HUMAN CYTOMEGALOVIRUS NEUTRALIZING ANTIBODIES AND USE THEREOF

This application claims the benefit of priority of United States provisional Application No. 61/081,334, filed July 16, 2008, the disclosures of which is hereby incorporated by reference as if written herein in its entirety.

BACKGROUND

Human cytomegalovirus (hCMV) is a widely distributed pathogen that may cause severe pathology in immunosuppressed adults and upon infection of the fetus and has been implicated in chronic diseases such as atherosclerosis. hCMV infects multiple cell types including fibroblasts, endothelial, epithelial and hematopoietic cells [1]. *In vitro* propagated attenuated strains of hCMV, which are being developed as candidate vaccines, have lost the tropism for endothelial cells, while retaining the capacity to infect fibroblasts [2]. Two viral glycoprotein complexes are believed to control the cellular tropism of hCMV. A complex of glycoproteins such as gH, gL and gO appears to be required for infection of fibroblasts, while a complex of gH, gL and proteins encoded by the UL131-UL128 genes is implicated in infection of endothelial cells, epithelial cells and dendritic cells [2-8].

Hyperimmune globulins are already commercialized for the prophylaxis of hCMV disease associated with transplantation and recent evidence indicates that they have therapeutic effect in pregnant women [9]. This therapeutic approach is limited by the low amount of neutralizing antibody that can be transferred and for this reason the availability of human antibodies (such as human monoclonal antibodies) with high neutralizing capacity would be highly desirable. Although some antibodies to gH, gB and UL128 and UL130 gene products have demonstrated *in vitro* neutralizing activities [7, 10, 11] and an antibody to gH was evaluated in clinical trials (that were discontinued due to lack of therapeutic effects), the neutralizing potency of the antibodies isolated so far is modest. Neutralization by these antibodies was observed at antibody concentrations ranging from 0.5 to 20 μg/ml. Further, the current methods typically measure the neutralizing potency of anti-hCMV antibodies using fibroblasts as target cells. However, hCMV is also known to cause pathology by infecting other cell types such as endothelial, epithelial cells and leukocytes. Known antibodies to UL128 and UL130 show very low potency in neutralizing infection of endothelial cells [7] and there do not appear to be any monoclonal antibodies available that would be capable of neutralizing infection of non-fibroblast target cells with high potency.

There is therefore a need for antibodies that neutralize hCMV infection, particularly hCMV infection of non-fibroblast target cells, with high potency, as well as the elucidation of the target(s) to which such antibodies bind.

SUMMARY OF INVENTION

The invention is based, in part, on the discovery of novel antibodies that neutralize hCMV infection with high potency as well as novel epitopes to which the antibodies of the invention bind. Accordingly, in one aspect, the invention comprises an antibody and antigen binding fragments thereof that have high potency in neutralizing hCMV.

In one embodiment of the invention, the invention comprises a monoclonal antibody, or an antigen binding fragment thereof, that binds to an epitope in the hCMV UL128 protein, wherein the antibody neutralizes hCMV infection. In another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, that binds to an epitope formed by the hCMV proteins gH, gL, UL128 and UL130, the hCMV proteins UL128, UL130 and UL131A, or the hCMV proteins UL130 and UL131A, wherein the antibody neutralizes hCMV infection.

In yet another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, comprising at least one complementarity determining region ("CDR") sequence having at least 95% sequence identity to any one of SEQ ID NOs: 188-193, 204, 205, 210, 174-177, 149, 178, 65-70, 81-86, 97-102, 129-134, 145-150, 113, 161-164, 1-6, 17-22, 33-38, 49-54, or 114-118, wherein the antibody neutralizes hCMV infection.

In yet another embodiment of the invention, the invention comprises a heavy chain CDR1 selected from the group consisting of SEQ ID NOs: 188, 174, 65, 81, 97, 129, 145, 113, 1, 17, 33, and 49; a heavy chain CDR2 selected from the group consisting of SEQ ID NOs: 189, 204, 175, 66, 82, 98, 130, 146, 161, 2, 2, 18, 34, 50, and 114; and a heavy chain CDR3 selected from the group consisting of SEQ ID NOs: 190, 205, 210, 176, 67, 83, 99, 131, 147, 162, 3, 19, 35, 51, and 115, wherein the antibody neutralizes hCMV infection. In yet another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, comprising a light chain CDR1 selected from the group consisting of SEQ ID NOs: 191, 177, 68, 84, 100, 132, 148, 163, 4, 20, 36, 52, and 116; a light chain CDR2 selected from the group consisting of SEQ ID NOs: 192, 149, 69, 85, 101, 133, 5, 21, 37, 53, and 117; and a light chain CDR3 selected from the group consisting of SEQ ID NOs: 193, 178, 70, 86, 102, 134,150, 164, 6, 22, 38, 54, and 118, wherein the antibody neutralizes hCMV infection.

In still another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, wherein the antibody comprises a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 200 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 201; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 200 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 213; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 208 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 201; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 208 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 213; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 212 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 201; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 212 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 213; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 184 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 185; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 77 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 78; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 93 and a light chain variable region comprising the amino acid

sequence of SEQ ID NO: 94; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 109 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 110; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 141 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 142; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 157 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 158; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 170 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 171; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 13 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 14; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 29 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 30; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 45 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 46; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 61 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 62; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 125 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 126, and wherein the antibody neutralizes hCMV infection.

In a further embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, that neutralizes infection of endothelial cells, epithelial cells, retinal cells, myeloid cells, dendritic cells, fibroblasts, or mesenchymal stromal cells by a clinical isolate of hCMV, wherein the concentration of antibody required for 90% neutralisation of hCMV is 1.2 μg/ml or less. In another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, that neutralizes infection of endothelial cells, epithelial cells, retinal cells, myeloid cells, dendritic cells, fibroblasts, or mesenchymal stromal cells by a clinical isolate of hCMV, wherein the concentration of antibody required for 90% neutralisation of hCMV is 10 μg/ml or less, and wherein the antibody is not MSL-109 or 8F9.

In yet another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, comprising at least one CDR sequence having at least 95% sequence identity to any one of SEQ ID NOs: 216-221, 232-235, 149, 236, 246-251, 278-283, 296-301, 312, 316-321, 332, 336-341, 352, 360, 361 or 262-267, wherein the antibody neutralizes hCMV infection.

In yet another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, comprising a heavy chain CDR1 selected from the group consisting of SEQ ID NOs: 216, 232, 246, 278, 296, 316, 336, 352, 360 and 262; a heavy chain CDR2 selected from the group consisting of SEQ ID NOs: 217, 233, 247, 279, 297, 312, 317, 337 and 263; and a heavy chain CDR3 selected from the group consisting of SEQ ID NOs: 218, 234, 248, 280, 298, 318, 332, 338, and 264, wherein the antibody neutralizes hCMV infection.

In yet another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, comprising a light chain CDR1 selected from the group consisting of SEQ ID NOs: 219, 235, 249, 281, 299, 319, 339 and 265; a light chain CDR2 selected from the

group consisting of SEQ ID NOs: 220, 149, 250, 282, 300, 320, 340 and 266; and a light chain CDR3 selected from the group consisting of SEQ ID NOs: 221, 236, 251, 283, 301, 321, 341, 361 and 267, wherein the antibody neutralizes hCMV infection.

In still another embodiment of the invention, the invention comprises an antibody, or an antigen binding fragment thereof, wherein the antibody comprises a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 228 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 229; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 242 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 243; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 258 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 259; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 290, and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 291; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 294, and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 291; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 308, and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 309; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 314, and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 309; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 328, and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 329; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 334, and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 329; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 348 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 349; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 357 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 291; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 367 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 368; or a heavy chain variable region comprising the amino acid sequence of SEQ ID NO: 274 and a light chain variable region comprising the amino acid sequence of SEQ ID NO: 275, and wherein the antibody neutralizes hCMV infection.

The invention further comprises an antibody, or an antigen binding fragment thereof, produced by immortalised B cell clone 8I21, 2C12, 8C15, 4N10, 11B12, 3G16, 4H9, 6B4, 10C6, or 6L3 deposited with the Advanced Biotechnology Center (ABC), Largo Rossana Benzi 10, 16132 Genoa (Italy), under the terms of the Budapest Treaty, on July 9, 2008 (under Accession Numbers PD 08005, PD 08007, PD 08006, PD 08009, PD 08011, PD 08012, PD 08013, PD 08004, PD 08014, and PD 08010, respectively) and by immortalized B cell clone 7H3 deposited on July 16, 2008 under Accession Number PD 08017. Antibodies and antigen binding fragments thereof, with the same amino acid sequence as those expressed from the aforementioned deposited immortalised B cells are also considered to be within the scope of the invention.

In another aspect, the invention comprises a nucleic acid molecule comprising a polynucleotide encoding an antibody or antibody fragment of the invention that neutralizes hCMV infection. In yet another aspect, the invention comprises a cell expressing an antibody of the invention. In still another aspect, the invention comprises an isolated or purified immunogenic polypeptide comprising an epitope that binds to an antibody of the invention.

The invention further comprises a pharmaceutical composition comprising an antibody of the invention or an antigen binding fragment thereof, a nucleic acid molecule of the invention, or an immunogenic polypeptide of the invention, and a pharmaceutically acceptable diluent or carrier. The invention also comprises a pharmaceutical composition comprising a first antibody or an antigen binding fragment thereof, and a second antibody, or an antigen binding fragment thereof, wherein the first antibody is an antibody of the invention, and the second antibody is an antibody that neutralizes hCMV infection.

Use of an antibody of the invention, or an antigen binding fragment thereof, a nucleic acid of the invention, an immunogenic polypeptide of the invention, or a pharmaceutical composition of the invention (i) in the manufacture of a medicament for the treatment of hCMV infection, (ii) in a vaccine, or (iii) in diagnosis of hCMV infection is also contemplated to be within the scope of the invention. Further, use of an antibody of the invention, or an antigen binding fragment thereof, for monitoring the quality of anti-hCMV vaccines by checking that the antigen of said vaccine contains the specific epitope in the correct conformation is also contemplated to be within the scope of the invention.

In a further aspect, the invention comprises an epitope which specifically binds to an antibody of any one of the invention, or an antigen binding fragment thereof, for use (i) in therapy, (ii) in the manufacture of a medicament for treating hCMV infection, (iii) as a vaccine, or (iv) in screening for ligands able to neutralise hCMV infection.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows staining of HEK293T cells transfected with hCMV UL128, UL130, UL131A, gH and gL genes, alone or in different combinations, by representative monoclonal antibodies (15D8, 2C12 and 8I21).

Figure 2 shows cross-competition experiments in which HEK293T cells transfected with hCMV gH (A) or gB (B) gene were first incubated with an unlabeled competitor antibody followed by staining with a biotinylated anti-gH or anti-gB antibody.

Figure 3 shows staining of HEK293T cells expressing either the wild type VR1814 UL128 gene or a pan-mutated UL128 gene by human monoclonal antibody 15D8 and a non-competing anti-UL128 mouse monoclonal antibody. The pan-mutated UL128 gene contains substitutions of the wild type VR1814 sequence with known variants described in other clinical isolates and laboratory strains of hCMV.

DETAILED DESCRIPTION OF THE INVENTION

The invention is based, in part, on the discovery of novel antibodies that neutralize hCMV infection with high potency as well as novel epitopes to which the antibodies of the invention bind. Such antibodies are desirable, as only low concentrations are required in order to neutralize a given

amount of virus. This facilitates higher levels of protection whilst administering lower amounts of antibody. Accordingly, in one aspect, the invention comprises a neutralizing antibody and antigen binding fragments thereof having high potency in neutralizing hCMV infection. Human monoclonal antibodies and the immortalised B cell clones that secrete such antibodies are also included within the scope of the invention.

As used herein, the terms "fragment," "antigen binding fragment" and "antibody fragment" are used interchangeably to refer to any fragment of an antibody of the invention that retains the antigen-binding activity of the antibodies. Exemplary antibody fragments include, but are not limited to, a single chain antibody, Fab, Fab', F(ab')2, Fv or scFv.

As used herein, the term "high potency" is used to refer to an antibody of the invention or an antigen binding fragment thereof that neutralizes hCMV infection with an IC_{90} of less than about 2 μg/ml, (*i.e.* the concentration of antibody required for 90% neutralisation of a clinical isolate of hCMV is about 2μg/ml or less, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, or 1.05 μg/ml or less). In one embodiment, the antibody of the present invention, or antigen binding fragment thereof, has an IC_{90} of 1 μg/ml or less (*i.e.* 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.05, 0.01 μg/ml or less). In another embodiment, the antibody of the present invention, or antigen binding fragment thereof, has an IC_{90} of 0.16 μg/ml or less (*i.e.* 0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 μg/ml or less). In another embodiment, the antibody can neutralize hCMV infection at a concentration of 0.016 μg/ml or less (*i.e.* at 0.015, 0.013, 0.01, 0.008, 0.005, 0.003, 0.002, 0.001, 0.0005μg/ml or less). This means that only very low concentrations of antibody are required for 90% neutralisation of a clinical isolate of hCMV *in vitro* compared to the concentration of known antibodies, *e.g.*, MSL-109, 8F9 or 3E3, required for neutralisation of the same titre of hCMV. Potency can be measured using a standard neutralisation assay as known to one of skill in the art.

In one embodiment, the invention provides an antibody, for example, a monoclonal antibody or a human monoclonal antibody, or an antigen binding fragment thereof, that binds to an epitope in the hCMV UL128 protein and neutralizes hCMV infection with an IC_{90} of less than about 2 μg/ml, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, 1.05, 1, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 0.001, 0.0005μg/ml or less.

In another embodiment, the invention provides an antibody, or an antigen binding fragment thereof, that binds to an epitope formed by the hCMV proteins gH, gL, UL128 and UL130, and neutralizes hCMV infection with an IC_{90} of less than about 2 μg/ml, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, 1.05, 1, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 0.001, 0.0005μg/ml or less.

In another embodiment, the invention provides an antibody, or an antigen binding fragment thereof, that binds to an epitope formed by the hCMV proteins UL128, UL130, and UL131A, and neutralizes hCMV infection with an IC_{90} of less than about 2 μg/ml, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, 1.05, 1, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2,

0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 0.001, 0.0005μg/ml or less.

In another embodiment, the invention provides an antibody, or an antigen binding fragment thereof, that binds to an epitope formed by the hCMV proteins UL130 and UL131A, and neutralizes hCMV infection with an IC_{90} of less than about 2μg/ml, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, 1.05, 1, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 0.001, 0.0005μg/ml or less.

In yet another embodiment, the invention provides an antibody, or an antigen binding fragment thereof, that binds to an epitope in the hCMV gH protein and neutralizes hCMV infection with an IC_{90} of less than about 2 μg/ml, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, 1.05, 1, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 0.001, 0.0005μg/ml or less.

In yet another embodiment, the invention provides an antibody, or an antigen binding fragment thereof, that binds to an epitope in the hCMV gB protein and neutralizes hCMV infection with an IC_{90} of less than about 2μg/ml, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, 1.05, 1, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 0.001, 0.0005μg/ml or less.

In another embodiment, the invention provides an antibody, or an antigen binding fragment thereof, that binds to an epitope formed by the hCMV proteins gM and gN and neutralizes hCMV infection with an IC_{90} of less than about 2μg/ml, for example 1.9, 1.8, 1.75, 1.7, 1.6, 1.5, 1.4, 1.3, 1.25, 1.2, 1.15, 1.1, 1.05, 1, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.125, 0.1, 0.075, 0.05, 0.025, 0.02, 0.015, 0.0125, 0.01, 0.0075, 0.005, 0.004, 0.003, 0.002 0.001, 0.0005μg/ml or less.

Antibodies of the invention

The invention provides antibodies having particularly high potency in neutralizing hCMV. As used herein, an "antibody that neutralizes" is one that prevents, reduces, delays or interferes with the ability of a pathogen, *e.g.*, hCMV, to initiate and/or perpetuate an infection in a host. The antibodies of the invention and antigen-binding fragments thereof are able to neutralize hCMV infection of several kinds of cells. In one embodiment, an antibody according to the invention neutralizes infection of epithelial cells, retinal cells, endothelial cells, myeloid cells and dendritic cells. The antibodies of the invention may also neutralize hCMV infection of fibroblasts and mesenchymal stromal cells. These antibodies can be used as prophylactic or therapeutic agents upon appropriate formulation, or as a diagnostic tool, as described herein.

The antibodies of the invention may be monoclonal antibodies, human antibodies, or recombinant antibodies. In one embodiment, the antibodies of the invention are monoclonal antibodies, *e.g.*, human monoclonal antibodies. The invention also provides fragments of the antibodies of the invention, particularly fragments that retain the antigen-binding activity of the antibodies and neutralize hCMV infection. Although the specification, including the claims, may, in some places, refer explicitly to antibody fragment(s), variant(s) and/or derivative(s) of antibodies, it

is understood that the term "antibody" or "antibody of the invention" includes all categories of antibodies, namely, antibody fragment(s), variant(s) and derivative(s) of antibodies.

In one embodiment, the antibodies of the invention and antigen binding fragments thereof bind to one or more hCMV proteins. The antibodies of the invention may bind to an epitope formed by a single hCMV protein or by a combination of two or more hCMV proteins. Exemplary hCMV proteins include, but are not limited to, products of viral genes UL55 (envelope glycoprotein B, "gB"), UL75 (envelope glycoprotein H, "gH"), UL100 (glycoprotein M, "gM"), UL73 (glycoprotein N, "gN"), UL115 (glycoprotein L, "gL"), UL74 (glycoprotein O, "gO"), UL128 (glycoprotein UL128, "UL128"), UL130 (glycoprotein UL130, "UL130") or UL131A (glycoprotein UL131A, "UL131A"). In one embodiment, the antibodies of the invention bind to an epitope formed by a single hCMV protein. In another embodiment, the antibodies bind to an epitope formed by the combination of 2, 3, or more hCMV proteins.

In an exemplary embodiment, the invention comprises an antibody, or an antibody fragment thereof, that binds to an epitope in the hCMV protein UL128, or to an epitope formed by the hCMV proteins UL130 and UL131A, or to an epitope formed by the hCMV proteins UL128, UL130 and UL131A, or to an epitope formed by the hCMV proteins gH, gL, UL128, and UL130, or to an epitope in the hCMV protein gH, or the hCMV protein gB or to an epitope formed by the hCMV proteins gM and gN.

In one embodiment, the invention comprises an antibody, or an antibody fragment thereof, that binds to an epitope in UL128. In another embodiment, the invention comprises an antibody, or an antibody fragment thereof, that binds to an epitope formed by UL130 and UL131A. As used herein, an epitope formed by UL130 and UL131A means that the epitope may be formed by both UL130 and UL131A protein or may be formed by one of the two proteins, the presence of the other protein being necessary for antibody binding. In yet another embodiment, the invention comprises an antibody, or an antibody fragment thereof, that binds to an epitope formed by UL128, UL130 and UL131A. As used herein, an epitope formed by UL128, UL130 and UL131A means that the epitope may be formed by all three proteins (UL128, UL130 and UL131A) or may be formed by one or more protein(s), the presence of the other protein(s) being necessary for antibody binding. In still another embodiment, the invention comprises an antibody, or an antibody fragment thereof, that binds to an epitope formed by gH, gL, UL128, and UL130. As used herein, an epitope formed by gH, gL, UL128, and UL130 means that the epitope may be formed by all four proteins (gH, gL, UL128, and UL130) or may be formed by one or more of the four protein(s), the presence of the other protein(s) being necessary for antibody binding. In another embodiment, the invention comprises an antibody, or an antibody fragment thereof, that binds to an epitope formed by gM and gN. As used herein, an epitope formed by gM and gN means that the epitope may be formed by both gM and gN or may be formed by one of the two proteins, the presence of the other protein being necessary for antibody binding.

The sequences of the heavy chains and light chains of several exemplary antibodies of the invention, each comprising three CDRs on the heavy chain and three CDRs on the light chain have been determined. The position of the CDR amino acids are defined according to the IMGT numbering system [12, 13, 14]. The sequences of the CDRs, heavy chains, light chains as well as the

sequences of the nucleic acid molecules encoding the CDRs, heavy chains, light chains are disclosed in the sequence listing. Table 1 provides the SEQ ID NOs. for the sequences of the six CDRs of the exemplary antibodies of the invention. Tables 2 and 3 provide the SEQ ID NOs for the sequences of the heavy and light chains, respectively, of the exemplary antibodies of the invention, and Table 4 provides the SEQ ID NOs for the sequences of the nucleic acid molecules encoding the CDRs, heavy chains and light chains of the antibodies.

Table 1.

Antibody	SEQ ID NOs. for CDRH1, CDRH3, CDRH3	SEQ ID NOs. for CDRL1, CDRL2, CDRL3
15D8	188, 189, 190	191, 192, 193
15D8 variant 1	188, 204, 205	191, 192, 193
15D8 variant 2	188, 189, 210	191, 192, 193
4N10	1, 2, 3	4, 5, 6
10F7	17, 18, 19	20, 21, 22
10P3	33, 34, 35	36, 37, 38
4I22	49, 50, 51	52, 53, 54
8L13	113, 114, 115	116, 117, 118
2C12	65, 66, 67	68, 69, 70
8C15	81, 82, 83	84, 85, 86
9I6	97, 98, 99	100, 101, 102
7B13	129, 130, 131	132, 133, 134
8J16	145, 146, 147	148, 149, 150
8I21	174, 175, 176	177, 149, 178
7I13	113, 161, 162	163, 149, 164
7H3	316, 317, 318	319, 320, 321
7H3 variant 1	316, 317, 332	319, 320, 321
6B4	336, 337, 338	339, 340, 341
5F1	278, 279, 280	281, 282, 283
10C6	352, 279, 280	281, 282, 283
4H9	296, 297, 298	299, 300, 301
4H9 variant 1	296, 312, 298	299, 300, 301
11B12	232, 233, 234	235, 149, 236
13H11	216, 217, 218	219, 220, 221
3G16	246, 247, 248	249, 250, 251
2B11	360, 279, 280	281, 282, 361
6L3	262, 263, 264	265, 266, 267

Table 2.

Antibody	SEQ ID NOs for Heavy Chains
15D8	200
15D8 variant 1	208
15D8 variant 2	212
4N10	13
10F7	29
10P3	45
4I22	61
8L13	125
2C12	77
8C15	93
9I6	109
7B13	141
8J16	157
8I21	184
7I13	170

7H3	328
7H3 variant 1	334
6B4	348
5F1	290
5F1 variant 1	294
10C6	357
4H9	308
4H9 variant 1	314
11B12	242
13H11	228
3G16	258
2B11	367
6L3	274

Table 3.

Antibody	SEQ ID NO for Light Chains
15D8	201
15D8 variant 1	201
15D8 variant 2	213
4N10	14
10F7	30
10P3	46
4I22	62
8L13	126
2C12	78
8C15	94
9I6	110
7B13	142
8J16	158
8I21	185
7I13	171
7H3	329
7H3 variant 1	329
6B4	349
5F1	291
5F1 variant 1	291
10C6	291
4H9	309
4H9 variant 1	309
11B12	243
13H11	229
3G16	259
2B11	368
6L3	275

Table 4.

Antibody	SEQ ID NO for Nucleic Acids encoding CDRs, Heavy Chains, Light Chains and Variants (CDRH1, CDRH2, CDRH3, CDRL1, CDRL2, CDRL3 and variants; Heavy Chain and variants; and Light Chains and variants)
15D8	194-199 and 206, 207, 211; 202 and 209, 214; 203 and 215
4N10	7-12; 15; 16
10F7	23-28; 31; 32
10P3	39-44; 47; 48
4I22	55-60; 63; 64
8L13	119-124; 127; 128

2C12	71-76; 79; 80
8C15	87-92; 95; 96
9I6	103-108, 111, 112
7B13	135-140; 143; 144
8J16	151-156; 159; 160
8I21	179-182,155,183; 186; 187
7I13	165, 166, 167, 168, 155, 169; 172; 173
7H3	322-327 and 333; 330 and 335; 331
6B4	342-347; 350; 351
5F1	284-289; 292 and 295; 293
10C6	353-355, 287, 288, 356; 358; 359
4H9	302-307 and 313; 310 and 315; 311
11B12	237-240, 155, 241; 244; 245
13H11	222-227; 230; 231
3G16	252-257; 260; 261
2B11	362-364; 287,365,366; 369; 370
6L3	268-273; 276; 277

In one embodiment, the antibodies or antibody fragments of the invention comprise one or more heavy or light chain CDRs of the exemplary antibodies of the invention. In an exemplary embodiment, the antibodies or antibody fragments of the invention comprise an amino acid sequence selected from the group consisting of SEQ ID NOs: 188-193, 204-205, 210, 1-6, 17-22, 33-38, 49-54, 113-118, 65-70, 81-86, 97-102, 129-134, 145-150, 174-178, and 161-164.

In another embodiment, the antibodies of the invention comprise a heavy chain comprising an amino acid sequence of one or more of SEQ ID NOs: 188-190, 204, 205, 210, 1-3, 17-19, 33-35, 49-51, 113-115, 65-67, 81-83, 97-99, 129-131, 145-147, 174-176, 161 or 162. For example, the antibodies of the invention comprise a heavy chain comprising SEQ ID NO: 188 for CDRH1, SEQ ID NO: 189 for CDRH2, SEQ ID NO: 190 for CDRH3; SEQ ID NO: 188 for CDRH1, SEQ ID NO; 204 for CDRH2, SEQ ID NO: 205 for CDRH3; SEQ ID NO; 188 for CDRH1, SEQ ID NO: 189 for CDRH2, SEQ ID NO: 210 for CDRH3; SEQ ID NO: 1 for CDRH1, SEQ ID NO: 2 for CDRH2, SEQ ID NO: 3 for CDRH3; SEQ ID NO; 17 for CDRH1, SEQ ID NO; 18 for CDRH2, SEQ ID NO: 19 for CDRH3; SEQ ID NO: 33 for CDRH1, SEQ ID NO: 34 for CDRH2, SEQ ID NO: 35 for CDRH3; SEQ ID NO 49 for CHRH1, SEQ ID NO: 50 for CHRH2, SEQ ID NO: 51 for CDRH3; SEQ ID NO: 113 for CDRH1, SEQ ID NO: 114 for CDRH2, SEQ ID NO: 115 for CDRH3; SEQ ID NO: 65 for CDRH1, SEQ ID NO: 66 for CDRH2, SEQ ID NO: 67 for CDRH3; SEQ ID NO: 81 for CDRH1, SEQ ID NO 82 for CDRH2, SEQ ID NO: 83 for CDRH3; SEQ ID NO: 97 for CDRH1, SEQ ID NO: 98 for CDRH2, SEQ ID NO: 99 for CDRH3; SEQ ID NO: 129 for CDRH1, SEQ ID NO: 130 for CDRH2, SEQ ID NO: 131 for CDRH3; SEQ ID NO: 145 for CDRH1, SEQ ID NO: 146 for CDRH2, SEQ ID NO: 147 for CDRH3; SEQ ID NO: 174 for CDRH1, SEQ ID NO: 175 for CDRH2, SEQ ID NO: 176 for CDRH3; and SEQ ID NO: 113 for CDRH1, SEQ ID NO: 161 for CDRH2, SEQ ID NO: 162 for CDRH3.

In yet another embodiment, the antibodies of the invention comprise a light chain comprising an amino acid sequence of one or more of SEQ ID NOs: 191-193, 4-6, 20-22, 36-38, 52-54, 116-118, 68-70, 84-86, 100-102, 132-134, 148-150, 177, 178, 163, or 164. For example, the antibodies of the invention comprise a light chain comprising SEQ ID NO: 191 for CDRL1, SEQ ID NO: 192 for CDRL2; SEQ ID NO: 193 for CDRL3; SEQ ID NO: 4 for CDRL1, SEQ ID NO: 5 for CDRL2

and SEQ ID NO: 6 for CDRL3; SEQ ID NO: 20 for CDRL1, SEQ ID NO: 21 for CDRL2, SEQ ID NO: 22 for CDRL3; SEQ ID NO; 36 for CDRL1, SEQ ID NO: 37 for CDRL2, SEQ ID NO: 38 for CDRL3; SEQ ID NO: 52 for CDRL1, SEQ ID NO: 53 for CDRL2, SEQ ID NO: 54 for CDRL3; SEQ ID NO: 116 for CDRL1, SEQ ID NO: 117 for CDRL2, SEQ ID NO: 118 for CDRL3; SEQ ID NO: 68 for CDRL1, SEQ ID NO: 69 for CDRL2, SEQ ID NO: 70 for CDRL3; SEQ ID NO 84 for CDRL1, SEQ ID NO: 85 for CDRL2, SEQ ID NO: 86 for CDRL3; SEQ ID NO: 100 for CDRL1, SEQ ID NO: 101 for CDRL2, SEQ ID NO: 102 for CDRL3; SEQ ID NO: 132 for CDRL1, SEQ ID NO: 133 for CDRL2, SEQ ID NO: 134 for CDRL3; SEQ ID NO: 148 for CDRL1, SEQ ID NO: 149 for CDRL2, SEQ ID NO: 150 for CDRL3; SEQ ID NO: 177 for CDRL1, SEQ ID NO: 149 for CDRL2, SEQ ID NO: 178 for CDRL3; SEQ ID NO: 163 for CDRL1, SEQ ID NO: 149 for CDRL2 and SEQ ID NO: 164 for CDRL3.

In still another embodiment, the antibodies of the invention comprise a heavy chain with an amino acid sequence that is at least 70% identical to those of SEQ ID NOs: 200, 208, 212, 13, 29, 45, 61, 125, 77, 93, 109, 141, 157, 184, or 170, and neutralize hCMV infection. In one embodiment, the antibody binds to an epitope in the hCMV UL128 protein and comprises a heavy chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 200, 208 or 212, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a heavy chain having the sequence recited in SEQ ID NO: 200, 208 or 212, and neutralizes hCMV infection.

In another embodiment, the antibody binds to an epitope formed by the hCMV proteins UL130 and UL131A and comprises a heavy chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 13, 29, 45, 61 or 125, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a heavy chain having the sequence recited in SEQ ID NO: 13, 29, 45, 61 or 125, and neutralizes hCMV infection.

In yet another embodiment, the antibody binds to an epitope formed by the hCMV proteins UL128, UL130 and UL131A and comprises a heavy chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 77, 93, 109, 141, 157, or 170, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a heavy chain having the sequence recited in SEQ ID NO: 77, 93, 109, 141, 157, or 170, and neutralizes hCMV infection.

In a further embodiment, the antibody binds to an epitope formed by the hCMV proteins gH, gL, UL128 and UL130 and comprises a heavy chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 184, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a heavy chain having the sequence recited in SEQ ID NO: 184, and neutralizes hCMV infection.

In yet another embodiment, the antibodies of the invention comprise a light chain with an amino acid sequence that is at least 70% identical to those of SEQ ID NOs: 201, 213, 14, 30, 46, 62, 126, 78, 94, 110, 142, 158, 185, or 171, and neutralize hCMV infection.

In one embodiment, the antibody binds to an epitope in the hCMV UL128 protein and comprises a light chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 201or 213, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a light chain having the sequence recited in SEQ ID NO: 201 or 213, and neutralizes hCMV infection.

In one embodiment, the antibody binds to an epitope formed by the hCMV proteins UL130 and UL131A and comprises a light chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 14, 30, 46, 62 or 126, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a light chain having the sequence recited in SEQ ID NO: 14, 30, 46, 62 or 126, and neutralizes hCMV infection.

In another embodiment, the antibody binds to an epitope formed by the hCMV proteins UL128, UL130 and UL131A and comprises a light chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 78, 94, 110, 142, 158, or 171, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a light chain having the sequence recited in SEQ ID NO: 78, 94, 110, 142, 158, or 171, and neutralizes hCMV infection.

In a further embodiment, the antibody binds to an epitope formed by the hCMV proteins gH, gL, UL128 and UL130 and comprises a light chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 185, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a light chain having the sequence recited in SEQ ID NO: 185, and neutralizes hCMV infection.

In another embodiment, the antibodies or antibody fragments of the invention comprise one or more heavy or light chain CDRs of the exemplary antibodies of the invention. In an exemplary embodiment, the antibodies or antibody fragments of the invention comprise an amino acid sequence selected from the group consisting of SEQ ID NOs: 316-321, 332, 336-341, 278-283, 352, 296-301, 312, 232-236, 149, 216-221, 246-251, 360, 361 and 262-267, and neutralize hCMV infection.

In yet another embodiment, the antibodies of the invention comprise a heavy chain comprising an amino acid sequence of one or more of SEQ ID NOs: 316-318, 332, 336-338, 278-280, 352, 296-298, 312, 232-234, 216-218, 246-248, 360, 361 and 262-264. For example, the antibodies of the invention comprise a heavy chain comprising SEQ ID NO: 316 for CDRH1, SEQ ID NO: 317 for CDRH2, SEQ ID NO: 318 for CDRH3; SEQ ID NO: 316 for CDRH1, SEQ ID NO: 317 for CDRH2, and SEQ ID NO: 332 for CDRH3; SEQ ID NO: 336 for CDRH1, SEQ ID NO: 337 for CDRH2, SEQ ID NO: 338 for CDRH3; SEQ ID NO: 278 for CDRH1, SEQ ID NO: 279 for

CDRH2, SEQ ID NO: 280 for CDRH3; SEQ ID NO: 352 for CDRH1, SEQ ID NO: 279 for CDRH2, SEQ ID NO: 280 for CDRH3; SEQ ID NO: 296 for CDRH1, SEQ ID NO: 297 for CDRH2, SEQ ID NO: 298 for CDRH3; SEQ ID NO: 296 for CDRH1, SEQ ID NO: 312 for CDRH2, SEQ ID NO: 298 for CDRH3; SEQ ID NO: 232 for CDRH1, SEQ ID NO: 233 for CDRH2, SEQ ID NO: 234 for CDRH3; SEQ ID NO: 216 for CDRH1, SEQ ID NO: 217 for CDRH2, SEQ ID NO: 218 for CDRH3; SEQ ID NO: 246 for CDRH1, SEQ ID NO: 247 for CDRH2, SEQ ID NO: 248 for CDRH3; and SEQ ID NO: 360 for CDRH1, SEQ ID NO: 279 for CDRH2, SEQ ID NO: 280 for CDRH3; and SEQ ID NO: 262 for CDRH1, SEQ ID NO: 263 for CDRH2, SEQ ID NO: 264 for CDRH3.

In still another embodiment, the antibodies of the invention comprise a light chain comprising an amino acid sequence of one or more of SEQ ID NOs: 319-321, 339-341, 281-283, 299-301, 149, 235, 236, 219-221, 249-251, 265-267. For example, the antibodies of the invention comprise a light chain comprising SEQ ID NO: 319 for CDRL1, SEQ ID NO: 320 for CDRL2, SEQ ID NO: 321 for CDRL3; SEQ ID NO: 339 for CDRL1, SEQ ID NO: 340 for CDRL2, SEQ ID NO: 341 for CDRL3; SEQ ID NO: 281 for CDRL1, SEQ ID NO: 282 for CDRL2, SEQ ID NO: 283 for CDRL3; SEQ ID NO: 299 for CDRL1, SEQ ID NO: 300 for CDRL2, SEQ ID NO: 301 for CDRL3; SEQ ID NO: 235 for CDRL1, SEQ ID NO: 149 for CDRL2, SEQ ID NO: 236 for CDRL3; SEQ ID NO: 219 for CDRL1, SEQ ID NO: 220 for CDRL2, SEQ ID NO: 221 for CDRL3; SEQ ID NO: 249 for CDRL1, SEQ ID NO: 250 for CDRL2, SEQ ID NO: 251 for CDRL3; and SEQ ID NO: 281 for CDRL1, SEQ ID NO: 282 for CDRL2, SEQ ID NO: 361 for CDRL3; and SEQ ID NO: 265 for CDRL1, SEQ ID NO: 266 for CDRL2, SEQ ID NO: 267 for CDRL3.

In a further embodiment, the antibodies of the invention comprise a heavy chain with an amino acid sequence that is at least 70% identical to those of SEQ ID NOs: 328, 334, 348, 290, 294, 357, 308, 314, 242, 228, 258, 367 or 274, and neutralizes hCMV infection.

In one embodiment, the antibody binds to an epitope in the hCMV gB protein and comprises a heavy chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 328, 334, 348, 290, 294, 308, 357, 314 or 367, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a heavy chain having the sequence recited in SEQ ID NO: 328, 334, 348, 290, 294, 308, 357, 314 or 367 and neutralizes hCMV infection.

In another embodiment, the antibody binds to an epitope in the hCMV gH protein and comprises a heavy chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 242, 228, or 258, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a heavy chain having the sequence recited in SEQ ID NO: 242, 228, or 258, and neutralizes hCMV infection.

In another embodiment, the antibody binds to an epitope formed by the hCMV proteins gM and gN and comprises a heavy chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 274, and neutralizes hCMV infection. In one embodiment,

an antibody according to the invention comprises a heavy chain having the sequence recited in SEQ ID NO: 274, and neutralizes hCMV infection.

In yet another embodiment, the antibodies of the invention comprise a light chain with an amino acid sequence that is at least 70% identical to those of SEQ ID NOs: 329, 349, 291, 309, 243, 229, 259, 368 or 275, and neutralize hCMV infection.

In one embodiment, the antibody binds to an epitope in the hCMV gB protein and comprises a light chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 329, 349, 291, 309, or 368 and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a light chain having the sequence recited in SEQ ID NO: 329, 349, 291, 309 or 368, and neutralizes hCMV infection.

In another embodiment, the antibody binds to an epitope in the hCMV gH protein and comprises a light chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 243, 229, or 259, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a light chain having the sequence recited in SEQ ID NO: 243, 229, or 259, and neutralizes hCMV infection.

In another embodiment, the antibody binds to an epitope formed by the hCMV proteins gM and gN and comprises a light chain having an amino acid sequence that is at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 275, and neutralizes hCMV infection. In one embodiment, an antibody according to the invention comprises a light chain having the sequence recited in SEQ ID NO: 275, and neutralizes hCMV infection.

In one embodiment, the antibody of the invention is not MSL-109, 8F9, 3E3 or R551A. In another embodiment, the antibody of the invention is not 1F11, 2F4, 5A2 or 6G4, disclosed in U.S. Application Nos. 11/ 969,104 and 12/174,568.

Exemplary antibodies of the invention include, but are not limited to, 15D8, 4N10, 10F7, 10P3, 4I22, 8L13, 2C12, 8C15, 9I6, 7B13, 8J16, 8I21, 7I13, 7H3, 6B4, 5F1, 10C6, 4H9, 2B11, 11B12, 13H11, 3G16 and 6L3.

Variants of 15D8 that neutralize hCMV infection consist of a heavy chain variant having amino acid sequence recited in SEQ ID NO: 208 ("15D8 variant 1"), and SEQ ID NO: 212 ("15D8 variant 2"), and a light chain having the amino acid sequence recited in SEQ ID NO: 213 (15D8 variant 2). The nucleic acid sequences encoding the variant heavy chain variants are recited in SEQ ID NO: 209 (15D8 variant 1) and SEQ ID NO: 214 (15D8 variant 2). The nucleic acid encoding the variant light chain is recited in SEQ ID NO: 215 (15D8 variant 2). Thus, antibodies comprising the 15D8 variant heavy chains (SEQ ID NO: 208, 212) and variant light chain (SEQ ID NO: 213) that neutralize hCMV infection are included within the scope of the invention.

As used herein, the term "15D8" is used to refer to any and/or all variants of 15D8 that neutralize hCMV infection, for example, those with heavy chains corresponding to SEQ ID NO: 208 and 212 and light chains corresponding to SEQ ID NO; 213.

A variant of 7H3 that neutralizes hCMV infection consists of a heavy chain having the amino acid sequence recited in SEQ ID NO: 334 ("7H3 variant 1"). The nucleic acid sequence encoding the variant heavy chain is recited in SEQ ID NO: 335. Thus, antibodies comprising the 7H3 variant heavy chain (SEQ ID NO: 334) that neutralize hCMV infection are included within the scope of the invention.

As used herein, the term "7H3" is used to refer to any and/or all variants of 7H3 that neutralize hCMV infection, for example, those with heavy chains corresponding to SEQ ID NO:334.

A variant of 5F1 that neutralizes hCMV infection consists of a heavy chain having the amino acid sequence recited in SEQ ID NO: 294 ("5F1 variant 1"). The nucleic acid sequence encoding the variant heavy chain is recited in SEQ ID NO: 295. Thus, antibodies comprising the 5F1 variant heavy chain (SEQ ID NO: 294) that neutralize hCMV infection are included within the scope of the invention.

As used herein, the term "5F1" is used to refer to any and/or all variants of 5F1 that neutralize hCMV infection, for example, those with heavy chains corresponding to SEQ ID NO:294.

A variant of 4H9 that neutralizes hCMV infection consists of a heavy chain having the amino acid sequence recited in SEQ ID NO: 314 ("4H9 variant 1"). The nucleic acid sequence encoding the variant heavy chain is recited in SEQ ID NO: 315. Thus, antibodies comprising the 4H9 variant heavy chain (SEQ ID NO: 314), that neutralize hCMV infection are included within the scope of the invention.

As used herein, the term "4H9" is used to refer to any and/or all variants of 4H9 that neutralize hCMV infection, for example, those with heavy chains corresponding to SEQ ID NO:314.

In one embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 15D8 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 15D8 variant 1 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 15D8 variant 2 as listed in Table 1, and neutralizes hCMV infection in a human host. In yet another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 8I21 as listed in Table 1, and neutralizes hCMV infection in a human host.

In yet another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 4N10 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 10F7 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 10P3 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 4I22 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the

invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 8L13 as listed in Table 1, and neutralizes hCMV infection in a human host.

In yet another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 2C12 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 8C15 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 9I6 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 7B13 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 8J16 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 7I13 as listed in Table 1, and neutralizes hCMV infection in a human host.

In yet another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 7H3 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 7H3 variant 1 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 6B4 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 5F1 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 10C6 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 4H9 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 4H9 variant 1 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 2B11 as listed in Table 1, and neutralizes hCMV infection in a human host.

In yet another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 11B12 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 13H11 as listed in Table 1, and neutralizes hCMV infection in a human host. In another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 3G16 as listed in Table 1, and neutralizes hCMV infection in a human host. In yet another embodiment, an antibody of the invention, or antigen binding fragment thereof, comprises all of the CDRs of antibody 6L3 as listed in Table 1, and neutralizes hCMV infection in a human host.

The invention further comprises an antibody, or fragment thereof, that binds to an epitope capable of binding to an antibody of the invention, or an antibody that competes with an antibody of the invention.

Antibodies of the invention also include hybrid antibody molecules that comprise one or more CDRs from an antibody of the invention and one or more CDRs from another antibody to the same epitope. In one embodiment, such hybrid antibodies comprise three CDRs from an antibody of the invention and three CDRs from another antibody to the same epitope. Exemplary hybrid antibodies comprise i) the three light chain CDRs from an antibody of the invention and the three heavy chain CDRs from another antibody to the same epitope, or ii) the three heavy chain CDRs from an antibody of the invention and the three light chain CDRs from another antibody to the same epitope.

In another aspect, the invention also includes nucleic acid sequences encoding part or all of the light and heavy chains and CDRs of the antibodies of the present invention. In one embodiment, nucleic acid sequences according to the invention include nucleic acid sequences having at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98%, or at least 99% identity to the nucleic acid encoding a heavy or light chain of an antibody of the invention. In another embodiment, a nucleic acid sequence of the invention has the sequence of a nucleic acid encoding a heavy or light chain CDR of an antibody of the invention. For example, a nucleic acid sequence according to the invention comprises a sequence that is at least 75% identical to the nucleic acid sequences of SEQ ID NOs: 7-12, 15, 16, 23-28, 31, 32, 39-44, 47, 48, 55-60, 63, 64, 71-76, 79, 80, 87-92, 95, 96, 103-108, 111, 112, 119-124, 127, 128, 135-140, 143, 144, 151-156, 159, 160, 165-169, 172, 173, 179-183, 186, 187, 194-199, 202, 203, 206, 207, 209, 211, 214, 215, 222-227, 230, 231, 237-241, 244, 245, 252-257, 260, 261, 268-273, 276, 277, 284-289, 292, 293, 295, 302-307, 310, 311, 313, 315, 322-327, 330, 331, 333, 335, 342-347, 350, 351, 353-356, 358, 359, 362-364, 365, 366, 369 and 370. In one embodiment, the nucleic acid sequence according to the invention comprises a sequence that is at least 80%, at least 85%, at least 90%, at least 95%, at least 97%, at least 98%, or at least 99% identical to the nucleic acid sequences of the above listed SEQ ID NOs.

Due to the redundancy of the genetic code, variants of these sequences will exist that encode the same amino acid sequences. These variants are included within the scope of the invention.

Variant antibodies that neutralize hCMV infection are also included within the scope of the invention. Thus, variants of the sequences recited in the application are also included within the scope of the invention. Such variants include natural variants generated by somatic mutation *in vivo* during the immune response or *in vitro* upon culture of immortalized B cell clones. Alternatively, variants may arise due to the degeneracy of the genetic code, as mentioned above or may be produced due to errors in transcription or translation.

Further variants of the antibody sequences having improved affinity and/or potency may be obtained using methods known in the art and are included within the scope of the invention. For example, amino acid substitutions may be used to obtain antibodies with further improved affinity. Alternatively, codon optimisation of the nucleotide sequence may be used to improve the efficiency of translation in expression systems for the production of the antibody. Further, polynucleotides

comprising a sequence optimized for antibody specificity or neutralizing activity by the application of a directed evolution method to any of the nucleic acid sequences of the invention are also within the scope of the invention.

In one embodiment variant antibody sequences that neutralize hCMV infection may share 70% or more (*i.e.* 75%, 80%, 85%, 90%, 95%, 97%, 98%, 99% or more) amino acid sequence identity with the sequences recited in the application. In some embodiments such sequence identity is calculated with regard to the full length of the reference sequence (*i.e.* the sequence recited in the application). In some further embodiments, percentage identity, as referred to herein, is as determined using BLAST version 2.1.3 using the default parameters specified by the NCBI (the National Center for Biotechnology Information) [Blosum 62 matrix; gap open penalty=11 and gap extension penalty=1].

Further included within the scope of the invention are vectors, for example expression vectors, comprising a nucleic acid sequence according to the invention. Cells transformed with such vectors are also included within the scope of the invention. Examples of such cells include but are not limited to, eukaryotic cells, *e.g.* yeast cells, animal cells or plant cells. In one embodiment the cells are mammalian, *e.g.* human, CHO, HEK293T, PER.C6, NS0, myeloma or hybridoma cells.

The invention also relates to monoclonal antibodies that bind to an epitope capable of binding the antibodies of the invention, including, but not limited to, a monoclonal antibody selected from the group consisting of 15D8, 4N10, 10F7, 10P3, 4I22, 8L13, 2C12, 8C15, 9I6, 7B13, 8J16, 8I21, 7I13, 7H3, 6B4, 5F1, 10C6, 4H9, 11B12, 13H11, 3G16, 2B11 and 6L3.

Monoclonal and recombinant antibodies are particularly useful in identification and purification of the individual polypeptides or other antigens against which they are directed. The antibodies of the invention have additional utility in that they may be employed as reagents in immunoassays, radioimmunoassays (RIA) or enzyme-linked immunosorbent assays (ELISA). In these applications, the antibodies can be labelled with an analytically-detectable reagent such as a radioisotope, a fluorescent molecule or an enzyme. The antibodies may also be used for the molecular identification and characterisation (epitope mapping) of antigens.

Antibodies of the invention can be coupled to a drug for delivery to a treatment site or coupled to a detectable label to facilitate imaging of a site comprising cells of interest, such as cells infected with hCMV. Methods for coupling antibodies to drugs and detectable labels are well known in the art, as are methods for imaging using detectable labels. Labelled antibodies may be employed in a wide variety of assays, employing a wide variety of labels. Detection of the formation of an antibody-antigen complex between an antibody of the invention and an epitope of interest (an hCMV epitope) can be facilitated by attaching a detectable substance to the antibody. Suitable detection means include the use of labels such as radionuclides, enzymes, coenzymes, fluorescers, chemiluminescers, chromogens, enzyme substrates or co-factors, enzyme inhibitors, prosthetic group complexes, free radicals, particles, dyes, and the like. Examples of suitable enzymes include horseradish peroxidase, alkaline phosphatase, β-galactosidase, or acetylcholinesterase; examples of suitable prosthetic group complexes include streptavidin/biotin and avidin/biotin; examples of suitable fluorescent materials include umbelliferone, fluorescein, fluorescein isothiocyanate, rhodamine, dichlorotriazinylamine fluorescein, dansyl chloride or phycoerythrin; an example of a

luminescent material is luminol; examples of bioluminescent materials include luciferase, luciferin, and aequorin; and examples of suitable radioactive material include ^{125}I, ^{131}I, ^{35}S, or ^{3}H. Such labeled reagents may be used in a variety of well-known assays, such as radioimmunoassays, enzyme immunoassays, *e.g.*, ELISA, fluorescent immunoassays, and the like. See for example, references 15-18.

An antibody according to the invention may be conjugated to a therapeutic moiety such as a cytotoxin, a therapeutic agent, or a radioactive metal ion or radioisotope. Examples of radioisotopes include, but are not limited to, I-131, I-123, I-125, Y-90, Re-188, Re-186, At-211, Cu-67, Bi-212, Bi-213, Pd-109, Tc-99, In-111, and the like. Such antibody conjugates can be used for modifying a given biological response; the drug moiety is not to be construed as limited to classical chemical therapeutic agents. For example, the drug moiety may be a protein or polypeptide possessing a desired biological activity. Such proteins may include, for example, a toxin such as abrin, ricin A, pseudomonas exotoxin, or diphtheria toxin.

Techniques for conjugating such therapeutic moiety to antibodies are well known. See, for example, Arnon *et al.* (1985) "Monoclonal Antibodies for Immunotargeting of Drugs in Cancer Therapy," in *Monoclonal Antibodies and Cancer Therapy*, ed. Reisfeld *et al.* (Alan R. Liss, Inc.), pp. 243-256; ed. Hellstrom *et al.* (1987) "Antibodies for Drug Delivery," in *Controlled Drug Delivery*, ed. Robinson *et al.* (2d ed; Marcel Dekker, Inc.), pp. 623-653; Thorpe (1985) "Antibody Carriers of Cytotoxic Agents in Cancer Therapy: A Review," in *Monoclonal Antibodies '84: Biological and Clinical Applications*, ed. Pinchera *et al.* pp. 475-506 (Editrice Kurtis, Milano, Italy, 1985); "Analysis, Results, and Future Prospective of the Therapeutic Use of Radiolabeled Antibody in Cancer Therapy," in *Monoclonal Antibodies for Cancer Detection and Therapy*, ed. Baldwin *et al.* (Academic Press, New York, 1985), pp. 303-316; and Thorpe *et al.* (1982) *Immunol. Rev.* 62:119-158.

Alternatively, an antibody can be conjugated to a second antibody to form an antibody heteroconjugate as described in reference 19. In addition, linkers may be used between the labels and the antibodies of the invention [20]. Antibodies or, antigen-binding fragments thereof may be directly labelled with radioactive iodine, indium, yttrium, or other radioactive particle known in the art [21]. Treatment may consist of a combination of treatment with conjugated and non-conjugated antibodies administered simultaneously or subsequently [22, 23].

Antibodies of the invention may also be attached to a solid support.

Additionally, antibodies of the invention, or functional antibody fragments thereof, can be chemically modified by covalent conjugation to a polymer to, for example, increase their circulating half-life, for example. Examples of polymers, and methods to attach them to peptides, are shown in references 24-27. In some embodiments the polymers may be selected from polyoxyethylated polyols and polyethylene glycol (PEG). PEG is soluble in water at room temperature and has the general formula: $R(O--CH_2--CH_2)_n O--R$ where R can be hydrogen, or a protective group such as an alkyl or alkanol group. In one embodiment the protective group may have between 1 and 8 carbons. In a further embodiment the protective group is methyl. The symbol n is a positive integer. In one embodiment n is between 1 and 1,000. In another embodiment n is between 2 and 500. In one embodiment the PEG has an average molecular weight between 1,000 and 40,000. In a further

embodiment the PEG has a molecular weight between 2,000 and 20,000. In yet a further embodiment the PEG has a molecular weight of between 3,000 and 12,000. In one embodiment PEG has at least one hydroxy group. In another embodiment the PEG has a terminal hydroxy group. In yet another embodiment it is the terminal hydroxy group which is activated to react with a free amino group on the inhibitor. However, it will be understood that the type and amount of the reactive groups may be varied to achieve a covalently conjugated PEG/antibody of the present invention.

Water-soluble polyoxyethylated polyols are also useful in the present invention. They include polyoxyethylated sorbitol, polyoxyethylated glucose, polyoxyethylated glycerol (POG), and the like. In one embodiment, POG is used. Without being bound by any theory, because the glycerol backbone of polyoxyethylated glycerol is the same backbone occurring naturally in, for example, animals and humans in mono-, di-, triglycerides, this branching would not necessarily be seen as a foreign agent in the body. In some embodiments POG has a molecular weight in the same range as PEG. The structure for POG is shown in reference 28, and a discussion of POG/IL-2 conjugates is found in reference 24.

Another drug delivery system that can be used for increasing circulatory half-life is the liposome. Methods of preparing liposome delivery systems are discussed in references 29, 30 and 31. Other drug delivery systems are known in the art and are described in, for example, references 32 and 33.

Antibodies of the invention may be provided in purified form. Typically, the antibody will be present in a composition that is substantially free of other polypeptides *e.g.* where less than 90% (by weight), usually less than 60% and more usually less than 50% of the composition is made up of other polypeptides.

Antibodies of the invention may be immunogenic in non-human (or heterologous) hosts *e.g.* in mice. In particular, the antibodies may have an idiotope that is immunogenic in non-human hosts, but not in a human host. Antibodies of the invention for human use include those that cannot be easily isolated from hosts such as mice, goats, rabbits, rats, non-primate mammals, *etc.* and cannot generally be obtained by humanisation or from xeno-mice.

Antibodies of the invention can be of any isotype (*e.g.* IgA, IgG, IgM *i.e.* an α, γ or μ heavy chain), but will generally be IgG. Within the IgG isotype, antibodies may be IgG1, IgG2, IgG3 or IgG4 subclass. Antibodies of the invention may have a κ or a λ light chain.

Production of antibodies

Monoclonal antibodies according to the invention can be made by any method known in the art. The general methodology for making monoclonal antibodies using hybridoma technology is well known [34, 35]. Preferably, the alternative EBV immortalisation method described in reference 36 is used.

Using the method described in reference 36, B cells producing the antibody of the invention can be transformed with EBV in the presence of a polyclonal B cell activator. Transformation with EBV is a standard technique and can easily be adapted to include polyclonal B cell activators.

Additional stimulants of cellular growth and differentiation may optionally be added during the transformation step to further enhance the efficiency. These stimulants may be cytokines such as IL-2 and IL-15. In one aspect, IL-2 is added during the immortalisation step to further improve the efficiency of immortalisation, but its use is not essential.

The immortalised B cells produced using these methods can then be cultured using methods known in the art and antibodies isolated therefrom.

The antibodies of the invention can also be made by culturing single plasma cells in microwell culture plates using the method described in UK Patent Application 0819376.5. Further, from single plasma cell cultures, RNA can be extracted and single cell PCR can be performed using methods known in the art. The VH and VL regions of the antibodies can be amplified by RT-PCR, sequenced and cloned into an expression vector that is then transfected into HEK293T cells or other host cells. The cloning of nucleic acid in expression vectors, the transfection of host cells, the culture of the transfected host cells and the isolation of the produced antibody can be done using any methods known to one of skill in the art.

Monoclonal antibodies may be further purified, if desired, using filtration, centrifugation and various chromatographic methods such as HPLC or affinity chromatography. Techniques for purification of monoclonal antibodies, including techniques for producing pharmaceutical-grade antibodies, are well known in the art.

Fragments of the monoclonal antibodies of the invention can be obtained from the monoclonal antibodies by methods that include digestion with enzymes, such as pepsin or papain, and/or by cleavage of disulfide bonds by chemical reduction. Alternatively, fragments of the monoclonal antibodies can be obtained by cloning and expression of part of the sequences of the heavy or light chains. Antibody "fragments" may include Fab, Fab', $F(ab')_2$ and Fv fragments. The invention also encompasses single-chain Fv fragments (scFv) derived from the heavy and light chains of a monoclonal antibody of the invention *e.g.* the invention includes a scFv comprising the CDRs from an antibody of the invention. Also included are heavy or light chain monomers and dimers as well as single chain antibodies, *e.g.* single chain Fv in which the heavy and light chain variable domains are joined by a peptide linker.

Standard techniques of molecular biology may be used to prepare DNA sequences coding for the antibodies or fragments of the antibodies of the present invention. Desired DNA sequences may be synthesised completely or in part using oligonucleotide synthesis techniques. Site-directed mutagenesis and polymerase chain reaction (PCR) techniques may be used as appropriate.

Any suitable host cell/vector system may be used for expression of the DNA sequences encoding the antibody molecules of the present invention or fragments thereof. Bacterial, for example *E. coli*, and other microbial systems may be used, in part, for expression of antibody fragments such as Fab and $F(ab')_2$ fragments, and especially Fv fragments and single chain antibody fragments, for example, single chain Fvs. Eukaryotic, *e.g.* mammalian, host cell expression systems may be used for production of larger antibody molecules, including complete antibody molecules. Suitable mammalian host cells include CHO, HEK293T, PER.C6, NS0, myeloma or hybridoma cells.

The present invention also provides a process for the production of an antibody molecule according to the present invention comprising culturing a host cell comprising a vector of the present invention under conditions suitable for leading to expression of protein from DNA encoding the antibody molecule of the present invention, and isolating the antibody molecule.

The antibody molecule may comprise only a heavy or light chain polypeptide, in which case only a heavy chain or light chain polypeptide coding sequence needs to be used to transfect the host cells. For production of products comprising both heavy and light chains, the cell line may be transfected with two vectors, a first vector encoding a light chain polypeptide and a second vector encoding a heavy chain polypeptide. Alternatively, a single vector may be used, the vector including sequences encoding light chain and heavy chain polypeptides.

Alternatively, antibodies according to the invention may be produced by i) expressing a nucleic acid sequence according to the invention in a cell, and ii) isolating the expressed antibody product. Additionally, the method may include iii) purifying the antibody.

Screening and isolation of B cells

Transformed B cells may be screened for those producing antibodies of the desired antigen specificity, and individual B cell clones may then be produced from the positive cells.

The screening step may be carried out by ELISA, by staining of tissues or cells (including transfected cells), a neutralisation assay or one of a number of other methods known in the art for identifying desired antigen specificity. The assay may select on the basis of simple antigen recognition, or may select on the additional basis of a desired function *e.g.* to select neutralizing antibodies rather than just antigen-binding antibodies, to select antibodies that can change characteristics of targeted cells, such as their signalling cascades, their shape, their growth rate, their capability of influencing other cells, their response to the influence by other cells or by other reagents or by a change in conditions, their differentiation status, *etc.*

The cloning step for separating individual clones from the mixture of positive cells may be carried out using limiting dilution, micromanipulation, single cell deposition by cell sorting or another method known in the art.

The immortalised B cell clones of the invention can be used in various ways *e.g.* as a source of monoclonal antibodies, as a source of nucleic acid (DNA or mRNA) encoding a monoclonal antibody of interest, for research, *etc.*

The invention provides a composition comprising immortalised B memory cells, wherein the cells produce antibodies with high neutralizing potency specific for hCMV, and wherein the antibodies are produced at $\geq$5pg per cell per day. The invention also provides a composition comprising clones of an immortalised B memory cell, wherein the clones produce a monoclonal antibody with a high affinity specific for hCMV, and wherein the antibody is produced at $\geq$5pg per cell per day. Preferably said clones produce a monoclonal antibody with a high potency in neutralizing hCMV infection.

Exemplary immortalised B cell clone according to the invention include, but are not limited to, 15D8, 4N10, 10F7, 10P3, 4I22, 8L13, 2C12, 8C15, 9I6, 7B13, 8J16, 8I21, 7I13, 7H3, 6B4, 5F1, 10C6, 4H9, 11B12, 13H11, 3G16, 2B11 and 6L3.

Epitopes

As mentioned above, the antibodies of the invention can be used to map the epitopes to which they bind. The inventors have discovered that the several antibodies neutralizing hCMV infection of endothelial cells, epithelial cells, retinal cells and dendritic cells, are directed towards epitopes in the hCMV UL128 protein, epitopes formed by the hCMV proteins UL130 and UL131A, epitopes formed by the hCMV proteins UL128, UL130 and UL131A, epitopes formed by the hCMV proteins gH, gL, UL128 and UL130, gB, gH, or epitopes formed by the hCMV proteins gM and gN. The epitopes to which the antibodies of the invention bind may be linear (continuous) or conformational (discontinuous) and formed by a single hCMV protein or by the combination of 2, 3 or more hCMV proteins.

The epitopes recognised by the antibodies of the present invention may have a number of uses. The epitope and mimotopes thereof in purified or synthetic form can be used to raise immune responses (*i.e.* as a vaccine, or for the production of antibodies for other uses) or for screening patient serum for antibodies that immunoreact with the epitope or mimotopes thereof. In one embodiment such an epitope or mimotope, or antigen comprising such an epitope or mimotope may be used as a vaccine for raising an immune response. The antibodies and antibody fragments of the invention can also be used in a method of monitoring the quality of vaccines. In particular the antibodies can be used to check that the antigen in a vaccine contains the specific immunogenic epitope in the correct conformation.

The epitope may also be useful in screening for ligands that bind to said epitope. Such ligands, include but are not limited to antibodies; including those from camels, sharks and other species, fragments of antibodies, peptides, phage display technology products, aptamers, adnectins or fragments of other viral or cellular proteins, may block the epitope and so prevent infection. Such ligands are encompassed within the scope of the invention.

Recombinant expression

The immortalised B memory cells of the invention may also be used as a source of nucleic acid for the cloning of antibody genes for subsequent recombinant expression. Expression from recombinant sources is more common for pharmaceutical purposes than expression from B cells or hybridomas *e.g.* for reasons of stability, reproducibility, culture ease, *etc.*

Thus the invention provides a method for preparing a recombinant cell, comprising the steps of: (i) obtaining one or more nucleic acids (*e.g.* heavy and/or light chain genes) from the B cell clone that encodes the antibody of interest; and (ii) inserting the nucleic acid into an expression host in order to permit expression of the antibody of interest in that host.

Similarly, the invention provides a method for preparing a recombinant cell, comprising the steps of: (i) sequencing nucleic acid(s) from the B cell clone that encodes the antibody of interest; and (ii) using the sequence information from step (i) to prepare nucleic acid(s) for insertion into an

expression host in order to permit expression of the antibody of interest in that host. The nucleic acid may, but need not, be manipulated between steps (i) and (ii) to introduce restriction sites, to change codon usage, and/or to optimise transcription and/or translation regulatory sequences.

The invention also provides a method of preparing a recombinant cell, comprising the step of transforming a host cell with one or more nucleic acids that encode a monoclonal antibody of interest, wherein the nucleic acids are nucleic acids that were derived from an immortalised B cell clone of the invention. Thus the procedures for first preparing the nucleic acid(s) and then using it to transform a host cell can be performed at different times by different people in different places (*e.g.* in different countries).

These recombinant cells of the invention can then be used for expression and culture purposes. They are particularly useful for expression of antibodies for large-scale pharmaceutical production. They can also be used as the active ingredient of a pharmaceutical composition. Any suitable culture techniques can be used, including but not limited to static culture, roller bottle culture, ascites fluid, hollow-fiber type bioreactor cartridge, modular minifermenter, stirred tank, microcarrier culture, ceramic core perfusion, *etc.*

Methods for obtaining and sequencing immunoglobulin genes from B cells are well known in the art (*e.g.* see reference 37).

The expression host is preferably a eukaryotic cell, including yeast and animal cells, particularly mammalian cells (*e.g.* CHO cells, NS0 cells, human cells such as PER.C6 [Crucell; reference 38] or HKB-11 [Bayer; references 39 & 40] cells, myeloma cells [41 & 42], *etc.*), as well as plant cells. Preferred expression hosts can glycosylate the antibody of the invention, particularly with carbohydrate structures that are not themselves immunogenic in humans. In one embodiment the expression host may be able to grow in serum-free media. In a further embodiment the expression host may be able to grow in culture without the presence of animal-derived products.

The expression host may be cultured to give a cell line.

The invention provides a method for preparing one or more nucleic acid molecules (*e.g.* heavy and light chain genes) that encode an antibody of interest, comprising the steps of: (i) preparing an immortalised B cell clone according to the invention; (ii) obtaining from the B cell clone nucleic acid that encodes the antibody of interest. The invention also provides a method for obtaining a nucleic acid sequence that encodes an antibody of interest, comprising the steps of: (i) preparing an immortalised B cell clone according to the invention; (ii) sequencing nucleic acid from the B cell clone that encodes the antibody of interest.

The invention also provides a method of preparing nucleic acid molecule(s) that encodes an antibody of interest, comprising the step of obtaining the nucleic acid from a B cell clone that was obtained from a transformed B cell of the invention. Thus the procedures for first obtaining the B cell clone and then preparing nucleic acid(s) from it can be performed at very different times by different people in different places (*e.g.* in different countries).

The invention provides a method for preparing an antibody (*e.g.* for pharmaceutical use), comprising the steps of: (i) obtaining and/or sequencing one or more nucleic acids (*e.g.* heavy and light chain genes) from the selected B cell clone expressing the antibody of interest; (ii) inserting the

nucleic acid(s) into or using the nucleic acid(s) to prepare an expression host that can express the antibody of interest; (iii) culturing or sub-culturing the expression host under conditions where the antibody of interest is expressed; and, optionally, (iv) purifying the antibody of the interest.

The invention also provides a method of preparing an antibody comprising the steps of: culturing or sub-culturing an expression host cell population under conditions where the antibody of interest is expressed and, optionally, purifying the antibody of the interest, wherein said expression host cell population has been prepared by (i) providing nucleic acid(s) encoding a selected B cell the antibody of interest that is produced by a population of B memory lymphocytes prepared as described above, (ii) inserting the nucleic acid(s) into an expression host that can express the antibody of interest, and (iii) culturing or sub-culturing expression hosts comprising said inserted nucleic acids to produce said expression host cell population. Thus the procedures for first preparing the recombinant expression host and then culturing it to express antibody can be performed at very different times by different people in different places (*e.g.* in different countries).

Further, cell lines expressing exemplary antibodies of the invention, 4N10, 2C12, 8C15, 8121, 6B4, 10C6, 4H9, 11B12, 3G16, and 6L3 were deposited with the Advanced Biotechnology Center (ABC), Largo Rossana Benzi 10, 16132 Genoa (Italy), under the terms of the Budapest Treaty, on July 9, 2008, (under Accession Numbers PD 08009, PD 08007, PD 08006, PD 08005, PD 08004, PD 08014, PD 08013, PD 08011, PD 08012, and PD 08010, respectively) and an immortalized B cell line expressing 7H3 was deposited on July 16, 2008 under Accession Number PD 08017. An antibody, or an antigen binding fragment thereof, expressed from the above cell lines as well as antibodies, and antigen binding fragments thereof, with the same amino acid sequence as those expressed from the above cell lines are also considered to be within the scope of the invention.

These deposits are provided for the convenience of those skilled in the art and are neither an admission that such deposits are required to practice the invention nor that equivalent embodiments are not within the skill of the art in view of the present disclosure. The public availability of these deposits is not a grant of a license to make, use or sell the deposited materials under this or any other patents. The nucleic acid sequences of the deposited materials are incorporated in the present disclosure by reference and are controlling if in conflict with any sequence described herein.

Pharmaceutical compositions

The invention provides a pharmaceutical composition containing the antibodies and/or antibody fragments of the invention and/or nucleic acid encoding such antibodies and/or immortalised B cells that express such antibodies and/or the epitopes recognised by the antibodies of the invention. A pharmaceutical composition may also contain a pharmaceutically acceptable carrier to allow administration. The carrier should not itself induce the production of antibodies harmful to the individual receiving the composition and should not be toxic. Suitable carriers may be large, slowly metabolised macromolecules such as proteins, polypeptides, liposomes, polysaccharides, polylactic acids, polyglycolic acids, polymeric amino acids, amino acid copolymers and inactive virus particles.

Pharmaceutically acceptable salts can be used, for example mineral acid salts, such as hydrochlorides, hydrobromides, phosphates and sulphates, or salts of organic acids, such as acetates, propionates, malonates and benzoates.

Pharmaceutically acceptable carriers in therapeutic compositions may additionally contain liquids such as water, saline, glycerol and ethanol. Additionally, auxiliary substances, such as wetting or emulsifying agents or pH buffering substances, may be present in such compositions. Such carriers enable the pharmaceutical compositions to be formulated as tablets, pills, dragees, capsules, liquids, gels, syrups, slurries and suspensions, for ingestion by the patient.

Within the scope of the invention, forms of administration may include those forms suitable for parenteral administration, *e.g.* by injection or infusion, for example by bolus injection or continuous infusion. Where the product is for injection or infusion, it may take the form of a suspension, solution or emulsion in an oily or aqueous vehicle and it may contain formulatory agents, such as suspending, preservative, stabilising and/or dispersing agents. Alternatively, the antibody molecule may be in dry form, for reconstitution before use with an appropriate sterile liquid.

Once formulated, the compositions of the invention can be administered directly to the subject. In one embodiment the compositions are adapted for administration to human subjects.

The pharmaceutical compositions of this invention may be administered by any number of routes including, but not limited to, oral, intravenous, intramuscular, intra-arterial, intramedullary, intraperitoneal, intrathecal, intraventricular, transdermal, transcutaneous, topical, subcutaneous, intranasal, enteral, sublingual, intravaginal or rectal routes. Hyposprays may also be used to administer the pharmaceutical compositions of the invention. Typically, the therapeutic compositions may be prepared as injectables, either as liquid solutions or suspensions. Solid forms suitable for solution in, or suspension in, liquid vehicles prior to injection may also be prepared.

Direct delivery of the compositions will generally be accomplished by injection, subcutaneously, intraperitoneally, intravenously or intramuscularly, or delivered to the interstitial space of a tissue. The compositions can also be administered into a lesion. Dosage treatment may be a single dose schedule or a multiple dose schedule. Known antibody-based pharmaceuticals provide guidance relating to frequency of administration *e.g.* whether a pharmaceutical should be delivered daily, weekly, monthly, *etc.* Frequency and dosage may also depend on the severity of symptoms.

Compositions of the invention may be prepared in various forms. For example, the compositions may be 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 (*e.g.* a lyophilised composition, like Synagis™ and Herceptin™, for reconstitution with sterile water containing a preservative). The composition may be prepared for topical administration *e.g.* as an ointment, cream or powder. The composition may be prepared for oral administration *e.g.* as a tablet or capsule, as a spray, or as a syrup (optionally flavoured). The composition may be prepared for pulmonary administration *e.g.* as an inhaler, using a fine powder or a spray. The composition may be prepared as a suppository or pessary. The composition may be prepared for nasal, aural or ocular administration *e.g.* as drops. The composition may be in kit form, designed such that a combined

composition is reconstituted just prior to administration to a patient. For example, a lyophilised antibody can be provided in kit form with sterile water or a sterile buffer.

It will be appreciated that the active ingredient in the composition will be an antibody molecule, an antibody fragment or variants and derivatives thereof. As such, it will be susceptible to degradation in the gastrointestinal tract. Thus, if the composition is to be administered by a route using the gastrointestinal tract, the composition will need to contain agents which protect the antibody from degradation but which release the antibody once it has been absorbed from the gastrointestinal tract.

A thorough discussion of pharmaceutically acceptable carriers is available in Gennaro (2000) *Remington: The Science and Practice of Pharmacy,* 20th edition, ISBN: 0683306472.

Pharmaceutical compositions of the invention generally have a pH between 5.5 and 8.5, in some embodiments this may be between 6 and 8, and in further embodiments about 7. The pH may be maintained by the use of a buffer. The composition may be sterile and/or pyrogen free. The composition may be isotonic with respect to humans. In one embodiment pharmaceutical compositions of the invention are supplied in hermetically-sealed containers.

Pharmaceutical compositions will include an effective amount of one or more antibodies of the invention and/or one or more immortalised B cells of the invention and/or a polypeptide comprising an epitope that binds an antibody of the invention *i.e.* an amount that is sufficient to treat, ameliorate, or prevent a desired disease or condition, or to exhibit a detectable therapeutic effect. Therapeutic effects also include reduction in physical symptoms. The precise effective amount for any particular subject will depend upon their size and health, the nature and extent of the condition, and the therapeutics or combination of therapeutics selected for administration. The effective amount for a given situation is determined by routine experimentation and is within the judgment of a clinician. For purposes of the present invention, an effective dose will generally be from about 0.01mg/kg to about 50mg/kg, or about 0.05 mg/kg to about 10 mg/kg of the compositions of the present invention in the individual to which it is administered. Known antibody-based pharmaceuticals provide guidance in this respect *e.g.* Herceptin™ is administered by intravenous infusion of a 21 mg/ml solution, with an initial loading dose of 4mg/kg body weight and a weekly maintenance dose of 2mg/kg body weight; Rituxan™ is administered weekly at 375mg/m^2; *etc.*

In one embodiment compositions can include more than one (*e.g.* 2, 3, 4, 5, *etc.*) antibody of the invention to provide an additive or synergistic therapeutic effect. In a further embodiment the composition may comprise one or more (*e.g.* 2, 3, 4, 5, *etc.*) antibody of the invention and one or more (*e.g.* 2, 3, 4, 5, *etc.*) additional antibodies that neutralize hCMV infection.

For example, one antibody may bind to an epitope in the hCMV UL128 protein, an epitope formed by the hCMV proteins UL130 and UL131A, an epitope formed by the hCMV proteins UL128, UL130 and UL131A, an epitope formed by the hCMV proteins gH, gL, UL128 and UL130, an epitope in the hCMV gB protein, an epitope in the hCMV gH protein, or an epitope formed by the hCMV proteins gM and gN, while another may bind to a different epitope in the hCMV UL128 protein, an epitope formed by UL130 and UL131A, an epitope formed by UL128, UL130 and UL131A, an epitope formed by gH, gL, UL128 and UL130, gB, gH, gL, gM, gN, gO, or an epitope

formed by gM and gN. Without being bound to any theory, one antibody may be targeted to the mechanism that mediates infection of fibroblasts, while the other antibody may be targeted to the mechanism that mediates infection of endothelial cells. For optimal clinical effect it may well be advantageous to address both mechanisms of hCMV infection and maintenance.

In one embodiment, the invention provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is specific for a first UL128 epitope, and the second antibody is specific for a second UL128 epitope, a combination of UL130 and UL131A, a combination of UL128, UL130 and UL131A, a combination of gH, gL, UL128 and UL130, gB, gH, gL, gM, gN, gO, or a combination of gM and gN.

In another embodiment, the invention provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is specific for a first epitope on a combination of UL130 and 131A, and the second antibody is specific for UL128, a second epitope on a combination of UL130 and 131A, a combination of UL128, UL130 and UL131A, a combination of gH, gL, UL128 and UL130, gB, gH, gL, gM, gN, gO, or a combination of gM and gN.

In yet another embodiment, the invention provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is specific for a first epitope on a combination of UL128, UL130 and 131A, and the second antibody is specific for UL128, a combination of UL130 and UL131A, a second epitope on a combination of UL128, UL130 and 131A, a combination of gH, gL, UL128 and UL130, gB, gH, gL, gM, gN, gO, or a combination of gM and gN.

In still another embodiment, the invention provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is specific for a first epitope on a combination of gH, gL, UL128, UL130 and UL131A, and the second antibody is specific for UL128, a combination of UL130 and UL131A, a combination of UL128, UL130 and 131A, a second epitope on a combination of gH, gL, UL128 and UL130, gB, gH, gL, gM, gN, gO, or a combination of gM and gN.

In a further embodiment, the invention provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is specific for a first gB epitope, and the second antibody is specific for UL128, a combination of UL130 and UL131A, a combination of UL128, UL130 and UL131A, a combination of gH, gL, UL128 and UL130, a second gB epitope, gH, gL, gM, gN, gO, or a combination of gM and gN.

In another embodiment, the invention provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is specific for a first gH epitope, and the second antibody is specific for UL128, a combination of UL130 and UL131A, a combination of UL128, UL130 and UL131A, a combination of gH, gL, UL128 and UL130, gB, a second gH epitope, gL, gM, gN, gO, or a combination of gM and gN.

In yet another embodiment, the invention provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is specific for a first epitope on a combination of gM and gN, and the second antibody is specific for UL128, a combination of UL130 and UL131A, a combination of UL128, UL130 and UL131A, a combination of gH, gL, UL128 and UL130, gB, gH, gL, gM, gN, gO, or a second epitope on a combination of gM and gN.

Exemplary antibodies of the invention for use in a pharmaceutical composition that bind to an epitope in the hCMV UL128 protein include, but are not limited to, 15D8. Exemplary antibodies of the invention for use in a pharmaceutical composition that bind an epitope formed by the hCMV proteins UL130 and UL131A include, but are not limited to, 4N10, 10F7, 10P3, 4I22, 8L13, 1F11, 2F4 and 5A2 (see U.S. Application No. 11/ 969,104, filed January 3, 2008). Exemplary antibodies of the invention for use in a pharmaceutical composition that bind an epitope formed by the hCMV proteins UL128, UL130 and UL131A include, but are not limited to, 2C12, 7B13, 7I13, 8C15, 8J16, 9I6, and 6G4 (see U.S. Application No. 12/174,568, filed July 16, 2008). Exemplary antibodies of the invention for use in a pharmaceutical composition that bind an epitope formed by the hCMV proteins gH, gL, UL128 and UL130 include, but are not limited to, 8I21. Exemplary antibodies of the invention for use in a pharmaceutical composition that bind to an epitope in the hCMV gB protein include, but are not limited to, 7H3, 10C6, 5F1, 6B4, 4H9 and 2B11. Exemplary antibodies of the invention for use in a pharmaceutical composition that bind to an epitope in the hCMV gH protein include, but are not limited to, 11B12, 13H11, and 3G16. Exemplary antibodies of the invention for use in a pharmaceutical composition that bind an epitope formed by the hCMV proteins gM and gN include, but are not limited to, 6L3. The invention further provides a pharmaceutical composition comprising two or more antibodies, wherein the first antibody is an antibody or antibody fragment of the invention and the second antibody is an antibody now known in the art, or later discovered, that neutralises hCMV infection. Examples of such antibodies include, but are not limited to MSL-109, 8F9 or 3E3.

In one embodiment, the invention provides a pharmaceutical composition comprising the antibody 15D8 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 15D8 variant 1or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 15D8 variant 2or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 8I21 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier.

In yet another embodiment, the invention provides a pharmaceutical composition comprising the antibody 2C12 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 8C15 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 9I6 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 7B13 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 8J16 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 7I13 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier.

In yet another embodiment, the invention provides a pharmaceutical composition comprising the antibody 4N10 or an antigen binding fragment thereof, and a pharmaceutically acceptable

carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 10F7 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 10P3 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 4I22 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 8L13 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier.

In yet another embodiment, the invention provides a pharmaceutical composition comprising the antibody 7H3 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 7H3 variant 1 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 10C6 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 5F1 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 6B4 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 4H9 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 4H9 variant 1 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 2B11 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier.

In yet another embodiment, the invention provides a pharmaceutical composition comprising the antibody 13H11 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 11B12 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 3G16 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier. In another embodiment, the invention provides a pharmaceutical composition comprising the antibody 6L3 or an antigen binding fragment thereof, and a pharmaceutically acceptable carrier.

In one embodiment, the pharmaceutical compositions of the invention may comprise the above antibodies or antigen binding fragments thereof, as the sole active ingredient. In another embodiment, the pharmaceutical composition may comprise 2 or more, *e.g.*, 2, 3, 4, 5, 6, 7, 8, or more of the above antibodies or antigen binding fragment thereof. As discussed herein, the pharmaceutical compositions of the invention may also comprise one or more antibodies, or antigen binding fragment thereof, and a second antibody, or antigen binding fragment thereof, that neutralises hCMV infection.

Antibodies of the invention may be administered (either combined or separately) with other therapeutics *e.g.* with chemotherapeutic compounds, with radiotherapy, *etc.* Preferred therapeutic

compounds include anti-viral compounds such as ganciclovir, foscarnet and cidofovir. Such combination therapy provides an additive or synergistic improvement in therapeutic efficacy relative to the individual therapeutic agents when administered alone. The term "synergy" is used to describe a combined effect of two or more active agents that is greater than the sum of the individual effects of each respective active agent. Thus, where the combined effect of two or more agents results in "synergistic inhibition" of an activity or process, it is intended that the inhibition of the activity or process is greater than the sum of the inhibitory effects of each respective active agent. The term "synergistic therapeutic effect" refers to a therapeutic effect observed with a combination of two or more therapies wherein the therapeutic effect (as measured by any of a number of parameters) is greater than the sum of the individual therapeutic effects observed with the respective individual therapies.

Antibodies may be administered to those patients who have previously shown no response to treatment for hCMV infection, *i.e.* have been shown to be refractive to anti-hCMV treatment. Such treatment may include previous treatment with an anti-viral agent. This may be due to, for example, infection with an anti-viral resistant strain of hCMV.

In compositions of the invention that include antibodies of the invention, the antibodies may make up at least 50% by weight (*e.g.* 60%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, 98%, 99% or more) of the total protein in the composition. The antibodies are thus in purified form.

The invention provides a method of preparing a pharmaceutical, comprising the steps of: (i) preparing an antibody of the invention; and (ii) admixing the purified antibody with one or more pharmaceutically-acceptable carriers.

The invention also provides a method of preparing a pharmaceutical, comprising the step of admixing an antibody with one or more pharmaceutically-acceptable carriers, wherein the antibody is a monoclonal antibody that was obtained from a transformed B cell of the invention. Thus the procedures for first obtaining the monoclonal antibody and then preparing the pharmaceutical can be performed at very different times by different people in different places (*e.g.* in different countries).

As an alternative to delivering antibodies or B cells for therapeutic purposes, it is possible to deliver nucleic acid (typically DNA) that encodes the monoclonal antibody (or active fragment thereof) of interest to a subject, such that the nucleic acid can be expressed in the subject *in situ* to provide a desired therapeutic effect. Suitable gene therapy and nucleic acid delivery vectors are known in the art.

Compositions of the invention may be immunogenic compositions, and in some embodiments may be vaccine compositions comprising an antigen comprising an epitope in the hCMV UL128 protein, formed by the hCMV proteins UL130 and 131A, formed by the hCMV proteins UL128, UL130 and UL131A, formed by the hCMV proteins gH, gL, UL128 and UL130, in the hCMV gB protein, in the hCMV gH protein, or formed by the hCMV proteins gM and gN. Alternative compositions may comprise (i) an antigen comprising an epitope formed by a combination of hCMV proteins UL128, UL130 and UL131A, and (ii) an antigen comprising an epitope found on gB, gH, gL, gM, gN, gO, UL128, UL130 or UL131A, or a combination thereof. Vaccines according to the invention may either be prophylactic (*i.e.* to prevent infection) or therapeutic (*i.e.* to treat infection).

Compositions may include an antimicrobial, particularly if packaged in a multiple dose format. They may comprise a detergent *e.g.*, a Tween (polysorbate), such as Tween 80. Detergents are generally present at low levels *e.g.* <0.01%. Compositions may also include sodium salts (*e.g.* sodium chloride) to give tonicity. A concentration of 10±2mg/ml NaCl is typical.

Compositions may comprise a sugar alcohol (*e.g.* mannitol) or a disaccharide (*e.g.* sucrose or trehalose) *e.g.* at around 15-30mg/ml (*e.g.* 25 mg/ml), particularly if they are to be lyophilised or if they include material which has been reconstituted from lyophilised material. The pH of a composition for lyophilisation may be adjusted to around 6.1 prior to lyophilisation.

The compositions of the invention may also comprise one or more immunoregulatory agents. In one embodiment, one or more of the immunoregulatory agents include(s) an adjuvant.

The epitope compositions of the invention may elicit both a cell mediated immune response as well as a humoral immune response in order to effectively address a hCMV infection. This immune response may induce long lasting (*e.g.* neutralizing) antibodies and a cell mediated immunity that can quickly respond upon exposure to hCMV.

Medical treatments and uses

The antibodies, antibody fragments of the invention or derivatives and variants thereof may be used for the treatment of hCMV infection, for the prevention of hCMV infection or for the diagnosis of hCMV infection.

Methods of diagnosis may include contacting an antibody or an antibody fragment with a sample. Such samples may be tissue samples taken from, for example, salivary glands, lung, liver, pancreas, kidney, ear, eye, placenta, alimentary tract, heart, ovaries, pituitary, adrenals, thyroid, brain or skin. The methods of diagnosis may also include the detection of an antigen/antibody complex.

The invention therefore provides (i) an antibody, an antibody fragment, or variants and derivatives thereof according to the invention, (ii) an immortalised B cell clone according to the invention, (iii) an epitope capable of binding an antibody of the invention or (iv) a ligand, preferably an antibody, capable of binding an epitope that binds an antibody of the invention for use in therapy.

Also provided is a method of treating a patient comprising administering to that patient (i) an antibody, an antibody fragment, or variants and derivatives thereof according to the invention, or, a ligand, preferably an antibody, capable of binding an epitope that binds an antibody of the invention.

The invention also provides the use of (i) an antibody, an antibody fragment, or variants and derivatives thereof according to the invention, (ii) an immortalised B cell clone according to the invention, (iii) an epitope capable of binding an antibody of the invention, or (iv) a ligand, preferably an antibody, that binds to an epitope capable of binding an antibody of the invention, in the manufacture of a medicament for the prevention or treatment of hCMV infection.

The invention provides a composition for use as a medicament for the prevention or treatment of an hCMV infection. It also provides the use of an antibody and/or a protein comprising an epitope to which such an antibody binds in the manufacture of a medicament for treatment of a patient and/or diagnosis in a patient. It also provides a method for treating a subject in need of

treatment, comprising the step of administering a composition of the invention to the subject. In some embodiments the subject may be a human. One way of checking efficacy of therapeutic treatment involves monitoring disease symptoms after administration of the composition of the invention. Treatment can be a single dose schedule or a multiple dose schedule.

In one embodiment, an antibody of the invention, an antigen-binding fragment thereof, an epitope or a composition of the invention is administered to a subject in need of such prophylactic or therapeutic treatment. Such a subject includes, but is not limited to, one who is particularly at risk of, or susceptible to, hCMV infection. Exemplary subjects include, but are not limited to, immunocompromised subjects or hCMV-seronegative or hCMV recently infected pregnant women. Exemplary immunocompromised subjects include, but are not limited to, those afflicted with HIV or those undergoing immunosuppressive therapy.

Antibodies of the invention and antigen-biding fragments thereof can also be used in passive immunisation. Further, as described in the present invention, they may also be used in a kit for the diagnosis of hCMV infection.

Epitopes capable of binding an antibody of the invention, *e.g.*, the monoclonal antibodies 15D8, 4N10, 10F7, 10P3, 4I22, 8L13, 2C12, 8C15, 9I6, 7B13, 8J16, 8I21, 7I13, 7H3, 6B4, 5F1, 10C6, 4H9, 2B11, 11B12, 13H11, 3G16, and 6L3, may be used in a kit for monitoring the efficacy of vaccination procedures by detecting the presence of protective anti-hCMV antibodies.

Antibodies, antibody fragment, or variants and derivatives thereof, as described in the present invention may also be used in a kit for monitoring vaccine manufacture with the desired immunogenicity.

The invention also provides a method of preparing a pharmaceutical, comprising the step of admixing a monoclonal antibody with one or more pharmaceutically-acceptable carriers, wherein the monoclonal antibody is a monoclonal antibody that was obtained from an expression host of the invention. Thus the procedures for first obtaining the monoclonal antibody (*e.g.* expressing it and/or purifying it) and then admixing it with the pharmaceutical carrier(s) can be performed at very different times by different people in different places (*e.g.* in different countries).

Starting with a transformed B cell of the invention, various steps of culturing, sub-culturing, cloning, sub-cloning, sequencing, nucleic acid preparation *etc.* can be performed in order to perpetuate the antibody expressed by the transformed B cell, with optional optimisation at each step. In a preferred embodiment, the above methods further comprise techniques of optimisation (*e.g.* affinity maturation or optimisation) applied to the nucleic acids encoding the antibody. The invention encompasses all cells, nucleic acids, vectors, sequences, antibodies *etc.* used and prepared during such steps.

In all these methods, the nucleic acid used in the expression host may be manipulated to insert, delete or amend certain nucleic acid sequences. Changes from such manipulation include, but are not limited to, changes to introduce restriction sites, to amend codon usage, to add or optimise transcription and/or translation regulatory sequences, *etc.* It is also possible to change the nucleic acid to alter the encoded amino acids. For example, it may be useful to introduce one or more (*e.g.* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, *etc.*) amino acid substitutions, deletions and/or insertions into the

antibody's amino acid sequence. Such point mutations can modify effector functions, antigen-binding affinity, post-translational modifications, immunogenicity, *etc.*, can introduce amino acids for the attachment of covalent groups (*e.g.* labels) or can introduce tags (*e.g.* for purification purposes). Mutations can be introduced in specific sites or can be introduced at random, followed by selection (*e.g.* molecular evolution). For instance, one or more nucleic acids encoding any of the CDR regions, heavy chain variable regions or light chain variable regions of antibodies of the invention can be randomly or directionally mutated to introduce different properties in the encoded amino acids. Such changes can be the result of an iterative process wherein initial changes are retained and new changes at other nucleotide positions are introduced. Moreover, changes achieved in independent steps may be combined. Different properties introduced into the encoded amino acids may include, but are not limited to, enhanced affinity.

General

The term "comprising" encompasses "including" as well as "consisting" *e.g.* a composition "comprising" X may consist exclusively of X or may include something additional *e.g.* X + Y.

The word "substantially" does not exclude "completely" *e.g.* a composition which is "substantially free" from Y may be completely free from Y. Where necessary, the word "substantially" may be omitted from the definition of the invention.

The term "about" in relation to a numerical value *x* means, for example, $x \pm 10\%$.

The term "disease" as used herein is intended to be generally synonymous, and is used interchangeably with, the terms "disorder" and "condition" (as in medical condition), in that all reflect an abnormal condition of the human or animal body or of one of its parts that impairs normal functioning, is typically manifested by distinguishing signs and symptoms, and causes the human or animal to have a reduced duration or quality of life.

As used herein, reference to "treatment" of a patient is intended to include prevention and prophylaxis. The term "patient" means all mammals including humans. Examples of patients include humans, cows, dogs, cats, horses, goats, sheep, pigs, and rabbits. Generally, the patient is a human.

EXAMPLES

Exemplary embodiments of the present invention are provided in the following examples. The following examples are presented only by way of illustration and to assist one of ordinary skill in using the invention. The examples are not intended in any way to otherwise limit the scope of the invention.

Example 1: Cloning of B cells and screening for hCMV neutralizing activity

Donors with high hCMV neutralizing antibody titres in the serum were identified. Memory B cells were isolated and immortalised using EBV and CpG as described in reference 36. Briefly, memory B cells were isolated by negative selection using CD22 beads, followed by removal of IgM^+, IgD^+ IgA^+ B cells using specific antibodies and cell sorting. The sorted cells (IgG^+) were immortalized with EBV in the presence of CpG 2006 and irradiated allogeneic mononuclear cells. Replicate cultures each containing 50 memory B cells were set up in twenty 96 well U bottom

plates. After two weeks the culture supernatants were collected and tested for their capacity to neutralize hCMV infection of either fibroblasts or epithelial cells in separate assays. B cell clones were isolated from positive polyclonal cultures as described in reference 36. IgG concentrations in the supernatant of selected clones were determined using an IgG-specific ELISA.

For the viral neutralization assay a titrated amount of a clinical hCMV isolate was mixed with an equal volume of culture supernatant or with dilutions of human sera containing neutralizing antibodies. After 1 hour incubation at room temperature the mixture was added to confluent monolayers of either endothelial cells (*e.g.* HUVEC cells or HMEC-1 cells), epithelial cells (*e.g.* ARPE retinal cells), fibroblasts (*e.g.* MRC-9 or mesenchymal stromal cells) or myeloid cells (*e.g.* monocyte-derived dendritic cells) in 96 well flat-bottom plates and incubated at 37°C for two days. The supernatant was discarded, the cells were fixed with cold methanol and stained with a mixture of mouse monoclonal antibodies to hCMV early antigens, followed by a fluorescein-labeled goat anti mouse Ig. The plates were analyzed using a fluorescence microscope. In the absence of neutralizing antibodies the infected cells were 100-1,000/field, while in the presence of saturating concentrations of neutralizing antibodies the infection was completely inhibited. The neutralizing titer is indicated as the concentration of antibody (μg/ml) that gives a 50% or 90% reduction of hCMV infection.

Table 5A shows the neutralization of a hCMV clinical isolate (VR1814) on both a fibroblastic cell line (MRC-9) and a human retinal epithelial cell line (ARPE). Some antibodies neutralized hCMV infection of epithelial cells (ARPE) but they did not neutralize infection of fibroblasts (MRC-9). This agrees with previous data that different proteins are responsible for tropism towards a particular cell type [7]. Most of these antibodies, which are specific for one or more proteins of the gH/gL/UL128/UL130/UL131A protein complex, neutralized hCMV infection of epithelial cells at very low concentrations (50% reduction of hCMV infection at concentrations ranging from 0.01 μg/ml and 0.001 μg/ml). Other antibodies, which are specific for the hCMV protein gB, gH or a combination of gM and gN, neutralized hCMV infection of fibroblasts and epithelial cells with comparable potency. These results show that some of the hCMV neutralizing antibodies are equally potent on both fibroblasts and epithelial cells, while others show differential activity on the two cell types.

Based on the analysis shown in Table 5A, antibodies were grouped into Group 1 (neutralizing hCMV infection of both fibroblasts and epithelial cells) and Group 2 (neutralizing hCMV infection of epithelial cells). Table 5B shows an independent experiment performed using purified antibodies. The results show that Group 2 antibodies neutralized infection of epithelial cells with IC90 values (i.e. the concentration of antibody required to give 90% reduction of viral infection) ranging from 0.007 μg/ml to 0.003 μg/ml while Group 1 antibodies neutralized infection of both fibroblasts and epithelial cells with IC90 values ranging from 0.1 μg/ml to 30 μg/ml. Group 2 antibodies also neutralized infection of endothelial cells (HUVEC) and myeloid cells (monocyte-derived dendritic cells) (data not shown). Group 1 antibodies also neutralized infection of endothelial cells (HUVEC), myeloid cells (monocyte-derived dendritic cells) and bone marrow mesenchymal stromal cells, as shown for some representative antibodies in Table 5C. Antibodies of the invention also neutralized infection of endothelial cells (HUVEC) by different hCMV clinical

isolates: VR6952 (from urine), VR3480B1 (from blood, ganciclovir-resistant) and VR4760 (from blood, ganciclovir and foscarnet-resistant) (data not shown).

It is anticipated that antibodies that neutralize infection of different cell types may be combined to bring about an additive or synergistic neutralization effect when the different cell types are present during infection. As one example, a neutralizing antibody, such as 15D8 which is potent in neutralizing infection of epithelial cells but does not neutralize infection of fibroblasts might be combined with 3G16 which does have virus neutralizing activity on fibroblasts. As another example, a neutralizing antibody, such as 9I6 which is potent in neutralizing infection of epithelial cells but does not neutralize infection of fibroblasts, might be combined with 6B4 which does have virus neutralizing activity on fibroblasts.

Table 5A

			50% Neutralization[1]	50% Neutralization[1]
mAb	**Donor**	**Specificity[2]**	**MRC-9**	**ARPE**
15D8	GRA	UL128	–	++++
4N10	GIO	UL130/UL131A	+	++++
10F7	PAP	UL130/UL131A	+	+++
10P3	PEL	UL130/UL131A	–	++++
4I22	PEL	UL130/UL131A	–	+++
8L13	PEL	UL130/UL131A	–	+++
2C12	PAP	UL128/UL130/UL131A	+	+++
7B13	PAP	UL128/UL130/UL131A	–	++++
7I13	PAP	UL128/UL130/UL131A	–	+++
8C15	PAP	UL128/UL130/UL131A	–	++++
8J16	PAP	UL128/UL130/UL131A	–	++++
9I6	PEL	UL128/UL130/UL131A	–	++++
8I21	PEL	gH/gL/UL128/UL130	–	+++
11B12	PAP	gH	+	+
13H11	GRA	gH	+	+++
3G16	PEL	gH	+	+
7H3	PEL	gB	+	–
10C6	PEL	gB	+	+
5F1	PEL	gB	+	+
6B4	PEL	gB	+	+
4H9	PEL	gB	+	+
6L3	PEL	gM/gN	Not done	+

1) Values indicating the concentration of antibody required to give a 50% reduction of hCMV infection of fibroblasts (*e.g.* MRC-9) or epithelial cells (*e.g.* ARPE retinal cells). Concentration as follows:
++++ < 0.001 μg/ml; +++ < 0.01 μg/ml; ++ < 0.1 μg/ml; + ≤ 2 μg/ml;
– Not neutralizing at the highest concentration tested (2 μg/ml).
2) Specificity as defined in Table 6.

Table 5B

				90% Neutralization[1]	90% Neutralization[1]
Group	**mAb**	**Donor**	**Specificity[2]**	**MRC-9**	**ARPE**
2	**15D8**	GRA	UL128	nn[3]	0.008
2	**4N10**	GIO	UL130/UL131A	nn	0.02
2	**10F7**	PAP	UL130/UL131A	nn	0.002
2	**10P3**	PEL	UL130/UL131A	nn	0.0025
2	**4I22**	PEL	UL130/UL131A	nn	0.0015
2	**8L13**	PEL	UL130/UL131A	nn	0.001
2	**2C12**	PAP	UL128/UL130/UL131A	nn	0.006
2	**7B13**	PAP	UL128/UL130/UL131A	nn	0.003
2	**7I13**	PAP	UL128/UL130/UL131A	nn	0.008
2	**8C15**	PAP	UL128/UL130/UL131A	nn	0.0025
2	**8J16**	PAP	UL128/UL130/UL131A	nn	0.0008
2	**9I6**	PEL	UL128/UL130/UL131A	nn	0.0007
2	**8I21**	PEL	gH/gL/UL128/UL130	nn	0.03
1	**11B12**	PAP	gH	3.5	1.2
1	**13H11**	GRA	gH	1.12	0.4
1	**3G16**	PEL	gH	1.0	0.3
1	**7H3**	PEL	gB	3	0.6
1	**10C6**	PEL	gB	0.75	0.2
1	**5F1**	PEL	gB	0.5	0.1
1	**6B4**	PEL	gB	1.0	0.15
1	**4H9**	PEL	gB	10	0.4
1	**2B11**	PEL	gB	0.75	0.2
1	**6L3**	PEL	gM/gN	30	10

1) Values indicating the concentration of antibody in µg/ml required to give a 90% reduction of hCMV (VR1814) infection of fibroblasts (*e.g.* MRC-9) or epithelial cells (*e.g.* ARPE retinal cells).
2) Specificity as defined in Table 6.
3) nn, not neutralizing at the highest concentration tested (10 µg/ml).

Table 5C

			50% Neutralization[1]		
Group	**mAb**	**Specificity**	**HUVEC**	**Mo-DC**	**BM-MSC**
1	**7H3**	gH	nd	0.06	2
1	**10C6**	gH	0.19	0.02	0.3
1	**5F1**	gH	0.21	0.05	0.3
1	**6B4**	gH	nd	0.11	2

1) Values indicating the concentration of antibody in µg/ml required to give a 50% reduction of hCMV (VR1814) infection of primary cells. HUVEC, human umbilical vein endothelial cells, Mo-DC, monocyte-derived dendritic cells, BM-MSC, mesenchymal bone-marrow stromal cells.

Example 2: Identification of the target antigens recognized by the monoclonal antibodies

To map the specificity of the hCMV neutralizing antibodies, HEK293T cells were transfected with one or more vectors encoding full length hCMV proteins UL128, UL130, UL131A, gH, gL, gB, gM, and gN. After 36h, cells were fixed, permeabilized and stained with the human monoclonal antibodies followed by goat anti-human IgG. Figure 1 shows the binding of

representative antibodies to HEK293T cells expressing one or more hCMV proteins. Table 6 shows the staining pattern of all the different antibodies to hCMV gene-transfected HEK293T cells. With the exception of antibody 15D8, that stained UL128-transfected cells, all the other Group 2 antibodies did not stain single gene transfectants, suggesting that they may recognize epitopes that require co-expression of more than one gene product. Indeed, five antibodies (4N10, 10F7, 10P3, 4I22 and 8L13) stained cells co-expressing UL130 and UL131A, six antibodies (2C12, 7B13, 7I13, 8C15, 8J16 and 9I6) stained cells co-expressing UL128, UL130 and UL131A, and one antibody (8I21) stained cells transfected with UL128 and UL130 as well as with gH and gL. All these antibodies also stained HEK293T cells transfected with all genes forming the gH/gL/UL128-130 complex. Among the Group 1 antibodies, three (11B12, 13H11 and 3G16) stained cells expressing the hCMV protein gH, six (7H3, 10C6, 5F1, 6B4, 4H9 and 2B11) stained cells expressing the hCMV protein gB and one (6L3) stained cells coexpressing the hCMV proteins gM and gN.

Table 6.

HEK293T cells transfected with:	Monoclonal antibody						
	Group 2				Group 1		
	15D8	**4N10 10F7 10P3 4I22 8L13**	**2C12 7B13 7I13 8C15 8J16 9I6**	**8I21**	**11B12 13H11 3G16**	**7H3 10C6 5F1 6B4 4H9 2B11**	**6L3**
UL128	+	–	–	–	–	–	nd[1]
UL130	–	–	–	–	–	–	nd
UL131A	–	–	–	–	–	–	nd
UL128+UL130	+	–	–	–	–	–	nd
UL128+UL131A	+	–	–	–	–	–	nd
UL130+UL131A	–	+	–	–	–	–	nd
UL128+UL130+UL131A	+	+	+	–	–	–	–
gH	–	–	–	–	+	–	–
gH+gL	–	–	–	–	+	–	–
gH+UL128+UL130+UL131A	+	+	+	–	+	nd	nd
gL+UL128+UL130+UL131A	+	+	+	–	–	nd	nd
gH+gL+UL128	+	–	–	–	+	nd	nd
gH+gL+UL130	–	–	–	–	+	nd	nd
gH+gL+UL131A	–	–	–	–	+	nd	nd
gH+gL+UL128+UL130	+	–	–	+	+	nd	nd
gH+gL+UL128+UL130+UL131A	+	+	+	+	+	–	–
gB	–	–	–	nd	–	+	–
gM	nd	–	–	nd	nd	nd	–
gN	nd	–	–	nd	nd	nd	–
gM+gN	–	–	–	–	nd	nd	+

1) nd, not done.

To further explore the identity of the antigen sites to which the antibodies bind, cross-competition experiments were performed. Here, HEK293T cells were transfected with vectors encoding full length hCMV proteins gH, gL, UL128, UL130 and UL131A. The cells were then incubated with a 20-fold excess of a competitor hCMV neutralizing antibody before addition of a biotinylated antibody. This procedure was repeated several times with different competitor antibodies and biotinylated antibodies. In these experiments four antibodies described in Patent Application No. 11/ 969,104 (11F11, 2F4 and 5A2) and Patent Application No. 12/174,568 (6G4) were included. The data is shown in Table 7A, B.

Table 7A.

		Inhibition of binding (%)						
Competitor (20-fold excess)	**Specificity**[1]	**15D8-biotin**	**4N10-biotin**	**10F7-biotin**	**4I22-biotin**	**1F11-biotin**	**2F4-biotin**	**5A2-biotin**
15D8	UL128	**100**	0	0	0	0	0	0
4N10	UL130/UL131A	0	**100**	0	0	0	0	**100**
10F7	UL130/UL131A	0	0	**100**	**100**	**100**	**100**	0
10P3	UL130/UL131A	0	nd	nd	0	0	0	Nd
4I22	UL130/UL131A	nd	0	**100**	**100**	**100**	**100**	0
8L13	UL130/UL131A	nd	nd	**100**	nd	**100**	Nd	nd
1F11	UL130/UL131A	0	0	**100**	**100**	**100**	**100**	0
2F4	UL130/UL131A	nd	0	**100**	**100**	**100**	**100**	0
5A2	UL130/UL131A	nd	**100**	0	0	0	**50**[2]	**100**
2C12	UL128/UL130/UL131A	0	0	0	0	0	0	0
7B13	UL128/UL130/UL131A	nd	nd	nd	nd	nd	nd	nd
7I13	UL128/UL130/UL131A	nd	nd	nd	nd	0	nd	nd
8C15	UL128/UL130/UL131A	nd	nd	nd	0	nd	nd	nd
8J16	UL128/UL130/UL131A	nd	nd	nd	0	0	0	nd
9I6	UL128/UL130/UL131A	nd	nd	Nd	0	0	0	nd
6G4	UL128/UL130/UL131A	0	0	0	0	0	0	0
8I21	gH/gL/UL128/UL130	0	**90**	nd	0	0	0	**95**

1) Specificity as defined is Table 6.
2) Competition below 100% may be due to partial overlap of epitopes or to steric hindrance or to lower affinity.

Table 7B.

		Inhibition of binding (%)					
Competitor (20-fold excess)	**Specificity**[1]	**2C12-biotin**	**8C15-biotin**	**8J16-biotin**	**9I6-biotin**	**6G4-biotin**	**8I21-biotin**
15D8	UL128	0	nd	nd	nd	0	0
4N10	UL130/UL131A	0	nd	nd	nd	0	**90**[2]
10F7	UL130/UL131A	0	nd	nd	nd	0	0
10P3	UL130/UL131A	0	nd	nd	nd	0	0
4I22	UL130/UL131A	0	nd	0	nd	nd	0
8L13	UL130/UL131A	nd	nd	nd	nd	nd	nd

1F11	UL130/UL131A	0	nd	nd	nd	0	0
2F4	UL130/UL131A	0	nd	nd	0	0	0
5A2	UL130/UL131A	0	nd	nd	0	0	**92**
2C12	UL128/UL130/UL131A	**100**	**100**	**100**	**100**	**100**	0
7B13	UL128/UL130/UL131A	**100**	**100**	**100**	**100**	**100**	0
7I13	UL128/UL130/UL131A	0	0	0	0	0	0
8C15	UL128/UL130/UL131A	**100**	**100**	**100**	**100**	**100**	0
8J16	UL128/UL130/UL131A	**100**	**100**	**100**	**70**	**100**	0
9I6	UL128/UL130/UL131A	**100**	**100**	**100**	**100**	**100**	0
6G4	UL128/UL130/UL131A	**100**	**100**	**100**	**100**	**100**	0
8I21	gH/gL/UL128/UL130	0	nd	nd	nd	0	**100**
3G16	gH	0	nd	nd	nd	0	0

1) Specificity as defined is Table 6.
2) Competition below 100% may be due to partial overlap of epitopes or to steric hindrance or to lower affinity.

Based on the data in Table 7A, B, at least seven distinct antigenic sites can be distinguished on the hCMV complex formed by gH, gL, UL128 and UL130 (Table 8). Site 1 is present in UL128 and is defined by antibody 15D8. Sites 2 to 4 are formed by the combination of UL130 and UL131A and are defined by the antibodies 10F7 4I22, 8L13, 1F11 and 2F4 (site 2), by 4N10 and 5A2 (site 3), and by 10P3 (site 4), respectively. Sites 5 and 6 are formed by the combination of UL128, UL130 and UL131A and are defined by antibodies 2C12, 7B13, 8C15, 8J16, 9I6 and 6G4 (site 5) and by 7I13 (site 6), respectively. Finally, site 7 is formed by the combination of gH, gL, UL128 and UL130 and is defined by the antibody 8I21. Antibodies defining site 7 and site 3 partially competed with each other, suggesting that these sites may be close in the structure of the gH/gL/UL128-131A complex.

It is anticipated that neutralizing antibodies targeted to different epitopes on the same target can be used in combination to achieve robust neutralization of virus infection, as exemplified by 10F7 and 4N10 or by 8J16 and 7I13. Moreover, it is anticipated that neutralizing antibodies targeted to different target molecules or combinations of target molecules may be used together to achieve robust virus neutralization. As one example, Table 8 suggests that 15D8 and 10F7, 15D8 and 2C12, or 8J16 and 8I21 could be combined to bring about additive or synergenic hCMV neutralization effects.

Table 8.

Target antigen	**Antigenic site**	**Antibodies defining the antigenic site**
UL128	1	15D8
UL130/UL131A	2	10F7, 4I22, 8L13, 1F11, 2F4
UL130/UL131A	3	4N10, 5A2
UL130/UL131A	4	10P3
UL128/UL130/UL131A	5	2C12, 7B13, 8C15, 8J16, 916, 6G4
UL128/UL130/UL131A	6	7I13
gH/gL/UL128/UL130	7	8I21

In a manner similar to what described in Table 7, HEK293T cells were transfected with a vector encoding full length gH to examine the cross-competition binding of the anti-gH antibodies. As can be seen in Figure 2A and Table 9, at least two different binding sites were identified in the hCMV gH protein. The antibody 3G16 defines one site and the antibodies 11B12 and 13H11 define a second site. Finally, HEK293T cells were transfected with a vector encoding full length gB to examine the cross-competition binding of the anti-gB antibodies. As can be seen in Figure 2B and Table 10, at least three different antigenic sites were identified in the hCMV gB protein. The antibody 6B4 defines one site, 7H3 defines a second site and the set of 10C6, 5F1, 4H9 and 2B11 define a third site. Antibody 6B4 (recognizing gB site 1) reacted by ELISA with the gB 69-78 peptide (EC_{50} of 0.044 μg/ml). It is anticipated that antibodies that target different sites even on the same target molecule can be used in combination to achieve robust virus neutralization. It is anticipated that antibodies that target different sites even on the same target molecule can be used in combination to achieve robust virus neutralization.

Table 9.

		Inhibition of binding (%) of:			
Competitor 20-fold excess	**Specificity**[1]	**3G16-biotin**	**11B12-biotin**	**13H11-biotin**	**Antigenic site in gH**
3G16	gH	**100**	0	0	1
11B12	gH	0	**100**	**100**	2
13H11	gH	0	**100**	**100**	2

1) As defined in Table 6.

Table 10.

		Inhibition of binding (%) of:						
Competitor 20-fold excess	**Specificity**[1]	**7H3-biotin**	**10C6-biotin**	**5F1-biotin**	**6B4-biotin**	**4H9-biotin**	**2B11-biotin**	**Antigenic site in gB**
6B4	gB	0	0	0	**100**	0	0	1
7H3	gB	**100**	0	0	0	0	0	2
10C6	gB	0	**100**	**100**	0	**100**	**100**	3
5F1	gB	0	**100**	**100**	0	**100**	**100**	3
4H9	gB	0	**100**	**100**	0	**100**	**100**	3
2B11	gB	0	**100**	**100**	0	**100**	**100**	3

1) As defined in Table 6.
2) Competition below 100% may be due to partial overlap of epitopes, to steric hindrance or to lower affinity.

To summarize, **15D8** binds to an epitope in UL128 that is distinct from the epitope recognized by 2C12, 7B13, 6G4 (all specific for a combination of UL128, UL130 and UL131A) and from the epitope recognized by 8I21 (specific for a combination of gH, gL, UL128 and UL130). In addition binding of **15D8** to its epitope is not inhibited by 4N10, 10F7, 10P3 and 1F11 (all specific for a combination of UL130 and UL131A).

4N10 binds to an epitope which requires expression of UL130 and UL131A and that is the same or largely overlapping to the epitopes recognized by 5A2 (specific for a combination of UL130 and UL131A) and 8I21 (specific for a combination of gH, gL, UL128 and UL130) but distinct from the

epitopes recognized by 10F7, 4I22, 1F11, 2F4 (all specific for a combination of UL130 and UL131A), 2C12 and 6G4 (both specific for a combination of UL128, UL130 and UL131A). In addition binding of **4N10** to its epitope is not inhibited by 15D8 (specific for UL128).

10F7 binds to an epitope which requires expression of UL130 and UL131A that is the same or largely overlapping to the epitope(s) recognized by 4I22, 8L13, 1F11 and 2F4 but distinct from epitope(s) recognized by 4N10 and 5A2 (both specific for a combination of UL130 and UL131A) as well as distinct from epitopes recognized by 2C12 and 6G4 (both specific for a combination of UL128, UL130 and UL131A). In addition binding of **10F7** to its epitope is not inhibited by 15D8 (specific for UL128) or by 13H11 (specific for gH).

4I22 binds to an epitope which requires expression of UL130 and UL131A and that is the same or partially overlapping to epitope(s) recognized by 2F4, 1F11 and 10F7 but distinct from epitope(s) recognized by 4N10, 10P3 and 5A2 (all specific for a combination of UL130 and UL131A) as well as distinct from the epitopes recognized by 2C12, 8C15, 8J16, 9I6, 6G4 (all specific for a combination of UL128, UL130 and UL131A) and 8I21 (specific for a combination of gH, gL, UL128 and UL130. In addition binding of **4I22** to its epitope is not inhibited by the antibodies 15D8 (specific for UL128) or by 13H11 (specific for gH).

2C12 binds to an epitope which requires expression of hCMV UL128, UL130 and UL131A gene products and that is the same or largely overlapping to epitope(s) recognized by 7B13, 8C15, 8J16, 9I6 and 6G4 but distinct from the epitope recognized by 7I13 (all specific for a combination of UL128, UL130 and UL131A) and distinct from epitope(s) recognized by 15D8 (specific for UL128), 4N10, 10F7, 10P3, 4I22, 8L13, 1F11, 2F4, 5A2 (all specific for a combination of UL130 and UL131A) and 8I21 (specific for a combination of gH, gL, UL128 and UL130). In addition binding of **2C12** to its epitope is not inhibited by 3G16 (specific for gH).

8C15 binds to an epitope which requires expression of hCMV UL128, UL130 and UL131A gene products and that is the same or largely overlapping to epitope(s) recognized by 2C12, 7B13, 8J16, 9I6 and 6G4 but distinct from the epitope recognized by 7I13 (all specific for a combination of UL128, UL130 and UL131A).

8J16 binds to an epitope which requires expression of hCMV UL128, UL130 and UL131A gene products and that is the same or largely overlapping to epitope(s) recognized by 2C12, 7B13, 8C15, 9I6 and 6G4, but distinct from the epitope recognized by 7I13 (all specific for a combination of UL128, UL130 and UL131A) and from the epitope recognized by 4I22 (specific for a combination of UL130 and UL131A).

9I6 binds to an epitope which requires expression of hCMV UL128, UL130 and UL131A gene products and that is the same or largely overlapping to epitope(s) recognized by 2C12, 7B13, 8C15, 8J16 and 6G4 but distinct from the epitope recognized by 7I13 (all specific for a combination of UL128, UL130 and UL131A) and from the epitope(s) recognized by 2F4 and 5A2 (specific for a combination of UL130 and UL131A).

8I21 binds to an epitope which requires expression of hCMV gH, gL, UL128 and UL130 gene products and that may be partially overlapping to epitope(s) recognized by 4N10 and 5A2 (both specific for a combination of UL130 and UL131A) but distinct from epitopes recognized by 15D8

(specific UL128), 10F7, 10P3, 4I22, 1F11, 2F4 (all specific for a combination of UL130 and UL131A), 2C12, 7B13, 7I13, 8C15, 8J16, 9I6 and 6G4 (all specific for a combination of UL128, UL130 and UL131A). In addition binding of **8I21** to its epitope is not inhibited by 3G16 (specific for gH).

3G16 binds to an epitope in gH that is distinct from the epitope(s) recognized by 11B12 and 13H11 (both specific for gH).

11B12 binds to an epitope in gH that is the same or largely overlapping to the epitope recognized by 13H11 and distinct from the epitopes recognized by 3G16 (both specific for gH).

13H11 binds to an epitope in gH that is the same or largely overlapping to the epitope recognized by 11B12 and distinct from the epitopes recognized by 3G16 (both specific for gH).

6B4 recognizes an epitope in gB that is distinct from the epitope(s) recognized by 7H3, 4H9, 5F1, 10C6 and 2B11 (all specific for gB).

7H3 binds to an epitope in gB that is distinct from the epitope(s) recognized by 6B4, 7H3, 4H9, 5F1, 10C6 and 2B11 (all specific for gB).

10C6 binds to an epitope in gB that is the same or partially overlapping to the epitope(s) recognized by 5F1, 4H9 and 2B11, but distinct from the epitope(s) recognized by 7H3 and 6B4 (all specific for gB).

5F1 binds to an epitope in gB that is the same or largely overlapping to the epitope(s) recognized by 10C6, 4H9 and 2B11 but distinct from the epitope(s) recognized by 6B4 and 7H3 (all specific for gH).

4H9 binds to an epitope in gB that is the same or largely overlapping to the epitope(s) recognized by 5F1, 10C6 and 2B11, but distinct from the epitope(s) recognized by 6B4 and 7H3 (all specific for gH).

2B11 binds to an epitope in gB that is the same or largely overlapping to the epitope(s) recognized by 5F1, 10C6 and 4H9 but distinct from the epitope(s) recognized by 6B4 and 7H3 (all specific for gH).

Example 3: Breadth of neutralizing activity of antibody 15D8

UL128 is the most conserved gene of the UL132-128 locus. However, sequences derived from several clinical isolates revealed the existence of 10 variants with one or more mutations when compared to the VR1814 sequence. We therefore investigated whether the binding of the UL128-specific antibody 15D8 would be affected by any of these mutations. To this aim, published amino acid sequences of variants of UL128 from clinical isolates (VR4603-M, VR4836-M, VR5001-M, VR4254-M, VR4969-M, VR4313-M, VR4116-M, VR5235-T, VR5055-T, VR4168-A, VR1814-PCR) and laboratory strains (Towne, TB40/E, AD169, Merlin and Toledo) were aligned, and a gene was synthesized encoding a protein that includes all amino acid substitutions described as well as an additional mutation that we found to be generated at very high frequency *in vitro* upon PCR amplification (F33V). The nucleotide sequence of the synthetic gene was:

atgaacagcaaagacctgacgccgttcttgacgaccttgtggctgctattggaccacagccgcgtgccgcgggtacgcgcagaagaatgttgcg
aattcataaacgtcaaccacccgccggaacgctgttacgatttcaaaatgtgcaatctgttcaccgtcgcgctgcggtgtccggacggcgaagtct
gctacagtcccgagaaaacggctgagattcgcgggatcgtcaccaccatgacccattcattgacacgccaggtcatccacaacaaactgacga

gctgcaactacaatccgttatacctcgaagctgacgggcgaatacgctgcggcaaagtgagcgacaaggcgcagtacctgctgggcgccgct
ggcagcgttccctatcgatggatcaacctggaatacgacaagataacccggatcgtgggcctggatcagtacctggagagcgttaagaaacaca
aacggctggatgtgtgccgcgctaaaatgggctatatgctgcagtag.

HEK293T cells were transfected with the original UL128 from VR1814 or with the pan-mutated gene and stained with serial dilutions of 15D8 antibody. As shown in Figure 3, the original and the pan-mutated UL128 protein were recognized by 15D8 with comparable efficiency (saturated staining at ~ 0.2 μg/ml). These findings indicate that 15D8 recognize a highly conserved epitope in the UL128 encoded protein.

All patents and publications referred to herein are expressly incorporated by reference in their entirety.

It should be noted that there are alternative ways of implementing the present invention and that various modifications can be made without departing from the scope and spirit of the invention. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

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CLAIMS

1. An isolated antibody, or an antigen binding fragment thereof, that is specific for a complex of human cytomegalovirus (hCMV) proteins UL130 and UL131A, wherein the complex forms the epitope recognized by the antibody or fragment, comprising:

(a) heavy chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 49, 50, and 51, respectively, and light chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 52, 53, and 54, respectively;

(b) heavy chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 1, 2, and 3, respectively, and light chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 4, 5, and 6, respectively;

(c) heavy chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 33, 34, and 35, respectively, and light chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 36, 37, and 38, respectively;

(d) heavy chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 17, 18, and 19, respectively, and light chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 20, 21, and 22, respectively; or

(e) heavy chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 113, 114, and 115, respectively, and light chain CDR1, CDR2, and CDR3 sequences as set forth in SEQ ID NOs: 116, 117, and 118, respectively.

2. The antibody, or antigen binding fragment of claim 1, comprising:

(a) a heavy chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 61 and a light chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 62;

(b) a heavy chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 13 and a light chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 14;

(c) a heavy chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 45 and a light chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 46;

(d) a heavy chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 29 and a light chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 30; or

(e) a heavy chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 125 and a light chain variable region sequence having at least 85% sequence identity to SEQ ID NO: 126.

3. An isolated antibody, or an antigen binding fragment thereof, that is specific for a complex of hCMV proteins UL130 and UL131A, wherein the complex forms the epitope recognized by the antibody or fragment, comprising:

(a) heavy and light chain variable region sequences as set forth in SEQ ID NOs: 61 and 62, respectively;

(b) heavy and light chain variable region sequences as set forth in SEQ ID NOs: 29 and 30, respectively;

(c) heavy and light chain variable region sequences as set forth in SEQ ID NOs: 125 and 126, respectively; or

(d) heavy and light chain variable region sequences as set forth in SEQ ID NOs: 13 and 14, respectively.

4. An isolated antibody, or an antigen binding fragment thereof, that is specific for a complex of hCMV proteins UL130 and UL131A, wherein the complex forms the epitope recognized by the antibody or fragment, comprising heavy and light chain variable region sequences as set forth in SEQ ID NOs: 45 and 46, respectively.

5. An isolated antibody, or an antigen binding fragment thereof, that inhibits hCMV infection and binds to the same epitope as the antibody or fragment of claim 4, or competes for binding to hCMV with the antibody or fragment of claim 4.

6. The antibody or fragment of any one of the preceding claims, which inhibits hCMV infection and wherein the concentration of antibody required for 50% inhibition of hCMV is 0.01μg/ml or less.

7. The antibody or fragment of any one of the preceding claims, which binds a conformational epitope formed by the two proteins.

8. The antibody or fragment of any one of the preceding claims, wherein the

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antibody is a human antibody, a monoclonal antibody, a human monoclonal antibody, a single chain antibody, Fab, Fab', $F(ab')_2$, Fv or scFv.

9. An isolated nucleic acid molecule comprising a nucleotide sequence encoding a variable region of the antibody or fragment of any one of the preceding claims.

10. The nucleic acid molecule of claim 9, comprising a nucleotide sequence that is at least 85% identical to anyone of SEQ ID NOs: 63, 64, 15, 16, 47, 48, 31, 32, 127, or 128.

11. A vector comprising the nucleic acid molecule of claim 9 or 10.

12. An isolated cell comprising the vector of claim 11.

13. A composition comprising the antibody or fragment of any one of claims 1-8, or the nucleic acid of claim 9 or 10, and a pharmaceutically acceptable diluent or carrier and, optionally, a second antibody, or antigen binding fragment thereof, which inhibits hCMV infection.

14. The composition of claim 13, wherein the second antibody binds to

(a) a complex of hCMV UL130 and UL131A proteins;

(b) a complex of hCMV UL128, UL130, and UL131A proteins;

(c) a complex of hCMV gH, gL, UL128, and UL130 proteins;

(d) a complex of hCMV gM and gN proteins;

(e) an hCMV gH protein;

(f) an hCMV UL128 protein; or

(g) an hCMV gB protein.

15. The composition of claim 14, wherein the second antibody comprises heavy and light chain variable region sequences, respectively, as set forth in:

(a) SEQ ID NOs: 348 and 349;

(b) SEQ ID NOs: 328 and 329;

(c) SEQ ID NOs: 334 and 329;

(d) SEQ ID NOs: 290 and 291 ;

(e) SEQ ID NOs: 294 and 291;
(f) SEQ ID NOs: 357 and 291;
(g) SEQ ID NOs: 308 and 309;
(h) SEQ ID NOs: 314 and 309;
(i) SEQ ID NOs: 367 and 368;
(j) SEQ ID NOs: 13 and 14;
(k) SEQ ID NOs: 45 and 46;
(l) SEQ ID NOs: 258 and 259;
(m) SEQ ID NOs: 242 and 243;
(n) SEQ ID NOs: 228 and 229;
(o) SEQ ID NOs: 77 and 78;
(p) SEQ ID NOs: 141 and 142;
(q) SEQ ID NOs: 93 and 94;
(r) SEQ ID NOs: 157 and 158;
(s) SEQ ID NOs: 109 and 110;
(t) SEQ ID NOs: 170 and 171;
or an antibody which binds to the same epitope as the antibody of any one of (a) - (t).

16. The composition of claim 14, wherein the second antibody has heavy and light chains which respectively comprise SEQ ID NOs: 328 and 329, or SEQ ID NOs: 334 and 329.

17. Use of the antibody or fragment of any one of claims 1-8, the nucleic acid of claim 9 or 10, or the cell of claim 12, in the manufacture of a medicament for the treatment of hCMV infection.

18. A method for producing the antibody or fragment of any one of claims 1-8, comprising (i) culturing the cell of claim 12 and (ii) isolating the antibody or fragment.

19. An *in vitro* method of inhibiting hCMV infection in a cell, comprising contacting the cell with the antibody or fragment of any one of claims 1-8, wherein hCMV infection is inhibited.

20. The method of claim 19, further comprising the step of contacting the cell with a second antibody, or an antigen binding fragment thereof, which inhibits hCMV infection, wherein the cell is contacted by the antibodies or fragments simultaneously or sequentially.