p2-51	VQTSLVPLT	314	36 nM	241 pM	420 pM
20C2-10A	SJ-p3-33	FQGSRLPVS	281	--	84 nM	--

20C2-11A	SJ-p3-6	FQGSLLPLS	319	--	--	--
20C2-12A	4P1-32	LQSSLVPLT	296	617 nM	1.5 nM	--
20C2-13A	4p1-20	LQTSNVPLT	299	94 nM	3 nM	--
20C2-18A	SJ-p1-9M	MQSSFVPLT	306	126 nM	1.8 nM	--
20C2-20A	SJ-p3-15	FQGSLFPPV	278		21 nM	
20C2-22A	SJ-p2-66	SQASRVPLT	310		2.3 nM	
20C2-23A	4P1-40	HQSSKVPLT	287		649 pM	1.5 nM
20C2-24A	SJ-p2-44	GQTTLVPLT	285		1.9 nM	
20C2A		FQGSLVPLT	60		27 nM	
20C2B		FQGSLVPLT	60		5.4 nM	
Mouse-20C2		FQGSLVPLT	60	83 nM	3.4 nM	

TABLE 12

Name	Clone	LC-CDR3	SEQ ID NO:	KD (bADDL)		
				Fab	IgG1#1	IgG1#2
20C2-1A	SJ-p2-60	FQASRVPLT	262	85 nM	75 pM	--
20C2-2A	SJ-p1-18	FQATRVPLT	273	28 nM	15 pM	0.3 pM
20C2-3A	SJ-p3-16	FQGSFIPGT	275	--	3.7 nM	--
20C2-5A	SJ-p2-1F	FQSSEVPLT	283	41 nM	317 pM	68 pM
20C2-6A	4P1-22	FQSSRVPLT	284	42 nM	4.3 pM	24 pM
20C2-6B	4P1-22	FQSSRVPLT	284	--	53 pM	--
20C2-7A	SJ-p2-27	LNSTTVPLT	293	435 nM	--	--
20C2-8A	SJ-p2-39	LQTTRVPLT	300	13 nM	3 pM	0.7 pM
20C2-8B	SJ-p2-39	LQTTRVPLT	300	--	13 pM	0.8 pM
20C2-9A	SJ-p2-51	VQTSLVPLT	314	40 nM	--	2 pM
20C2-10A	SJ-p3-33	FQGSRLPVS	281	--	7.7 nM	
20C2-11A	SJ-p3-6	FQGSLLPLS	319	--	--	--
20C2-12A	4P1-32	LQSSLVPLT	296	238 nM	15 pM	--
20C2-13A	4p1-20	LQTSNVPLT	299	567 nM	764 pM	
20C2-18A	SJ-p1-9M	MQSSFVPLT	306	85 nM	149 pM	
20C2-20A	SJ-p3-15	FQGSLFPPV	278		6.9 nM	
20C2-22A	SJ-p2-66	SQASRVPLT	310		198 pM	
20C2-23A	4P1-40	HQSSKVPLT	287		85 pM	66 pM
20C2-24A	SJ-p2-44	GQTTLVPLT	285		114 pM	
20C2A		FQGSLVPLT	60			
20C2B		FQGSLVPLT	60			
Mouse-20C2		FQGSLVPLT	60	62 nM	4.1 nM	

What is claimed is:

1. An isolated antibody, or fragment thereof, capable of differentially recognizing a multi-dimensional conformation of one or more Aβ-derived diffusible ligands.

2. A pharmaceutical composition comprising an isolated antibody, or fragment thereof, capable of differentially recognizing a multi-dimensional conformation of one or more Aβ-derived diffusible ligands in admixture with a pharmaceutically acceptable carrier.

3. A method for preventing binding of Aβ-derived diffusible ligands to a neuron comprising contacting the neuron with the antibody of claim 1 so that binding of Aβ-derived diffusible ligands to the neuron is prevented.

4. A method for inhibiting assembly of Aβ-derived diffusible ligands comprising contacting a sample containing amyloid β 1-42 peptides with the antibody of claim 1 thereby inhibiting assembly of Aβ-derived diffusible ligands.

5. A method for blocking the phosphorylation of tau protein at Ser202/Thr205 comprising contacting a sample containing a tau protein with the antibody of claim 1 thereby blocking the phosphorylation of tau protein at Ser202/Thr205.

6. A method for prophylactically or therapeutically treating a disease associated with Aβ-derived diffusible ligands comprising administering an effective amount of the pharmaceutical composition of claim 2.

7. A method for identifying a therapeutic agent that prevents the binding of Aβ-derived diffusible ligands to a neuron comprising contacting a neuron with Aβ-derived diffusible ligands in the presence of an agent and using an antibody of claim 1 to determine binding of Aβ-derived

diffusible ligands to the neuron in the presence of the agent.

8. A method for detecting Aβ-derived diffusible ligands in a sample comprising contacting a sample with the antibody of claim 1 so that Aβ-derived diffusible ligands are detected.

9. A method for diagnosing a disease associated with Aβ-derived diffusible ligands comprising contacting a sample with the antibody of claim 1 so that a disease associated with Aβ-derived diffusible ligands is diagnosed.

10. A kit for detecting Aβ-derived diffusible ligands comprising the isolated antibody, or fragment thereof, of claim 1.