Improved Aβ protofibril binding antibodies

Field of the invention

The present invention relates to the amyloid beta peptide (Aβ) and more specifically to antibodies that bind to Aβ protofibrils and their use in therapy and/or prophylactic treatment of Alzheimer's disease and other disorders associated with Aβ protein aggregation. Further the invention may relate to diagnosis of such diseases as well as monitoring of disease progression by use of the antibodies of the invention. Further, the invention may relate to veterinary use of the antibodies of the invention.

Background of the invention

Alzheimer's disease (AD) belongs to a group of neurodegenerative disorders and causes cognitive, memory and behavioral impairments. The hallmarks of Alzheimer's disease include extracellular amyloid plaques, intraneuronal neurofibrillary tangles, neuronal dysfunction and ultimately brain atrophy. The risk for developing AD increases with age and with increased number of persons reaching high age, a condition with increasing impact on the quality of life for elderly people. In addition the society faces a situation with accelerating costs.

In spite of the fact that the disease has been known for many years and several suggestions for treatment have been made, even today, there is no such efficient disease modifying therapy available today but only drugs which at best may provide symptomatic treatment. The mechanism behind the disease has been subject to a lot of studies. Briefly, Aβ for some reason starts to aggregate and via several intermediate forms, finally produces insoluble fibril/plaque deposits in the brain. It was early believed that the plaques, as such, affect the neurons and the signals transmitted by these, but today the results of the extensive studies indicate that soluble, aggregated, intermediate forms of Aβ most likely are a major cause of the disease and the symptoms observed in the patients.

One such intermediate form in the cascade of aggregated forms from Aβ monomers to insoluble Aβ fibrils is the soluble, high molecular weight Aβ protofibril, which was first described by Walsh in 1997 in The Journal of Biological Chemistry (Vol. 272(35) p. 22364-72). The importance of the Aβ protofibril for the development of AD was identified by the group of scientists headed by Lars Lannfelt, Uppsala University, in their studies of the Arctic

mutation, which is an E693G mutation in the amyloid precursor protein (APP) causing increased formation of Aβ protofibrils. A family in northern Sweden carrying this mutation was found to develop severe Alzheimer's disease early in life and the finding of this combination provided the basic ideas for a new therapy. Accordingly, the Aβ protofibril was identified as strongly related to the disease and an important target for therapy. Based on their studies with Aβ peptides comprising the Arctic mutation, Lannfelt et al were able to produce Aβ protofibrils *in vitro*, Arctic as well as wild-type, in sufficient amounts for immunization and subsequent selection of antibodies with high affinity for Aβ protofibrils compared to other species in the Aβ system. Examples of methods for production of Aβ protofibrils and antibodies that bind to these are disclosed in WO02/03911 and WO2005/123775.

Of special importance was the development of the mouse monoclonal antibody mAb158, an antibody that binds to Aβ protofibrils, which is disclosed in EP2004688, which comprises the following CDR sequences:

VH-CDR1: SFGMH	SEQ ID NO: 1
VH-CDR2: YISSGSSTIYYGDTVKG	SEQ ID NO: 2
VH-CDR3: EGGYYYGRSYYTMDY	SEQ ID NO: 3
VL-CDR1: RSSQSIVHSNGNTYLE	SEQ ID NO: 4
VL-CDR2: KVSNRFS	SEQ ID NO: 5
VL-CDR3: FQGSHVPPT	SEQ ID NO: 6

The high affinity and selectivity of the humanized version of mAb158, BAN2401, makes it a very important candidate for use in therapy and/or prevention of Alzheimer's disease in particular, and it is presently subject to clinical trials in preparation for use as a pharmaceutical product. Characteristics of BAN2401 are described in EP2004688.

The efficacy of an antibody depends on several pharmacokinetic and pharmacodynamics factors, see e.g. Deng et al, Expert Opin. Drug Metab. Toxicol 8(2) (2012): p. 141-160; Boswell et al, Bioconjugate Chem. 21(2010): p. 2153-2163; Konterman, Current Opinion in Biotechnology 22 (2011): p. 1-9 and Igawa et al, mAbs 3:3 (2011): p. 243-252. Among these, extended serum half-life with increased systemic exposure often provides a considerable potential for improvements of significant therapeutic value. It also provides an opportunity for reduction of the dose which has systemic, important implications.

Description of the invention

The present invention provides antibodies that bind to Aβ protofibrils and their use in therapy and/or prophylactic treatment of Alzheimer's disease and other disorders associated with Aβ protein aggregation. Further the invention may relate to antibodies useful in diagnosis of such diseases as well as their use in monitoring of disease progression of such diseases, as well as veterinary use of said antibodies. It has been identified that surprisingly the half-life as well as exposure of the humanized antibody based on mAb158, i.e. BAN2401, is considerably enhanced, e.g. about twice or more, primarily, by introducing one or more mutations in certain positions, i.e 17, 79 and/or 82, of the variable light chain of the BAN2401 antibody (Kabat positions 17, 74 and 77), respectively, see further Figure 9 where these positions are referred to as x_1, x_2 and x_3. In BAN2401 the amino acid in position 17 (Kabat position 17) is A, the amino acid in position 79 (Kabat position 74) is R and the amino acid in position 82 (Kabat position 77) is R. The Kabat numbering is given in accordance with Kabat et al., Sequences of Proteins of Immunological Interest, 1991 (NIH Publications No. 91-3242).

Optionally, further improvements of an antibody according to the invention can be achieved by combining each of the mutations providing increased half-life with one or more neighboring mutations, i.e 13, 21, 81 and/or 84, of the variable light chain of the antibody (Kabat positions 13, 21, 76 and 79), respectively, see further Figure 9 where these positions are referred to as referred to as y_{1-4}, 37, 38 and/or 40, of the variable Heavy chain of the antibody (Kabat positions 37, 38 and 40), respectively, see further Figure 10 where these positions are referred to as referred to as z_{1-3}, for further improvements of immunological significance, i.e. low immunogenicity. When, compared to the BAN2401 sequence, x_1 is mutated the mutations y_1 and/or y_2 may be introduced and when x_2 and/or x_3 are mutated, the mutations y_3 and/or y_4 may be introduced. Further, the mutations z_{1-3} may be introduced.

The present invention is as follows:

[1] An antibody or antigen binding fragment thereof having affinity against Aβ protofibrils, wherein the antibody or antigen binding fragment thereof has a variable light chain according to SEQ ID NO: 8, wherein

x1 is selected from A, D, E and Q, or a functional analogue thereof;

x2 is selected from R, T, K, A and G, or a functional analogue thereof;

x3 is selected from R, S, C, G and N, or a functional analogue thereof;

y1 is selected from V and A;

y2 is selected from I and V;

y3 is selected from S and Q;

y4 is selected from E and D; and optionally

a variable heavy chain according to SEQ ID NO: 14, wherein

z1 is selected from V and I;

z2 is selected from R and Q; and

z3 is selected from A, N and T.

with the exception for the combination x1=A, x2=R and x3=R.

[2] The antibody or antigen binding fragment according to [1], wherein

x1 is selected from A, D, E and Q;

x2 is selected from R, T, K, A and G;

x3 is selected from R, S, C, G and N;

y1 is selected from V and A;

y2 is selected from I and V;

y3 is selected from S and Q;

y4 is selected from E and D; and

a variable heavy chain according to SEQ ID NO: 14, wherein

z1 is selected from V and I;

z2 is selected from R and Q; and

z3 is selected from A, N and T;

with the exception for the combination x1=A, x2=R and x3=R.

[3] The antibody or antigen binding fragment according to [1] or [2], wherein the light chain a comprises a combination of mutations selected from:

x1 and (y1 and/or y2);

x1 and (y1 and/or y2) and x2 and (y3 and/or y4);

x1 and (y1 and/or y2) and x2 and x3 and (y3 and/or y4);

x1 and (y1 and/or y2) and x3 and (y3 and/or y4);

x2 (y3 and/or y4);

x2 and x3 and (y3 and/or y4); and

x3 and (y3 and/or y4);

with the exception for the combination x1=A, x2=R and x3=R.

[4] The antibody or antigen binding fragment according to any one of [1] to [3], wherein the variable light chain comprises one or more mutations, selected from:

x1 is D and (y1 and/or y2);

x1 is D and (y1 and/or y2), x2 is T and (y3 and/or y4);

x1 is D and (y1 and/or y2), x2 is T, x3 is S and (y3 and/or y4);

x1 is D and (y1 and/or y2) and x3 is S and (y3 and/or y4);

x2 is T (y3 and/or y4);

x2 is T and x3 is S and (y3 and/or y4); and

x3 is S and (y3 and/or y4);

wherein y1 is V or A and y2 is V or I, with exclusion of the combination y1=V and y2=I; y3 is S or Q and y4 is E or D with exclusion of the combination y3=S and Y4=E.

[5] The antibody or antigen binding fragment according to any one of [1] to [4], wherein

x1 is D;

x2 is T;

x3 is R;

y1 is selected from V and A;

y2 is selected from V and I;

y3 is selected from Q and S;

y4 is selected from D and E;

z1 is V;

z2 is R; and

z3 is selected from N, T and A;

with exclusion of the combination wherein y1 is V, y2 is I, y3, is S, y4 is E, z1 is V, z2 is R and z3 is A.

[6] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 12; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

[7] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 9; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

[8] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 10; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

[9] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 11; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

[10] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 12; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

[11] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 9; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

[12] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 10; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

[13] An antibody or antigen binding fragment thereof, according to [1], comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 11; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

[14] The antibody or antigen binding fragment according to any one of [1] to [13], wherein the antibody or the antigen binding fragment comprises an IgG heavy chain constant region.

[15] An antibody according to any one of [1] to [14], for use in therapy.

[16] An antibody according to any one of [1] to [14], for use in treatment and/or prophylaxis of Alzheimer's disease and other disorders associated with Aβ protein aggregation.

[17] An antibody according to [16], for use, wherein such other disorders associated with Aβ protein aggregation are selected from traumatic brain injury (TBI), Lewy body dementia (LBD), Downs syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidoses, atherosclerosis and Parkinson's disease dementia (PDD).

[18] Use of an antibody according to any one of [1] to [14], in the manufacture of a medicament useful in the treatment and/or prophylaxis of Alzheimer's disease and other disorders associated with Aβ protein aggregation.

[19] The use according to [18], wherein such other disorders associated with Aβ protein aggregation are selected from Traumatic brain injury (TBI), Lewy body dementia (LBD), Downs syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidoses, atherosclerosis and Parkinson's disease dementia (PDD).

[20] A method of reducing amount of Aβ protofibrils in a subject, comprising administering to said subject a therapeutically effective amount of the antibody or antigen binding fragment according to [1] to [14].

[21] A method for treatment and/or prophylaxis of Alzheimer's disease in a subject having, or being at risk of developing said disease, comprising administering to said subject a therapeutically effective amount of the antibody or antigen binding fragment according to [1] to [14].

[22] A method for treatment and/or prophylaxis of traumatic brain injury (TBI), Lewy body dementia (LBD), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD) in a subject having, or being at risk of developing said disease, comprising administering to said subject a therapeutically effective amount of the antibody or antigen binding fragment according to [1] to [14].

[23] A method for measuring amount of Aβ protofibrils and/or aggregated Aβ protein in a person, comprising contacting the person's tissue or body fluid, in vivo or in vitro, with the antibody or antigen binding fragment according to [1] to [14] and measuring the amount of antibody or antigen binding fragment bound to said Aβ protofibrils and/or aggregated Aβ protein.

[24] A method for diagnosis of Alzheimer's disease in persons having or at risk of developing the disease, comprising contacting the person's tissue or body fluid, in vivo or in vitro, with the antibody or antigen binding fragment according to [1] to [14], or a fragment thereof, and measuring the amount of said antibody bound to aggregated Aβ protein.

[25] A method for diagnosis of traumatic brain injury (TBI), Lewy body dementia (LBD), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD)in persons having or at risk of developing any of said diseases, comprising contacting the person's tissue or body fluid, in vivo or in vitro, with the antibody or antigen binding fragment according to [1] to [14], or a fragment thereof, and measuring the amount of said antibody bound to aggregated Aβ protein.

[26] A pharmaceutical composition comprising the antibody or antigen binding fragment according to any one of [1] to [14], together with pharmaceutically acceptable excipient and/or diluents.

[27] An antibody according to any one of [1] to [14], for veterinary use.

Brief description of the drawings

Figure 1 provides analysis of binding and selectivity for Aβ protofibrils compared to Aβ monomers for A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S compared to BAN2401 (control). Binding inhibition by Aβ1-42 protofibrils in solution is shown by open circles and open squares and binding inhibition by Aβ1-40 monomers in solution are shown by closed circles and closed squares.

Figure 2 provides plasma drug exposure of BAN2401 and antibodies of the invention in mice presented as time *vs* concentration graphs. Plasma levels after single i.v. injection of

BAN2401, A17D, A17D/R79T and A17D/R79T/R82S collected at time points 0.5 h, 2 days, 7 days, 15 days and 29 days post administration, and of A17D/R82S collected at time points 0.5 h, 2 days, 7 days, 14 days and 28 days post administration are shown in the graph. A17D/R82S was not included in the same PK study as the other antibodies shown here, but was instead given at a separate occasion. However, with exception of two plasma sampling time points, the same study design was used for the two separate studies. All plasma samples were analyzed by ELISA at the same occasion to avoid inter-assay variation. The plasma drug concentration in µg/ml is shown on the y-axis (logarithmic scale) and the time post administration in hours (h) is shown on the x-axis. Mean group values are shown with error bars indicating standard deviations. Mean $AUC_{0\text{-}inf}$ values and terminal half-lives were calculated by non-compartment analysis using Phoenix WinNonlin 6.3 (Pharsight) and are shown in Table 1.

Figure 3 provides plasma drug exposure of BAN2401 and antibodies of the invention, in rats presented as time *vs* concentration graphs. Plasma levels after single i.v. injection of BAN2401, A17D, A17D/R79T and A17D/R79T/R82S collected at time-points 0.5 h, 2 h, 7 h, 24 h, 2 days, 4 days, 7 days, 14 days and 29 days post administration are shown in the graph. The plasma drug concentration in µg/ml is shown on the y-axis (logarithmic scale) and the time post administration in hours (h) is shown on the x-axis. Mean group values are shown with error bars indicating standard deviations. Mean $AUC_{0\text{-}inf}$ values and mean terminal half-lives were calculated by non-compartment analysis using Phoenix WinNonlin 6.3 (Pharsight) and are shown in Table 2.

Figure 4 provides data with analysis of binding and selectivity for Aβ protofibrils compared to Aβ monomers for the deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) compared to BAN2401. Binding inhibition by Aβ1-42 protofibrils in solution is shown by open circles and open squares, and binding inhibition by Aβ1-40 monomers in solution are shown by closed circles and closed squares. A) A17D/R79T_DI 1, B) A17D/R79T_DI 2, C) A17D/R79T_DI 3, D) A17D/R79T_DI 4, E) A17D/R79T_DI 5, F) A17D/R79T_DI 6, G) A17D/R79T_DI 7, H) A17D/R79T_DI 8.

Figure 5 provides plasma drug exposure of BAN2401 and antibodies of the invention, in mice presented as time *vs* concentration graphs. Plasma levels after a single i.v. injection of BAN2401, A17D/R79T and 8 deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8)

collected at time points 0.5 h, 2 days, 7 days, 14 days and 28 days post administration. The plasma drug concentration in µg/ml is shown on the y-axis (logarithmic scale) and the time post administration in hours (h) is shown on the x-axis. Mean group values are shown with error bars indicating standard deviations. Mean AUC_{0-inf} values and mean terminal half-lives were calculated by non-compartment analysis using Phoenix WinNonlin 6.3 (Pharsight) and are shown in Table 6.

Figure 6 provides plasma drug exposure of BAN2401 and mutants in rat presented as time *vs* concentration graphs. Plasma levels after a single i.v. injection of BAN2401, A17D/R79T and 8 deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) collected at time points 0.5 h, 2 days, 7 days, 14 days and 28 days post administration. The plasma drug concentration in µg/ml is shown on the y-axis (logarithmic scale) and the time post administration in hours (h) is shown on the x-axis. Mean group values are shown with error bars indicating standard deviations. Mean AUC_{0-inf} values and mean terminal half-lives were calculated by non-compartment analysis using Phoenix WinNonlin 6.3 (Pharsight) and are shown in Table 7.

Figure 7 provides dose corrected plasma drug exposure of BAN2401, A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8 in Cynomolgus monkey presented as time *vs* concentration graphs. Plasma evels of antibody after single i.v. infusion of BAN2401 collected at time points 5 min, 1 h, 2 h, 8 h, 24 h, 2 days, 4 days, 7 days, 14 days, 21 days and 28 days post administration, and A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8 collected at time points 5 min, 2 h, 8 h, 24 h, 3 days, 7 days, 14 days, 21 days and 28 days post administration. The antibodies of the invention were administered to the monkey in a different study and at a different dose (10 mg/kg) compared to BAN2401 (5 mg/kg). Therefore the plasma exposure graphs have been dose adjusted. The dose corrected plasma drug concentration in µg/ml per mg/kg injected dose is shown on the y-axis (logarithmic scale) and the time post administration in hours (h) is shown on the x-axis. Mean group values are shown with error bars indicating standard deviations. Dose adjusted mean AUC_{0-inf} values and terminal half-lives were calculated by non-compartment analysis using Phoenix WinNonlin 6.3 (Pharsight) and are shown in Table 8.

Figure 8 provides amino acid sequences in relation to the present invention.

Figure 9 provides a table, split on two pages, with the amino acid sequence of the light variable chain with VL-CDR1-3 sequences in grey. BAN2401: SEQ ID NO: 7. Novel antibodies with light variable chain according to the invention: SEQ ID NO: 8. Specific examples of such variable light chains: i): SEQ ID NO: 9; ii): SEQ ID NO: 10; iii): SEQ ID NO: 11; and iv): SEQ ID NO: 12.

Figure 10 provides a table, split on three pages, with the amino acid sequence of the heavy variable chain with the VH-CDR1-3 sequences in grey. BAN2401: SEQ ID NO: 13. Novel antibodies with heavy variable chain according to the invention SEQ ID NO: 14. Specific examples of such variable heavy chains: i): SEQ ID NO: 15; ii): SEQ ID NO: 16; iii): SEQ ID NO: 17; and iv): SEQ ID NO: 18.

Figure 11 provides simple allometric scaling of central clearance (CL) of BAN2401, A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8 including preclinical species mouse, rat and cynomolgus. The CLs of the different species are plotted against their weights (diamonds), respectively. The regression line has been extrapolated to indicate CL in a man with a body weight of 70 kg. For BAN2401 the true central CL measured is indicated by an open square, and deviates from the linear regression line based on CL of BAN2401 in mouse, rat and cynomolgus monkey. BAN2401 showed a poor linear correlation of CL indicating uncertain prediction of half-life, in contrast to the excellent linear correlation of CL of the antibodies of the invention.

The mutations A17D, R79T and R82S, represent positions in the BAN2401 antibody, wherein amino acids in positions 17, 79 and 82 are mutated in the variable light chain.

With “BAN2401” is meant a humanized monoclonal antibody of the mouse antibody mAb158 comprising a variable light chain with an amino acid sequence as set out in SEQ ID NO: 7 and a variable heavy chain as set out in SEQ ID NO: 13. Both BAN2401 and mAb158 and their characteristics, including VL-CDR1-3 and VH-CDR1-3 are described in EP2004688. BAN2401 is excluded from the present invention.

With the following abbreviations is meant:

BAN2401: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 7; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 13.

A17D: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 19 and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 13.

A17D/R79T: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 20 and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 13.

A17D/R79T/R82S: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 21 and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 13.

A17D/R82S: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 22 and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 13.

A17D/R79T_DI 1: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 9; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

A17D/R79T_DI 2: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 10; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

A17D/R79T_DI 3: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 11; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

A17D/R79T_DI 4: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 12; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

A17D/R79T_DI 5: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 9; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

A17D/R79T_DI 6: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 10; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

A17D/R79T_DI 7: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 11; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

A17D/R79T_DI 8: an antibody comprising a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 12; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

An antibody, or an antigen binding fragment thereof, according to the present invention comprises, in the light variable chain, in position 17 (Kabat position 17) the amino acid A, D, E, Q or a functional analogue, in position 79 (Kabat position 74) amino acid R, T, K, A, G or a functional analogue and in position 82 (Kabat position 77) amino acid R, S, C, G, N or a functional analogue. A functional analogue is an amino acid providing a lower pI value of the antibody compared to A (position 17) resp. R (position 79 and 82) without negatively affecting the binding to the antigen.

The amino acid sequences in the present disclosure are represented as follows:

SEQ ID NO: 1: variable heavy chain VH-CDR1 of BAN2401.

SEQ ID NO: 2: variable heavy chain VH-CDR2 of BAN2401.

SEQ ID NO: 3: variable heavy chain VH-CDR3 of BAN2401.

SEQ ID NO: 4: variable light chain VL-CDR1 of BAN2401.

SEQ ID NO: 5: variable light chain VL-CDR2 of BAN2401.

SEQ ID NO: 6: variable light chain VL-CDR3 of BAN2401.

SEQ ID NO: 7: variable light chain of BAN2401.

SEQ ID NO: 8: generic variable light chain sequence in antibodies of the invention.

SEQ ID NO: 9: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 10: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 11: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 12: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 13: variable heavy chain of BAN2401.

SEQ ID NO: 14: generic variable heavy chain sequence in antibodies of the invention.

SEQ ID NO: 15: specific variable heavy chain sequence in antibodies of the invention.

SEQ ID NO: 16: specific variable heavy chain sequence in antibodies of the invention.

SEQ ID NO: 17: specific variable heavy chain sequence in antibodies of the invention.

SEQ ID NO: 18: specific variable heavy chain sequence in antibodies of the invention.

SEQ ID NO: 19: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 20: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 21: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 22: specific variable light chain sequence in antibodies of the invention.

SEQ ID NO: 23: amino acid sequence of human IgG1 constant region comprised in antibodies of the invention.

SEQ ID NO: 24: amino acid sequence of human κ chain constant region comprised in antibodies of the invention.

The variable light chain (SEQ ID NO: 7) of BAN2401 and the antibodies of the invention comprises the three CDR-sequences (VL-CDR1-3):

VL-CDR1: RSSQSIVHSNGNTYLE	SEQ ID NO: 4
VL-CDR2: KVSNRFS	SEQ ID NO: 5
VL-CDR3: FQGSHVPPT	SEQ ID NO: 6

and the variable heavy chain (SEQ ID NO: 13) of BAN2401 and the antibodies of the invention, comprises the three CDR-sequences (VH-CDR1-3):

VH-CDR1: SFGMH	SEQ ID NO: 1
VH-CDR2: YISSGSSTIYYGDTVKG	SEQ ID NO: 2
VH-CDR3: EGGYYYGRSYYTMDY	SEQ ID NO: 3

According to one aspect of the invention, antibodies binding to Aβ protofibrils are provided, having the following CDR sequence combinations:

VH-CDR1: SFGMH	SEQ ID NO: 1
VH-CDR2: YISSGSSTIYYGDTVKG	SEQ ID NO: 2
VH-CDR3: EGGYYYGRSYYTMDY	SEQ ID NO: 3
VL-CDR1: RSSQSIVHSNGNTYLE	SEQ ID NO: 4
VL-CDR2: KVSNRFS	SEQ ID NO: 5
VL-CDR3: FQGSHVPPT	SEQ ID NO: 6

and comprising the variable light chain with SEQ ID NO: 8, wherein x_1 is A, D, E, Q or a functional analogue, x_2 is R, T, K, A, G or a functional analogue and x_3 is R, S, C, G, N or a functional analogue, with the exception for the combination x_1=A, x_2=R and x_3=R.

A functional analogue is an amino acid providing a lower pI value of the antibody compared to A (x_1) resp. R (x_2 and x_3) without negatively affecting the binding to the antigen.

The variable heavy chain has the amino acid sequence presented in SEQ ID NO: 14, comprising the z_1, z_2 and z_3 in any combination and wherein
z_1 is selected from V and I;
z_2 is selected from R and Q; and
z_3 is selected from A, N and T;
with the exception for the combination z_1=V, z_2=R and z_3=A.

It should be pointed out that based on this teaching, the identification of a functional analogue to the specific amino acids defined above for each of the positions is easily done by a person skilled in the art, as methods for introducing an amino acid in a specific position in accordance with the present invention, as well as testing the resulting product, e.g. with regard to affinity for Aβ protofibrils and other characteristics of importance, are disclosed, see below.

Accordingly, in one aspect of the invention there is provided an antibody, or antigen binding fragment thereof having affinity against Aβ protofibrils, wherein the antibody, or antigen binding fragment thereof has a variable light chain according to SEQ ID NO: 8, wherein
x_1 is selected from A, D, E and Q, or a functional analogue thereof;
x_2 is selected from R, T, K, A and G, or a functional analogue thereof;
x_3 is selected from R, S, C, G and N, or a functional analogue thereof;
y_1 is selected from V and A;
y_2 is selected from I and V;
y_3 is selected from S and Q;
y_4 is selected from E and D; and optionally
a variable heavy chain according to SEQ ID NO: 14, wherein
z_1 is selected from V and I;
z_2 is selected from R and Q; and
z_3 is selected from A, N and T;
with the exception for the combination x_1=A, x_2=R and x_3=R.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein
x_1 is selected from A, D, E and Q;

x_2 is selected from R, T, K, A and G;

x_3 is selected from R, S, C, G and N;

y_1 is selected from V and A;

y_2 is selected from I and V;

y_3 is selected from S and Q;

y_4 is selected from E and D; and

a variable heavy chain according to SEQ ID NO: 14, wherein

z_1 is selected from V and I;

z_2 is selected from R and Q; and

z_3 is selected from A, N and T;

with the exception for the combination x_1=A, x_2=R and x_3=R.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein the light chain comprises a combination of mutations selected from:

x_1 and (y_1 and/or y_2);

x_1 and (y_1 and/or y_2) and x_2 and (y_3 and/or y_4);

x_1 and (y_1 and/or y_2) and x_2 and x_3 and (y_3 and/or y_4);

x_1 and (y_1 and/or y_2) and x_3 and (y_3 and/or y_4);

x_2 (y_3 and/or y_4);

x_2 and x_3 and (y_3 and/or y_4); and

x_3 and (y_3 and/or y_4);

with the exception for the combination x_1=A, x_2=R and x_3=R.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein the variable light chain comprises one or more mutations, selected from:

x_1 is D and (y_1 and/or y_2);

x_1 is D and (y_1 and/or y_2), x_2 is T and (y_3 and/or y_4);

x_1 is D and (y_1 and/or y_2), x_2 is T, x_3 is S and (y_3 and/or y_4);

x_1 is D and (y_1 and/or y_2) and x_3 is S and (y_3 and/or y_4);

x_2 is T (y_3 and/or y_4);

x_2 is T and x_3 is S and (y_3 and/or y_4); and

x_3 is S and (y_3 and/or y_4);

wherein y_1 is V or A and y_2 is V or I, with exclusion of the combination y_1=V and y_2=I; y_3 is S or Q and y_4 is E or D with exclusion of the combination y_3=S and Y_4=E.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein y_1 is A, y_2 is V, y_3 is Q and y_4 is D.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is selected from V and A;

y_2 is selected from V and I;

y_3 is selected from Q and S;

y_4 is selected from D and E;

z_1 is V;

z_2 is R; and

z_3 is selected from N, T and A;

with exclusion of the combination wherein y_1 is V, y_2 is I, y_3, is S, y_4 is E, z_1 is V, z_2 is R and z_3 is A.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is V;

y_2 is V;

y_3 is Q;

y_4 is E;

z_1 is V;

z_2 is R; and

z_3 is N.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is V;

y_2 is V;

y_3 is S;

y_4 is D;

z_1 is V;

z_2 is R; and

z_3 is N.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is A;

y_2 is I;

y_3 is Q;

y_4 is E;

z_1 is V;

z_2 is R; and

z_3 is N.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is A;

y_2 is I;

y_3 is S;

y_4 is D;

z_1 is V;

z_2 is R; and

z_3 is N.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is V;

y_2 is V;

y_3 is Q;

y_4 is E;

z_1 is V;

z_2 is R; and

z_3 is T.

In one embodiment of this aspect, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is V;

y_2 is V;

y_3 is S;

y_4 is D;

z_1 is V;

z_2 is R; and

z_3 is T.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is A;

y_2 is I;

y_3 is Q;

y_4 is E;

z_1 is V;

z_2 is R; and

z_3 is T.

In one aspect of this embodiment, there is provided an antibody, or an antigen binding fragment thereof, wherein

x_1 is D;

x_2 is T;

x_3 is R;

y_1 is A;

y_2 is I;

y_3 is S;

y_4 is D;

z_1 is V;

z_2 is R; and

z_3 is T.

According to one aspect of the invention, each mutation x_1-x_3 is combined with one or more additional mutations y_1-y_4:

when x_1 is not A, the mutations y_1 and/or y_2 are introduced;

when x_2 is not R and/or x_3 is not R, the mutations y_3 and/or y_4 are introduced;

providing variable light chains comprising the following combinations of mutants compared to SEQ ID NO: 7:

x_1 and (y_1 and/or y_2); or

x_1 and (y_1 and/or y_2) and x_2 and (y_3 and/or y_4); or

x_1 and (y_1 and/or y_2) and x_2 and x_3 and (y_3 and/or y_4); or

x_1 and (y_1 and/or y_2) and x_3 and (y_3 and/or y_4); or

x_2 and (y_3 and/or y_4); or

x_2 and x_3 and (y_3 and/or y_4); or

x_3 and (y_3 and/or y_4);

wherein the parameters x and y are as defined above.

In one embodiment, the light chain (SEQ ID NO: 8) of an antibody, or an antigen binding fragment thereof according to the invention comprises only one or more of the mutations x_1-x_3 in the light variable chain (using N-terminal numbering): A17D (x_1), R79T (x_2) and R82S (x_3):

A17D; or

A17D and R79T; or

A17D and R79T and R82S; or

A17D and R82S; or

R79T; or

R79T and R82S; or

R82S;

wherein y_1 is V, y_2 is I, y_3 is S and y_4 is E (no changes compared to SEQ ID NO: 7).

According to a further embodiment, mutations y_1-y_4 are introduced providing any one of the following combinations:

A17D and (y_1 and/or y_2);

A17D and (y_1 and/or y_2) and R79T and (y_3 and/or y_4);

A17D and (y_1 and/or y_2) and R79T and R82S and (y_3 and/or y_4);

A17D and (y_1 and/or y_2) and R82S (y_3 and/or y_4);

R79T (y_3 and/or y_4);

R79T and R82S and (y_3 and/or y_4);

R82S and (y_3 and/or y_4);

wherein y_1 is V or A and y_2 is V or I, with exclusion of the combination y_1=V and y_2=I,

y_3 is S or Q and y_4 is E or D, with exclusion of the combination y_3=S and Y_4=E.

Further specific combinations are disclosed in SEQ ID NOS: 9-12.

The heavy, variable chain (VH) of antibodies according to the present invention has the amino acid sequence SEQ ID NO: 14, wherein z_1 is V or I, z_2 is R or Q and z_3 is A, N or T, e.g. SEQ ID NO: 15-18.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain selected from an amino acid sequence as set out in any one of SEQ ID NOS: 9-12.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable heavy chain selected from an amino acid sequence as set out in any one of SEQ ID NOS: 15-18.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain selected from an amino acid sequence as set out in in any one of SEQ ID NOS: 9-12; and a variable heavy chain selected from an amino acid sequence as set out in any one of SEQ ID NOS: 15-18.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 9; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 10; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 11; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 12; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 15.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 9; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 10; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 11; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

In one embodiment of this aspect, there is provided an antibody or an antigen binding fragment thereof, wherein the antibody or antigen binding fragment comprises a variable light chain comprising an amino acid sequence as set out in SEQ ID NO: 12; and a variable heavy chain comprising an amino acid sequence as set out in SEQ ID NO: 16.

In one embodiment, the antibody or antigen binding fragment according to the present invention, comprises a heavy chain constant region selected from the group consisting of IgG1, IgG2, IgG3, IgG4, IgM, IgA and IgE constant regions or any allelic variation thereof as discussed in Kabat et al. (Kabat, E. A., et al. (1991) Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH Publication No. 91-3242), included herein by reference. Any of such sequences may be used in the present invention. In a more preferred embodiment, the antibody heavy chain constant region is IgG1. The amino acid sequence of human IgG1 constant region is known in the art and set out in SEQ ID NO: 23.

In one embodiment, the antibody or antigen binding fragment according to the present invention comprises a light chain constant region selected from the group consisting of κ- and λ-chain constant regions or any allelic variation thereof as discussed in Kabat et al.

(Kabat, E. A., et al. (1991) Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH Publication No. 91-3242), included herein by reference. Any of such sequences may be used in the present invention. In a more preferred embodiment, the antibody light chain constant region is κ. The amino acid sequence of human κ chain constant region is known in the art and set out in SEQ ID: 24.

In one embodiment, the antigen binding fragment according to the present invention is a Fab fragment, or a $F(ab')_2$ fragment or a single chain Fv fragment.

Antibodies or antigen binding fragments according to the invention can comprise any combination of the variable light and heavy chains defined above.

According to one aspect of the invention there is provided improved antibodies, or antigen binding fragments with high affinity for Aβ protofibrils for use in therapy e.g. by administration of one or more antibodies, or antigen binding fragments according to the invention to a patient having or at risk of developing Alzheimer's disease and other disorders associated with Aβ protein aggregation, such as traumatic brain injury (TBI), dementia with Lewy body (DLB), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD). A suitable dose may vary within broad ranges, e.g. from 0.01 to 100 mg/kg/dose, depending on the medical indication and the patient's status, the route of administration, e.g. i.v., s.c., infusion or by local administration, in addition to the frequency chosen, e.g. single dose, daily, weekly, quarterly or even less frequent administration.

In one aspect, there is provided an antibody, or an antigen binding fragment thereof of the invention, for use in therapy.

In one aspect, there is provided an antibody, or an antigen binding fragment thereof of the invention, for use in treatment and/or prophylaxis of Alzheimer's disease and other disorders associated with Aβ protein aggregation. Typically, such other disorders may be selected from traumatic brain injury (TBI), Lewy body dementia (LBD), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD).

In one aspect, there is provided use of an antibody, or an antigen binding fragment thereof of the invention, in the manufacture of a medicament useful in the treatment and/or prophylaxis of Alzheimer's disease and other disorders associated with Aβ protein aggregation. Typically, such other disorders may be selected from traumatic brain injury (TBI), Lewy body dementia (LBD), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD).

In one aspect, there is provided a method of reducing amount of Aβ protofibrils in persons, comprising administering to the person a therapeutically effective amount of an antibody, or an antigen binding fragment thereof of the invention.

In one aspect, there is provided a method for treatment and/or prophylaxis of Alzheimer's disease and other disorders associated with Aβ protein aggregation in a subject having or at risk of developing the disease, comprising administering to the person a therapeutically effective amount of an antibody, or an antigen binding fragment thereof, of the invention. Typically, such other disorders may be selected from traumatic brain injury (TBI), Lewy body dementia (LBD), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD).

A "subject" is typically a mammal, such as a human. Other mammals represent such mammals, where veterinary use/treatment/propfylaxis would apply.

In one aspect, there may be provided a method for measuring amount of Aβ protofibrils and/or aggregated Aβ protein in a person, comprising contacting the person's tissue or body fluid, *in vivo* or *in vitro*, with a labeled antibody, or an antigen binding fragment thereof of the invention and measuring the amount of antibodies, or antigen binding fragments bound to said Aβ protofibrils and/or aggregated Aβ protein. The antibodies or antigen binding fragments could be labeled with a radioactive ligand such as I^{131}, C^{11}, C^{14}, H^{3}, F^{18}, or $Gallium^{68}$, but not limited to these radioisotopes, for detection purposes.

In one aspect, there may be provided a method for diagnosis of Alzheimer's disease and other disorders associated with Aβ protein aggregation, such as traumatic brain injury (TBI), dementia with Lewy body (DLB), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS),

Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD), in persons having or at risk of developing the disease comprising contacting the person's tissue or body fluid, *in vivo* or *in vitro*, with an antibody of the invention, or an antigen binding fragment thereof, and measuring the amount of antibody or antigen binding fragment bound to aggregated protein. Typically, said other disorders are associated with Aβ protein aggregation may be selected from traumatic brain injury (TBI), dementia with Lewy body (DLB), Down syndrome (DS), Amyotrophic lateral sclerosis (ALS), Frontotemporal dementia, tauopathies, systemic amyloidosis, atherosclerosis and Parkinson's disease dementia (PDD). Typically, a person's body fluid or tissue would be analysed *in vivo* or *in vitro* (in a sample taken from the patient) by contact with a preparation of one or more antibodies or antigen binding fragments of the invention and the amount of antibodies or antigen binding fragments bound to Aβ protofibrils would be measured. Quantification of protofibrils would be used in diagnosis of diseases mentioned above, follow up of various treatments as well as in the development of new medicines. Optionally, the antibodies or antigen binding fragments thereof, in such a preparation, would be labelled with an agent, which would be detected and measured by any of the techniques known in the art, e.g. analysis by ELISA, Biacore and/or imaging with SPECT, PET, MRI. The antibodies or antigen binding fragments could be labeled with a radioactive ligand such as I^{131}, C^{11}, C^{14}, H^{3}, F^{18} or Gallium^{68}, but not limited to these radioisotopes, for detection purposes.

According to a further aspect of the invention a pharmaceutical composition is prepared, comprising an effective amount of one or more of the antibodies or antigen binding fragment thereof according to the invention. A medical composition comprising an antibody according to the invention may comprise, in addition to an effective amount of the antibody, other components known for use in such preparations, e.g. buffers, components for preservation and stability.

In another aspect there may be provided an antibody of the invention, for veterinary use. Typically, said veterinary use would include treatment and/or prophylaxis of disorders associated with Aβ protein aggregation.

According to a further aspect of the invention there may be provided therapy utilizing antibodies according to the invention in combination with symptomatic treatments, such as acetylcholine esterase inhibitors, NMDA antagonists and 5HT6 inhibitors.

Combination with other disease modifying treatments, such as γ-secretase inhibitors (GSI), γ-secretase modulators (GSM), β-secretase (BACE) inhibitors, BACE modulators, vaccines, other antibodies, drugs targeting tau or neuroinflammatory processes, antihypertensives, etc., offers additional possibilities for efficient therapy.

Combination with nutrition products may offer additional possibilities for efficient therapy.

In one aspect, there is provided a pharmaceutical composition comprising an antibody of the invention, together with pharmaceutically acceptable excipient and/or diluents, said composition further may comprise an additional, therapeutic agent. Typically, said additional therapeutic agent may be selected from acetylcholine esterase inhibitors, NMDA antagonists, 5HT6 inhibitors, GSI, GSM, BACE inhibitors, BACE modulators, vaccines, other antibodies, drugs targeting tau or neuroinflammatory processes, antihypertensives and a nutrition product. The composition may be provided as a single or sequential dose.

The present invention will be illustrated by a number of non-limiting examples:

Example 1. Production of antibodies and methods used

Production of reference antibody

The reference antibody BAN2401 was produced according to previously described methods in EP2004688.

Production of the antibodies of the invention

The antibodies of the invention were produced by transient and/or stable production in Chinese Hamster Ovary (CHO) cells using the CHOK1SV GS and CHOK1SV GS-KO Xceed™ expression systems (Lonza), respectively. The following mutants were produced by transient transfection using the CHOK1SV GS-KO Xceed™ expression system: A17D, A17D/R79T and A17D/R79T/R82S. The following mutants were produced by both transient and stable transfection using the CHOK1SV GS-KO Xceed™ expression system: A17D/R79T_DI 1, A17D/R79T_DI 2, A17D/R79T_DI 3, A17D/R79T_DI 4, A17D/R79T_DI 5, A17D/R79T_DI 6, A17D/R79T_DI 7 and A17D/R79T_DI 8. The A17D/R82S mutant was produced by stable transfection using the CHOK1SV GS expression system.

Sequences of the light and heavy chain encoding regions of the mutants were synthesized by using conventional methods.

For transient transfections in the CHOK1SV GS-KO Xeed™ expression system, light chain encoding regions were sub-cloned into the pXC-17.4 vector and heavy chain encoding regions into the pXC-18.4 vector. Expression cultures were harvested 6 days post-transfection and clarified by centrifugation and sterile filtration. The clarified cell culture supernatants were subjected to purification using Protein A chromatography. Eluted antibody was provided in PBS (pH 7.4). The products were further purified by preparative Size Exclusion Chromatography (SEC) to remove aggregates. The monomer peak collected was thereafter analysed by analytical SEC, and aggregate levels were determined to be below 2% for all products.

Stable expression in the CHOK1SV GS-KO Xeed™ system was performed essentially according to the manufacturer's recommendations. In brief, the two vectors containing the light and heavy chains (pXC-17.4 and pXC -18.4) were ligated into one double gene vector containing both genes. CHOK1SV GS-KO cells were transfected by electroporation with the linearized double gene vector. Screening of clones and productivity screening of death cultures were analyzed by ELISA. Productions were performed with CD-CHO medium supplemented with 15% Feed A and 15% Feed B (Life Technologies). Supernatants were harvested by centrifugation and sterile filtration. The clarified cell culture supernatants were purified using Protein G chromatography and buffer exchanged to Dulbecco's PBS (Gibco).

For stable transfection using the CHOK1SV GS expression system (Lonza), the heavy chain gene was ligated into the pEE6.4 vector and the light chain gene in pEE12.4 vector. The two vectors were ligated to form a double gene vector. CHOK1SV cells were transfected by electroporation with the linearized double gene vector. In essence, transfections were performed according to the manufacturer's recommendations. Screening of clones and productivity screening of death cultures were analyzed by ELISA. Productions were performed with CD-CHO medium supplemented with 15% Feed A and 15% Feed B (Life Technologies). Supernatants were harvested by centrifugation and sterile filtration. The clarified cell culture supernatants were purified using Protein G chromatography and buffer exchanged to Dulbecco's PBS (Gibco). Product quality analysis by Size Exclusion HPLC and SDS-PAGE were carried out using purified material of all mutants produced.

Target binding analysis by inhibition ELISA

The binding characteristics towards Aβ protofibrils and Aβ monomers of the antibodies of the invention compared to BAN2401 were analyzed using an inhibition ELISA in which antibodies were pre-incubated in solution with Aβ protofibrils or Aβ monomers and then transferred to Aβ coated ELISA plates, as described in Tucker *et. al*. J Alzheimers Dis. 2015; 43(2):575-88. doi: 10.3233/JAD-140741. PubMed PMID: 25096615, and references cited therein.

Pharmacokinetic studies in wild type mice

8-10 weeks old female C57BL/6 mice were grouped and given single intravenous (i.v.) injections of BAN2401 or antibodies of the invention at a dosage of 10 mg/kg. Plasma from all animals was collected at time points varying from 30 minutes to 29 days post injection and used for measurements of antibody concentrations and subsequent calculations of pharmacokinetic (PK) parameters. Mice were sacrificed at the terminal plasma collection time point.

Pharmacokinetic studies in rats

8 weeks old female Sprague Dawley rats were grouped and given single i.v. injections of BAN2401 or antibodies of the invention at a dosage of 10 mg/kg. Plasma from all animals was collected at time points varying from 30 minutes to 29 days post injection and used for measurements of antibody concentrations and subsequent calculations of PK parameters. Rats were sacrificed at the terminal plasma collection time point.

Pharmacokinetic studies in monkeys

Male cynomolgus monkeys were grouped (N=3) and subjected to single i.v. infusions of 5 mg/kg BAN2401 or 10 mg/kg of the antibodies of the invention. Serum from all animals was collected at time points varying from 5 minutes to 28 days post injection and used for measurements of antibody concentrations. Serum levels of BAN2401 and the antibodies of the invention were determined by ELISA. Biotinylated Aβ1-42 protofibrils were added to an avidin immobilized microplate for coating. After blocking, monkey serum samples were added to the wells. After washing away any unbound substances, alkaline Phosphatase (AP) labeled goat anti-human IgG was added to the wells. Following a wash to remove any unbound reagents, p-nitrophenylphosphate, a substrate for AP, was added to the wells. The reaction was stopped with sodium hydroxide solution and absorbance was measured at 405 nm and 492 nm.

Absorbance at 492 nm was subtracted from that at 405 nm. Values were translated to concentrations by means of a standard curve and used for subsequent calculations of PK parameters.

Direct ELISA for measurement of Aβ antibodies

Levels of BAN2401 and antibodies of the invention in cell culture media, purified antibody product, and plasma collected in the mouse and rat PK studies were measured by direct ELISA for measurement of anti-Aβ antibodies. Samples were serially diluted and incubated in microtiter plate wells coated with Aβ1-40 to allow for BAN2401 and the antibodies of the invention to bind. Horse radish peroxidase (HRP)-conjugated goat anti-human IgG was utilized as detection antibody and TMB, a substrate for HRP, was added. The reaction was stopped by addition of 2M H_2SO_4, which results in a yellow color that is measured at 450 nm. The method was employed in a quantitative manner, where OD_{450} values are translated into concentrations by means of a standard curve.

Calculations of PK parameters by non-compartmental analysis

Individual terminal half-life calculations were performed using a non-compartmental model with the Phoenix WinNonLin 6.3 software (Pharsight). Area under the curve ($AUC_{0\text{-}inf}$) calculations were performed with Phoenix WinNonLin using the lin-up log-down method. Group means and standard deviations of AUCs and terminal half-lives were calculated using GraphPad Prism (v 6.04).

Statistical analyses

Statistical analyses of group means of individually determined terminal half-lives and AUCs were performed using the GraphPad Prism software (v. 6.04). One-way ANOVA followed by Bonferroni's multiple comparisons post-test was used in the studies. Tests were performed at significance levels * P <0.05, ** P <0.01, *** P <0.001 and **** P <0.0001.

Example 2. Target binding characterization

Aβ-protofibrils binding preserved in A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S compared to BAN2401

The target binding profiles of the antibodies of the invention were analyzed next to BAN2401 (control) by inhibition ELISA as described in Example 1 (inhibition ELISA). Results are presented in Figure 1, where analysis of binding and selectivity for Aβ protofibrils compared

to Aβ monomers for A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S and BAN2401 are shown. Results showed that the binding and selectivity of binding to Aβ protofibrils as compared to binding to the Aβ monomer was preserved in antibodies of the invention (A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S).

Example 3. Pharmacokinetic profile of antibodies in mice

Pharmacokinetic study of BAN2401, A17D, A17D/R79T, A17D/R82S, A17D/R79T/R82S in wild-type mice

In order to study the pharmacokinetic profile of the antibodies of the invention in wild-type mice, 8-10 weeks old C57BL/6 female mice were dosed with single i.v. injections of 10 mg/kg BAN2401 (N=8), A17D (N=7), A17D/R79T (N=6), A17D/R82S (N=8) or A17D/R79T/R82S (N=7). Animals were bled after 0.5 h, 2 days, 7 days, 14 or 15 days, and 28 or 29 days and levels of BAN2401 and antibodies of the invention were analysed by ELISA using Aβ1-40 for capture and HRP-coupled goat-anti-human IgG for detection as described in Example 1 (direct ELISA). A17D/R82S was administered in a study started at a separate occasion compared to the other antibodies. However, plasma samples from the two different studies were analyzed by ELISA at the same time to avoid inter-assay variation.

As shown in the time *vs* concentration graphs in Figure 2 and the calculated PK parameters presented in Table 1, the PK profiles of the antibodies of the invention (A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S) differ substantially from BAN2401, especially during the first 48 hours post injection. Whereas a 6-fold increase in exposure, measured as area under the curve ($AUC_{0\text{-}inf}$), was seen for A17D compared to BAN2401 the AUCs of A17D/R79T, A17D/R82S and A17D/R79T/R82S were improved by 10-11 times (Table 1). Also, the terminal plasma half-lives of the antibodies of the invention were considerably prolonged compared to BAN2401 (Table 1).

Table 1. Plasma PK parameters of BAN2401, A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S in mice. Half-life and $AUC_{0\text{-}inf}$ for all antibodies were calculated individually for all animals by non-compartmental analysis using Phoenix WinNonlin 6.3 (Pharsight) and subjected to statistical analysis by one-way ANOVA followed by Bonferroni's Multiple Comparisons post-test. Mean $AUC_{0\text{-}inf}$ values and mean terminal half-lives are shown in the table. Statistical differences in terminal half-life and $AUC_{0\text{-}inf}$ between BAN2401 and the mutants are indicated in the table, where *** denotes $p<0.001$, and **** $p<0.0001$.

Antibody	AUC_{0-inf} (mg*h/ml)	Terminal half-life (days)
BAN2401	3.7	4.5
A17D	23.3****	8.7***
A17D/R79T	40.2****	10.7****
A17D/R82S	37.9****	11.1****
A17D/R79T/R82S	41.0****	10.9****

Example 4. Pharmacokinetic profile of antibodies in rat

Pharmacokinetic study of BAN2401, A17D, A17D/R79T and A17D/R79T/R82S in rats

In order to study the pharmacokinetic profile of the antibodies of the invention in rats, 8 weeks old female Sprague Dawley rats were dosed with single i.v. injections of 10 mg/kg BAN2401 (N=3), A17D (N=4), A17D/R79T (N=6) or A17D/R79T/R82S (N=5). Animals were bled after 0.5 h, 2 h, 7 h, 24 h, 2 days, 4 days, 7 days, 14 days and 29 days post injection. Levels of BAN2401 and antibodies of the invention were analysed by ELISA using Aβ1-40 for capture and HRP-coupled goat-anti-human IgG for detection as described in Example 1 (direct ELISA). The rapid reduction of BAN2401 levels in plasma of wild-type mice during the first 48 hours post administration leading to low exposure (Figure 2) is not seen in rat, and instead BAN2401 and the antibodies of the invention display similar PK profiles (Figure 3). Statistical analysis of plasma half-lives and AUC_{0-inf} values calculated individually for all rats in the study, suggested no major differences in AUC_{0-inf} or terminal half-life between BAN2401 and A17D or A17D/R79T/R82S (Table 2). While, a significant increase in AUC_{0-inf} was indicated for A17D/R79T compared to BAN2401 there was no statistical difference in terminal half-life between the two of them (Table 2).

Table 2. Plasma PK parameters of BAN2401, A17D, A17D/R79T and A17D/R79T/R82S in rats. Half-lives and AUC_{0-inf} values for all antibodies were calculated individually for all animals by non-compartmental analysis using Phoenix WinNonlin 6.3 (Pharsight) and subjected to statistical analysis by one-way ANOVA followed by Bonferroni's Multiple Comparisons post-test. Mean AUC_{0-inf} values and mean terminal half-lives of BAN2401, A17D, A17D/R79T and A17D/R79T/R82S calculated are shown in the table. Statistical differences in terminal half-life and AUC_{0-inf} between BAN2401 and the mutants are indicated in the table, where ** denotes $P<0.01$.

Antibody	AUC_{0-inf} (mg*h/ml)	Terminal half-life (days)

BAN2401	31.1	10.2
A17D	38.0	10.9
A17D/R79T	47.6**	12.8
A17D/R79T/R82S	36.6	11.2

Example 5. Deimmunization

Ex vivo whole protein T cell assay of BAN2401, A17D, A17D/R79T and A17D/R79T/R82S

In order to evaluate whether mutations introduced in the antibodies of the invention had led to an increased risk for an immunogenic response in humans, A17D, A17D/R79T and A17D/R79T/R82S were analyzed next to BAN2401 by an *ex vivo* whole protein T cell activation assay. The EpiScreen™ time course T cell assay measures the capacity of an antibody to induce CD4+ T cell responses (Antitope Ltd, Cambridge, UK). The samples were tested against CD8+ depleted peripheral blood mononucleated cells (PBMC) from a cohort of 25 healthy donors (Donor 1-25, Table 3) with a broad HLA-diversity. The ability of the antibodies to induce CD4+ T cell responses was measured by proliferation and IL-2 secretion.

Results from the study indicated that the overall potential risk of immunogenicity was low for BAN2401 and borderline low for A17D with 8% and 12% of donors responding positively, respectively (Table 3). Analysis of A17D/R79T and A17D/R79T/R82S revealed unexpectedly somewhat higher risks of immunogenicity, as the combined frequency of proliferation and IL-2 secretion was 24% and 20% of the study cohort, respectively.

Table 3. Summary of healthy donor T cell proliferation and IL-2 ELISpot responses for BAN2401, A17D, A17D/R79T and A17D/R79T/R82S. Positive T cell responses for proliferation are indicated with a "P" and positive ELISpot responses are indicated with an "E". Borderline responses are indicated (*). Correlation is expressed as the percentage of proliferation responses also positive in the ELISpot assay. To be considered a response in one donor, both the proliferation and ELISpot assays have to be positive. Humanized A33 (Welt S et al., Clin Cancer Res. 2003 Apr; 9(4): 1347-53., 2003), which is a therapeutic antibody control with a known mean immunogenicity of 32% in the clinic, typically stimulates 20-30% of donors to respond positively in the T cell proliferation assay. Phytohaemagglutinin (PHA) and Keyhole Limpet Hemocyanin (KLH) are potent antigens used as positive controls.

	BAN2401	**A17D**	**A17D/R79T**	**A17D/R79T /R82S**	**A33**	**KLH**	**PHA**
Donor 1				PE		PE	PE
Donor 2		PE	P*E		PE	PE	PE

Donor 3			E*			PE	PE
Donor 4						PE	PE
Donor 5						PE	PE
Donor 6						PE	PE
Donor 7						PE	PE
Donor 8			PE	PE		PE	PE
Donor 9						PE	PE
Donor 10						PE	PE
Donor 11						E	PE
Donor 12						P*	PE
Donor 13					PE	PE	PE
Donor 14			PE	PE	PE	PE	PE
Donor 15					P	PE	PE
Donor 16	PE	P	P	P	E	PE	PE
Donor 17			PE	PE	PE	PE	PE
Donor 18						PE	PE
Donor 19	PE	PE	PE	PE		PE	PE
Donor 20						PE	PE
Donor 21	P	PE*	P	P		PE	PE
Donor 22						E	PE
Donor 23			PE			PE	PE
Donor 24				E	PE	PE	PE
Donor 25						PE	PE
Proliferation %	12	16	32	28	24	92	100
ELISpot %	8	12	28	24	24	96	100
Proliferation and ELISpot %	8	12	24	20	20	88	100
Correlation %	67	75	75	71	83	96	100

T-cell epitope screening of BAN2401 in silico

To further address the immunogenicity risk inferred by the mutations and to find relevant positions to deimmunize, BAN2401, A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S were subjected to *in silico* T cell epitope screening. Variable region sequences of BAN2401, A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S were provided to Antitope Ltd (Cambridge, UK) for analysis by their proprietary *in silico* technologies iTope™and TCED™. Non-germline promiscuous MHC class II binding sequences were identified in both the heavy chains and the light chains of the antibodies analyzed. BLAST search analysis of the TCED™ revealed two partial matches to previously identified epitopes in the database of peptides with known immunogenicity *ex vivo*.

Ex vivo T cell epitope mapping of BAN2401, A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S

In order to verify the immunogenicity risk inferred by the new mutations and to identify positions to deimmunize, 44 peptides (15-mers) derived from variable regions of BAN2401,

A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S were assessed for the presence of CD4+ T cell epitopes using EpiScreen™ T cell epitope mapping technology (Antitope Ltd, Cambridge, UK). The peptides were chosen to cover all the potential T cell epitopes identified by the *in silico* screen and also the two regions covering the areas of the A17D substitution and the R79T and R82S substitutions (including peptides with or without mutations).

The peptides were tested against a cohort of 11 human donors selected from the Episcreen™ whole antibody analysis described in the previous section. T cell responses were measured for each donor against each peptide using a proliferation assay that measures ^{3}[H]-thymidine incorporation. The results identified the presence of three potential T cell epitopes in the sequences (Epitope 1, 5 and 8). ”Epitope 1“ present in the heavy chain was considered weak. ”Epitope 5“ including the A17D mutation was weak and no donor responses were observed to the related peptide of the wild-type BAN2401 sequence. ”Epitope 8“ was the most significant epitope based upon frequency of T cell responses and was identified in the peptides of antibodies A17D/R79T, A17D/R82S and A17D/R79T/R82S but not in wild-type BAN2401 or A17D.

The data from the *ex vivo* T cell epitope mapping supported the conclusion from the whole antibody time course T cell assay that A17D/R79T and A17D/R79T/R82S are associated with an increased overall risk of immunogenicity. In addition, also A17D/R82S (not included in the whole antibody T cell assay) appeared to have increased risk of immunogenicity due to the R82S mutation in ”Epitope 8”.

Deimmunization of peptides identified as potential T cells epitopes by ex vivo T cell epitope mapping

In general, deimmunization is achieved by changing a single amino acid in one of the important anchoring positions (p1, p4, p6, p7 and p9 of a 9-mer) of the potential MHC class II binding peptide. Specific deimmunizing mutations in the three epitopes identified in the ex vivo peptide mapping (Epitope 1, 5 and 8) described above were chosen. The substitutions were chosen based on anticipated reduced binding affinity of the peptide to the binding pocket of the MHC class II molecule. Two deimmunizing substitutions were tested for each peptide that had been indicated as potentially immunogenic, and these peptides were analyzed alongside with the original peptides of BAN2401, A17D, A17D/R79T, A17D/R82S and A17D/R79T/R82S using the Episcreen™ peptide mapping technology.

T cell responses were measured for each donor against each peptide using a proliferation assay that measures ^{3}[H]-thymidine incorporation. The results from this study confirmed the

earlier findings, but all epitopes (Epitope 1, 5 and 8) were considered weak in this study (Table 4). Nevertheless, all deimmunizing substitutions successfully reduced the risk of immunogenicity for the peptides covering the three epitopes compared to the original peptides, with no or very few T cell responders (Table 4). This indicates that the chosen substitutions were effective and that the deimmunizations were successful.

Table 4. Deimmunization results at peptide level of epitopes identified as immunogenic using the EpiScreen™ T cell epitope mapping technology. Shown are the peptides derived from BAN2401 and the antibodies of the invention that were identified as immunogenic, and the same peptides with deimmunization substitutions introduced (underlined). Half-life improving mutations are shown in bold. All deimmunized peptides were tested in the *ex vivo* T cell assay and the results are shown in the rightmost column (donor response frequency).

Epitope area	Antibody of peptide origin and deimmunization substitutions	Peptide	Response frequency (%)
	BAN2401 and antibodies of the invention*	SFGMHWVRQAPGKGL	12
1.	A→N	SFGMHWVRQNPGKGL	0
	A→T	SFGMHWVRQTPGKGL	4
	All antibodies of the invention (A17D mutation)	PVTPG**D**PASISCRSS	16
5.	I→V	PVTPG**D**PASVSCRSS	0
	V→A	PATPG**D**PASISCRSS	0
	A17D/R79T (R79T mutation)	SGSGTDFTL**T**ISRVE	16
8.	S→Q	SGSGTDFTL**T**IQRVE	4
	E→D	SGSGTDFTL**T**ISRVD	4
	A17D/R79T (R79T mutation)	GTDFTL**T**ISRVEAED	20
8.	S→Q	GTDFTL**T**IQRVEAED	0
	E→D	GTDFTL**T**ISRVDAED	0
	A17D/R79T/R82S (R79T/R82S mutations)	SGSGTDFTL**T**IS**S**VE	12
8.	S→Q	SGSGTDFTL**T**IQ**S**VE	0
	E→D	SGSGTDFTL**T**IS**S**VD	0
	A17D/R79T/R82S (R79T/R82S mutations)	GTDFTL**T**IS**S**VEAED	16
8.	S→Q	GTDFTL**T**IQ**S**VEAED	0
	E→D	GTDFTL**T**IS**S**VDAED	0
	A17D/R82S (R82S mutation)	SGSGTDFTLRIS**S**VE	12
8.	S→Q	SGSGTDFTLRIQ**S**VE	0
	E→D	SGSGTDFTLRIS**S**VD	4
	A17D/R82S (R82S mutation)	GTDFTLRIS***S***VEAED	16
8.	S→Q	GTDFTLRIQ***S***VEAED	4
	E→D	GTDFTLRIS***S***VDAED	4

*) Non-deimmunized antibodies

Design and production of deimmunized variants of A17D/R79T

Eight deimmunized variants of A17D/R79T were designed based on the results from the T cell epitope mapping and peptide deimmunization described above. In all three epitopes identified as potentially immunogenic, deimmunization mutations shown to reduce

immunogenicity in the *ex vivo* T cells epitope mapping were introduced in the combinations indicated in Table 5.

Table 5. Summary of the eight deimmunized variants of the double mutant A17D/R79T. Deimmunization mutations for the epitopes 1, 5 and 8, chosen and functionally verified in the *ex vivo* T cell assay on peptide level, are indicated for the specific antibodies. N-terminal numbering has been used. VH = variable heavy chain, VL= variable light chain.

A17D/R79T variants	Deimmunization in epitope 1 (VH)	Deimmunization in epitope 5 (VL)	Deimmunization in epitope 8 (VL)
A17D/R79T _DI 1	A40N	I21V	S81Q
A17D/R79T _DI 2	A40N	I21V	E84D
A17D/R79T _DI 3	A40N	V13A	S81Q
A17D/R79T _DI 4	A40N	V13A	E84D
A17D/R79T _DI 5	A40T	I21V	S81Q
A17D/R79T _DI 6	A40T	I21V	E84D
A17D/R79T _DI 7	A40T	V13A	S81Q
A17D/R79T _DI 8	A40T	V13A	E84D

Example 6. Target binding characterization of deimmunized antibodies

Aβ-protofibril binding preserved in eight deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) compared to BAN2401

The target binding profiles of the eight deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) were analyzed next to BAN2401 (control) by inhibition method described in Example 1 (Inhibition ELISA). Results are presented in Figure 4, where analysis of binding and selectivity for Aβ protofibrils compared to Aβ monomers for A17D/R79T_DI 1-8 and BAN2401 are shown. Results showed that binding and selectivity of binding to Aβ protofibrils as compared to binding to the Aβ monomer was preserved in antibodies of the invention (A17D/R79T_DI 1-8).

Example 7. Pharmacokinetic profile of deimmunized antibodies in mice

Pharmacokinetic study of BAN2401, A17D/R79T and eight deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) in wild-type mice

In order to compare the PK profiles of the eight variants of deimmunized A17D/R79T (A17D/R79T_DI 1-8) to the PK profile of BAN2401 and A17D/R79T in wild-type mice, 8-10 weeks old C57BL/6 female mice were grouped (N=5) and subjected to single i.v. injections of

10 mg/kg antibody. Animals were bled after 0.5 h, 2 days, 7 days, 14 days and 28 days and levels of BAN2401 and antibodies of the invention were analysed by ELISA using Aβ1-40 for capture and HRP-coupled goat-anti-human IgG for detection as described in Example 1(direct ELISA). As shown in the time *vs* concentration graph in Figure 5, the PK profile of the deimmunized A17D/R79T mutants (A17D/R79T_DI 1-8) resembles the PK profile of A17D/R79T and differs from BAN2401. Results suggested that both $AUC_{0\text{-}inf}$ and terminal half-life of A17D/R79T and the deimmunized variants (A17D/R79T_DI 1-8) were significantly enhanced compared to BAN2401 (Table 6). Hence, all deimmunized variants showed an improved PK profile compared to BAN2401 and displayed PK profiles that were similar to the PK profile of A17D/R79T, with increased exposure and prolonged elimination half-life.

Table 6. Plasma PK parameters of BAN2401, A17D/R79T and deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) in mice. Half-life and $AUC_{0\text{-}inf}$ for all antibodies were calculated individually for all animals by non-compartmental analysis using Phoenix WinNonlin 6.3 (Pharsight) and subjected to statistical analysis by one-way ANOVA followed by Bonferroni's Multiple Comparisons post-test. Mean $AUC_{0\text{-}inf}$ and mean terminal half-lives are shown in the table. Statistical differences in terminal half-life and $AUC_{0\text{-}inf}$ between BAN2401 and the mutants are indicated in the table, where * denotes $P<0.05$, ** $P<0.01$, *** $P<0.001$ and **** $P<0.0001$.

Antibody	$AUC_{0\text{-}inf}$ (mg* h/ml)	Terminal half-life (days)
BAN2401	3.6	3.5
A17D/R79T	38.0****	10.7**
A17D/R79T_DI 1	42.3****	13.0***
A17D/R79T_DI 2	40.4****	10.5**
A17D/R79T_DI 3	44.9****	12.6***
A17D/R79T_DI 4	43.7****	12.7***
A17D/R79T_DI 5	32.6****	10.4*
A17D/R79T_DI 6	33.4****	12.2 ***
A17D/R79T_DI 7	41.7****	14.1****
A17D/R79T_DI 8	43.8****	10.0*

Example 8. Pharmacokinetic profile of deimmunized antibodies in rat

Pharmacokinetic profiles of BAN2401, A17D/R79T and eight deimmunized variants of A17D/R79T (A17D/R79T DI 1-8) in rats

In order to compare the PK profiles of the eight variants of deimmunized A17D/R79T (A17D/R79T_DI 1-8) to the PK profile of BAN2401 and A17D/R79T in rats, 8 weeks old female Sprague Dawley rats were grouped (N=5) and subjected to single i.v. injections of 10 mg/kg

antibody. Animals were bled after 0.5 h, 2 days, 7 days, 14 days and 28 days and levels of BAN2401 and antibodies of the invention were analysed by ELISA using Aβ1-40 for capture and HRP-coupled goat-anti-human IgG for detection (Example 1, direct ELISA).

As shown in Figure 6, BAN2401, A17D/R79T and the deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) displayed fairly similar PK profiles in rat. Results suggested that A17D/R79T_DI 1 had a significantly longer terminal half-life than BAN2401 in rats ($p<0.05$), whereas $AUC_{0\text{-}inf}$ was significantly larger for A17D/R79T, A17D/R79T_DI 1 and A17D/R79T_DI 4 in comparison to BAN2401 ($p<0.01$) (Table 7).

Table 7. Plasma PK parameters of BAN2401, A17D/R79T and deimmunized variants of A17D/R79T (A17D/R79T_DI 1-8) in rats. Half-life and $AUC_{0\text{-}inf}$ for all antibodies were calculated individually for all animals by non-compartmental analysis using Phoenix WinNonlin 6.3 (Pharsight) and subjected to statistical analysis by one-way ANOVA followed by Bonferroni's Multiple Comparison post-test. Mean AUCs and mean terminal half-lives are shown in the table. Statistical differences in terminal half-life and AUC between BAN2401 and antibodies of the invention are indicated in the table, where * denotes $P<0.05$ and ** $P<0.01$.

Antibody	$AUC_{0\text{-}inf}$ (mg*h/ml)	Terminal half-life (days)
BAN2401	35.1	10.2
A17D/R79T	48.6**	11.0
A17D/R79T_DI 1	47.3**	13.3*
A17D/R79T_DI 2	33.7	11.8
A17D/R79T_DI 3	43.1	11.7
A17D/R79T_DI 4	47.3**	11.7
A17D/R79T_DI 5	44.1	11.6
A17D/R79T_DI 6	39.6	11.3
A17D/R79T_DI 7	35.6	11.8
A17D/R79T_DI 8	40.9	10.6

Example 9. Pharmacokinetic profile of deimmunized antibodies in monkey

Pharmacokinetic profiles of BAN2401, A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8 in cynomolgus monkeys.

In order to compare the PK profiles of A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8 to the PK profile of BAN2401 in monkeys, male cynomolgus monkeys were grouped (N=3) and subjected to single i.v. infusions of 5 mg/kg BAN2401 or 10 mg/kg of the antibodies of the invention. BAN2401 injected monkeys were bled after 5 min, 1 h, 2 h, 8 h, 24 h, 2 days, 4 days,

7 days, 14 days, 21 days and 28 days post administration, whereas the monkeys injected with the antibodies of the invention were bled after 5 min, 2 h, 8 h, 24 h, 3 days, 7 days, 14 days, 21 days and 28 days. Plasma concentration of the administered antibodies were analysed by ELISA as described in Example 1 (direct ELISA). The PK profiles are shown as time *vs* concentration graphs in Figure 7, whereas half-life and $AUC_{0\text{-}inf}$ for all antibodies were calculated by non-compartment analysis using Phoenix WinNonlin 6.3 (Pharsight) (Table 8). PK parameters from BAN2401 shown in Table 8, are results from a separate study in which BAN2401 was administered by i.v. infusion at a dose of 5 mg/kg BAN2401.

Table 8. Plasma PK parameters of BAN2401, A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8 in cynomolgus monkeys. Terminal half-life and $AUC_{0\text{-}inf}$ for all antibodies were calculated by non-compartment analysis using Phoenix WinNonlin 6.3 (Pharsight). PK parameters from BAN2401 shown here is from a separate study in which BAN2401 was administered by i.v. infusion at a dose of 5 mg/kg BAN2401. To simplify AUC comparisons between BAN2401 and the antibodies of the invention dose adjusted mean $AUC_{0\text{-}inf}$ and mean terminal half-life values are shown in the table.

Antibody	**Dose corrected $AUC_{0\text{-}inf}$ (mg*h/ml) per (mg/kg)**	**Terminal half-life (days)**
BAN2401	5.3	12.0
A17D/R79T_DI 3	6.1	12.0
A17D/R79T_DI 4	6.5	12.6
A17D/R79T_DI 8	7.1	17.2

Example 10. Simple allometric scaling - mouse, rat and monkey to man

In order to predict human half-life of the antibodies of the invention (here shown for A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8), 2-comparmental modeling and simple allometric scaling were performed. A 2-compartmental model was applied to plasma PK profiles of BAN2401 and the antibodies of the invention using Phoenix WinNonlin 6.3 (Pharsight), in order to estimate clearance (CL) and volume (V) values in mouse rat and monkey. CL and V values were plotted versus body weight and simple allometric scaling was applied (Deng *et al. mAbs* 2011: 3(1): p. 61-66. doi:10.4161/mabs.3.1.13799). Terminal half-life was calculated following the equation:

$$t_{1/2} = \frac{\ln(2) * Volume}{Clearance}$$

In simple allometric scaling of volume or clearance, the values of the estimated parameters in preclinical species are plotted versus body weight. The constant and the exponent from the regression line are used to predict V and CL in man at a body weight of 70 kg. Both the exponent (which should preferably be around 0.85 for clearance and 1 for volume) and the adherence to the regression line are measures of confidence of the estimate of the specific parameters in man.

As shown in Figure 11, BAN2401 has a poor linear correlation of central CL among the species tested, resulting in uncertain simple allometric scaling. The deviation from the exponent (which should be close to 0.85) suggests that the poor correlation is an effect of the high clearance of BAN2401 in mice. This led to an underestimation of the expected CL in man and hence an overestimation of the predicted terminal half-life. The terminal half-life of BAN2401 was estimated to 41 days, which deviated considerably from the half-life measured in the clinic (5-7 days). The actual CL of BAN2401 has been indicated in Figure 11 (open square). In contrast to the poor linear correlation between mouse, rat and cynomolgus for BAN2401, the antibodies of the invention (A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8) showed an excellent correlation (Figure 11). The calculated terminal half-life from the predicted PK parameters in man suggested half-life in humans of 13, 15 and 20 days for A17D/R79T_DI 3, A17D/R79T_DI 4 and A17D/R79T_DI 8, respectively. Simple allometric scaling of volume (V) suggested good linear correlation and an exponent of approximately 1 for BAN2401 and the antibodies of the invention (not shown).

The antibodies of the invention show a linear correlation of CL among species with a more confident allometric scaling, and they behave like other therapeutic IgG1s, such as bevacizumab, omalizumab and trastuzumab, as described in Deng et al, Expert Opin. Drug Metab. Toxicol 8(2) (2012): p. 141-160., with half-lives in man of about 15-30 days. In contrast to BAN2401, with a suboptimal PK profile in mouse and man deviating from many other therapeutic IgG1s, the antibodies of the present invention have been engineered resulting in normalized PK profiles in mouse. They show PK profiles and half-lives in mouse, rat and cynomolgus similar to other therapeutic IgG1s with half-lives in man of about 15-30 days. This finding would suggest that the prolonged half-life of the antibodies of the invention in mice will translate to man.