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(54) Title: UNIVERSAL ANTI-CD22 CHIMERIC ANTIGEN RECEPTOR ENGINEERED IMMUNE CELLS

(57) Abstract: The present invention relates to an engineered immune cell endowed with a new CD22 Chimeric Antigen Receptors (CD22 CAR) with a deletion in the TRAC gene that is able to redirect said immune cell specificity and reactivity toward selected tumor cells. The engineered immune cells endowed with such CARs are particularly suited for treating relapsed refractory CD22 expressing cancers.

## UNIVERSAL ANTI-CD22 CHIMERIC ANTIGEN RECEPTOR ENGINEERED IMMUNE CELLS

### Field of the invention

The present invention generally relates to the field of immunotherapy, and more specifically to Universal chimeric antigen receptor T cells specific for CD22 (UCART22) that are engineered human primary immune cells comprising at least one edited gene, preferably a gene coding a TCR subunit or a CD52 gene, and a Chimeric Antigen Receptors (CAR) specific for the cluster of differentiation 22 (CD22), (CAR CD22), and to methods for engineering said cells. The invention further relates to UCART 22 for their use in patients who may or may not be the initial donor of cells ("allogenic" or "autologous" CD22 CAR engineered primary human immune cells) as a treatment for relapse refractory hematological cancers. The cells expressing a CD22 according to the invention are particularly efficient and safe for immunotherapy in particular against aggressive or relapsed cancer.

### Background of the invention

More than 45,000 deaths were expected from hematological cancer (non-Hodgkin's lymphoma, leukemia) in the United States in 2000 (Greenlee et al., CA Cancer J. Clin., 50:7-33 (2000)). The numbers published in 2014 were similar and despite advances in treatments such as chemotherapy, the prognosis for such cancers remains basically unchanged.(E K Mai, U Bertsch, J Dürig, C Kunz, M Haenel, I W Blau, M Munder, A Jauch, B Schurich, T Hielscher, M Merz, B Huegle-Doerr, A Seckinger, D Hose, J Hillengass, M S Raab, K Neben, H-W Lindemann, M Zeis, C Gerecke, I G H Schmidt-Wolf, K Weisel, C Scheid, H Salwender and H Goldschmidt. Phase III trial of bortezomib, cyclophosphamide and dexamethasone (VCD) versus bortezomib, doxorubicin and dexamethasone (PAd) in newly diagnosed myeloma. Leukemia (19 March 2015) | doi:10.1038/leu.2015.80.

Unique among the new investigational treatments for these hematologic cancers is the genetic modification of cells with cytolytic capacity such as T cells through the gene-transfer of a chimeric antigen receptor (CAR) (Jena, Dotti et al. 2010).

CARs are synthetic receptors consisting of a targeting moiety that is associated with one or more signaling intracellular domains in a single molecule or in multiple transmembrane domains forming a multimer. In particular CAR, the binding moiety consists of an antigen-binding domain from a single-chain antibody (scFv), comprising the variable fragments of a monoclonal antibody joined by a linker. Binding moieties based on receptor or ligand domains have also been used successfully to prepare a CAR.

5 Signaling domains from co-stimulatory molecules of the T cell receptor (TCR), as well as particular transmembrane and hinge domains have been added to form CARs of second and third generations, leading to successful therapeutic trials in humans. In these 10 studies, T-cells from a patient suffering a hematological ("liquid") cancer were redirected against malignant cells expressing for example CD19 or CD22 (June et al., 2011, Haso et al., 2013) and reinjected into the same patient. (Haso W, Lee DW, Shah NN, Stetler-Stevenson M, Yuan CM, Pastan IH, Dimitrov DS, Morgan RA, FitzGerald DJ, Barrett DM, Wayne AS, Mackall CL, Orentas RJ. Anti-CD22-chimeric antigen receptors 15 targeting B-cell precursor acute lymphoblastic leukemia. *Blood*. 2013 Feb 14;121(7):1165-74. doi: 10.1182/blood-2012-06-438002. Epub 2012 Dec 14).

Methods allowing immune cells from one individual to be engineered before reinjection to the same individual—usually suffering from a cancer— are not well adapted in particular for aggressive forms of cancers that may be a race against time. Moreover, 20 such method may be problematic or uncertain in patient whose immune system is altered.

To palliate this problem, immunotherapy using CAR-expressing so called "allogeneic" T cells (also called universal or "off the shelf" T cells) was recently implemented and the two first patients treated with such cells are still in remission about two years after 25 treatment.

Nevertheless, there are still aspects of such therapy that may be improved, such as efficiency in the presence of anti-T cell drugs, efficiency against escaping cancer cells, persistence, means of control, etc. Indeed, it seems that cancer cells – by downregulating the expression of surface antigen recognized by CARs, may escape the 30 treatment and subsist, despite the persistence of redirected immune in treated patients.

Further, one the primary adverse, and sometimes lethal, effect observed in patients treated either with autologous or allogeneic T cells, is the cytokine release syndrome.

Thus, there is still a need for developing efficient and safe treatments for these pathologies, in particular for their aggressive or refractory/relapsed forms of hematological cancers.

5

### **BRIEF SUMMARY OF THE INVENTION**

Here, the inventors have developed a new efficient treatment ("UCART22") comprising engineered primary human T cell with at least a deletion of the TRAC gene, endowed with a chimeric antigen receptor targeting CD22 and a safety marker allowing the number of said cells to be controlled in vivo and consequently the activity of said cells.

In the new efficient treatment ("UCART22") comprising engineered primary human T cell with at least a deletion of the TRAC gene, at least one additional deletion in CD52, dCK, beta2microglobulin are gene is contemplated.

These new UCART22 are particularly efficient for adoptive transfer in a patient suffering a CD22 mediated pathology, whether or not said patient is the initial donor of immune cells and whether or not said patient is already under therapy that affects immunity.

UCART 22 cells of the invention are resistant to at least one chemical or antibody drug usually used to treat CD22-mediated pathology, such as Campath and/or Purine nucleotide analogs (PNAs). UCART 22 cells of the invention can survive and be active in the presence of said drug used at a dose that kills more than 80% of the cells.

Significant and unexpected clinical advantages of the engineered isolated primary immune cells UCART 22 are observed, including low cytokine release, no or very mild graft versus host disease and still a significant activity against the refractory relapsed forms of hematological cancer cells.

Other advantages will be disclosed in this study.

This study which provides

1. An engineered human T Cell Receptor Knock Out (TCR KO) cell endowed with a Chimeric Antigen Receptor (CAR) specific for CD22 (UCART 22), a safety switch, preferably expressed at the cell surface, said anti-CD22 CAR (CD22 CAR) comprising:

i) at least one extracellular domain comprising :

5      - a hinge domain from CD8alpha,  
- an antigen binding domain specific for CD22, optionally a leader sequence,  
ii) a transmembrane domain from CD8alpha, and  
iii) an intracellular signaling domain said CD22 CAR having a polypeptide sequence with at least 80% identity with SEQ ID N°15,

10     said safety switch comprising :

- a RQR8 temporarily linked to the CD22 CAR by a peptide 2A, or  
- at least two rituximab mAb-specific epitopes, preferably located between the VH and the Hinge domain, or 3 rituximab mAb-specific epitopes or 3 rituximab mAb-specific epitopes and a QBEN-10 mAb-specific epitopes linked to the CD22 CAR.

15     2. The UCART 22 of embodiment 1 wherein a polynucleotide sequence having at least 80% identity with SEQ ID N°11 is inserted into the genome, and further comprising an inactivated TRAC gene with an insertion, a deletion or a mutation within SEQ ID N°18, with

undetectable level of T Cell Receptor (TCR) at the cell surface as measured by flow cytometry, and undetectable level of off site events as measured by guide sequence  
20     technique.

The UCART22 according to 2 wherein said anti-CD22 CAR is inserted preferably into the TRAC gene, preferably with SEQ ID N°18.

3. The UCART22 according to any one of embodiment 1 to 2 comprising another inactivated gene selected from dCK gene, B2M gene, CD52 gene, preferably CD52 gene.

25     4. The UCART22 according to any one of embodiment 1 to 3 wherein and at least one additional gene is inactivated, said gene is selected from a gene encoding aryl hydrocarbon receptor (AHR), Transforming growth factor beta receptor (TGF beta receptor), Interleukin 10 receptor (IL-10 R), Program cell death protein 1, a combination thereof.

5. The UCART22 according to any one of embodiment 1 to 4 wherein a gene encoding beta2Microglobulin (B2M), is inactivated.

6. The UCART22 according to any one of embodiment 1 to 5 wherein a gene encoding aryl hydrocarbon receptor (AHR), is inactivated.

5 7. The UCART22 according to any one of embodiment 1 to 6 wherein a gene encoding Transforming growth factor beta receptor) (TGF beta receptor), is inactivated.

8. The UCART22 according to any one of embodiment 1 to 7 wherein a gene encoding Interleukin 10 receptor (IL-10 R), is inactivated.

9. The UCART22 according to any one of embodiment 1 to 8 wherein a gene encoding 10 Program cell death protein 1 (PD1), is inactivated.

5. The UCART22 according to any one of embodiment 1 to 4 comprising an additional scfv specific for any one of the following tumor-associated surface antigens selected from CD19, CD20, CD30, a major histocompatibility complex (MHC) molecule, an Immunoglobulin (Ig), CD3, CD5, CD34, CD79, preferably CD79b, CD138, B7-1 (CD80), BCMA (CD269, TNFRSF 17), 15 FLT-3, or PAX5, preferably CD19.

6. The UCART22 according to any one of embodiment 1 to 5 wherein said CD22CAR further comprises an antigen binding domain specific for CD19 or wherein said UCART 22 further comprises a CD19CAR, preferably a CD19 CAR having at least 80% identity with SEQ ID N°25 20 or a SEQ ID N°26.

7. The UCART22 according to any one of embodiment 1 to 5 wherein the anti-CD22 CAR is a single-chain CAR or a multi-chain CAR.

25 8. The UCART22 according to any one of embodiment 5 or 6 wherein the anti-CD19 CAR is a single-chain CAR or a multi-chain CAR.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD19.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD20.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD30.

5 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for a major histocompatibility complex (MHC) molecule.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for an Immunoglobulin (Ig).

10 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD3.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD5.

15 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD34.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD79, preferably CD79b.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD138.

20 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD80.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for BCMA (CD269).

25 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for TNFRSF 17,

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for FLT-3.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain

30 CAR comprising an additional scfv specific for CD19.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR, comprising an additional scfv specific for CD79 a or CD79b.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD20.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain

5 CAR comprising an additional scfv specific for CD30.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for a major histocompatibility complex (MHC) molecule.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain

10 CAR comprising an additional scfv specific for an Immunoglobulin (Ig).

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD3.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD5.

15 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD34.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD138.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain

20 CAR comprising an additional scfv specific for CD80.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for BCMA (CD269).

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for TNFRSF 17,

25 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for FLT-3.

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9. A population of UCART cells comprising the UCART 22 according to any one of embodiment 1 to 8.

10. The population of UCART cells according to embodiment 9 comprising a UCART 19, preferably a UCART19 expressing an anti-CD19 CAR comprising a sequence of SEQ ID N°25 or SEQ ID N°26 at the cell surface.
11. A kit comprising a UCART 22 and a UCART19 for a successive (at least once) or a 5 concomitant or a successive (at least once) and then concomitant administration in a patient in need thereof.
12. The kit of embodiment 11 wherein the UCART 19 is used first at least once, twice, three, four or several times, and then the UCART 22, alone or with the UCART19.
13. The kit of embodiment 11 or 12 wherein the UCART 22 is used first at least once, twice, 10 three, four or several times, and then the UCART 19, alone or with the UCART22.
14. The kit according to any one of embodiment 11 to 13 further comprising a lymphodepleting treatment, administered before the UCART.
15. The kit according to any one of embodiment 11 to 14 wherein lymphodepletion is achieved using fludarabine and cyclophosphamide, preferably fludarabine 25 mg/m<sup>2</sup> i.v. × 5 doses 15 on days -6 to -2 and cyclophosphamide 60 mg/kg i.v. for 1 dose on day -5.
16. The kit according to any one of embodiment 11 to 15 comprising at least one other UCART cell directed against a cancer antigen selected from CD79a, CD79b, CD20, CD30, CD52, CD40, CD80, CD86, CD74, VEGF.
17. A pharmaceutical composition comprising the UCART 22 according to any one of 20 embodiment 1 to 8 or a population of cells comprising said UCART 22 according embodiment 9 or 10 and a pharmaceutically acceptable excipient.
18. The pharmaceutical composition of embodiment 17 further comprising a Bryostatin, preferably Bryostatin-1.
19. The pharmaceutical composition of embodiment 17 or 18 or the kit according to any one 25 of embodiment 11 to 16 for its use as a medication for preventing or treating a patient suffering a CD22+-mediated cancer or a CD22+-mediated inflammatory disease.

20. The pharmaceutical composition of according to any one of embodiment 17 to 18 or the kit according to any one of embodiment 11 to 16 for its use as a medication for preventing or treating a patient suffering a CD19+-mediated cancer or a CD19+-mediated inflammatory disease.

5 21. The pharmaceutical composition of according to any one of embodiment 17 to 18 or the kit according to any one of embodiment 11 to 16 for its use as a medication for preventing or treating a patient suffering a CD19+CD22+-mediated cancer or a CD19+CD22+-mediated inflammatory disease.

10 22. The pharmaceutical composition of according to any one of embodiment 17 to 18 or the kit according to any one of embodiment 11 to 16 for its use according any one of embodiment 19 or 21, wherein treating a patient comprises a step of administering the pharmaceutical composition at least twice (re dosing) to avoid a relapse /refractory development of the cancer.

15 23. The pharmaceutical composition of according to any one of embodiment 17 to 18 or the kit according to any one of embodiment 11 to 16 for its use according any one of embodiment 19 or 21, for the treatment of a CD22-mediated hematological cancer selected from lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and

20 Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, preferably a CD22 expressing hematological cancer selected from (lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, more preferably a relapse refractory CD22-expressing

25 hematological cancer, even more preferably an aggressive form of said CD22-related hematological cancer.

30 24. The pharmaceutical composition of according to any one of embodiment 17 to 18 or the kit according to any one of embodiment 11 to 16 for its use according any one of embodiment 20 or 21 for the treatment of a CD19-mediated hematological cancer selected from lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma,

B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, preferably a CD19 expressing hematological cancer selected from (lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, more preferably a relapse refractory CD19-expressing hematological cancer, even more preferably an aggressive form of said CD19-related hematological cancer.

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10 25. The pharmaceutical composition of according to any one of embodiment 17 to 18 or the kit according to any one of embodiment 11 to 16 for its use according any one of embodiment 19 to 22 for the treatment of a relapse or refractory expressing B ALL, preferably as a pediatric indication.

15 26. The pharmaceutical composition of according to any one of embodiment 17 to 18 or the kit according to any one of embodiment 11 to 16 for its use according any one of embodiment 19 to 25, wherein treating a patient comprises administering at least one monoclonal antibody (mAb), preferably QBEN 10 and or Rituximab, in a patient, at a dose allowing contacting said UCART22 with at least one specific mAb.

20

### **Embodiments for a CD22 CAR**

The invention provides an anti-CD22 CAR comprising a hinge domain selected from FcRIII $\alpha$ , CD8alpha, IgG1, IgG4, and PD1, preferably from CD8 alpha or IgG4.

The ANTI-CD22 CAR according the above wherein a scfv specific for CD22 comprising a VH 25 and a VL linked to each other by a linker L1, preferably a linker comprising 1 to 3 "GGGGS" motif, more preferably one GGGGS" motif.

The ANTI-CD22 CAR according to any one of the above wherein said scfv specific for CD22 is linked to a transmembrane domain by a hinge selected from a hinge from FcRIII $\alpha$ , CD8alpha, IgG1, preferably from CD8 alpha.

The ANTI-CD22 CAR according to any one of the above comprising an intracellular domain, said an intracellular domain comprising a CD3zeta signaling domain and a 4-1BB signaling domain.

The anti-CD22 CAR as any one of the above wherein the anti-CD22 CAR comprises at least 5 one, preferably two, three or four monoclonal antibody (mAb)-specific epitopes, preferably two inserted into the linker L of the scfv specific for CD22 and/or into the hinge.

The anti-CD22 CAR as any one of the above, wherein the mAb-specific epitope is a polypeptide selected from: CPYSNPSLC, NSELLSLINDMPITNDQKKLMSNN, CQFDLSTRRLKC, CQYNLSSRALKC, CVWQRWQKSYVC, CVWQRWQKSYVC, SFVLNWYRMSPSNQTDKLAAPEDR, 10 SGTYLCGAISLAPKAQIKE, ELPTQGTFSNVSTNVSPAKPTTTA, ELPTQGTFSNVSTNVSPAKPTTTA, GQNDTSQTSSPS, preferably ELPTQGTFSNVSTNVSPAKPTTTA and/or CPYSNPSLC (SEQ ID N°19).

The invention provides a polynucleotide encoding an ANTI-CD22 CAR according to any one of the above or a polynucleotide having at least 80% identity with said a polynucleotide 15 encoding an ANTI-CD22 CAR, a vector comprising a polynucleotide according to any one of the above polynucleotides .

as disclosed herein below other genes are edited in said UCART22 in particular the dCK gene, the B2M gene, CD52 gene.

### **UCART PROVIDED**

20 The UCART22 as above is provided wherein and at least one additional gene is edited or engineered, said gene is selected from a gene encoding aryl hydrocarbon receptor (AHR), Transforming growth factor beta receptor) (TGF beta receptor), Interleukin 10 receptor (IL-10 R), Program cell death protein 1, a combination thereof.

The UCART22 as above wherein and at least one additional gene comprises a mutation, a 25 deletion or an insertion inactivating its activity and /or expression said gene selected from a gene encoding aryl hydrocarbon receptor (AHR), Transforming growth factor beta receptor) (TGF beta receptor), Interleukin 10 receptor (IL-10 R), Program cell death protein 1, a combination thereof.

The UCART22 as above wherein and at least one additional gene comprises a mutation, a deletion or an insertion inactivating its activity and /or expression said gene selected from a gene encoding aryl hydrocarbon receptor (AHR), Transforming growth factor beta receptor) (TGF beta receptor), Interleukin 10 receptor (IL-10 R), a combination thereof.

5 The UCART22 as above wherein and at least one additional gene comprises a mutation, a deletion or an insertion inactivating its activity and /or expression said gene selected from a gene encoding Transforming growth factor beta receptor) (TGF beta receptor), Interleukin 10 receptor (IL-10 R), Program cell death protein 1, a combination thereof.

10 The UCART22 as above wherein and at least one additional gene comprises a mutation, a deletion or an insertion inactivating its activity and /or expression said gene selected from a gene encoding aryl hydrocarbon receptor (AHR), Interleukin 10 receptor (IL-10 R), Program cell death protein 1, a combination thereof.

15 The UCART22 as above wherein and at least one additional gene comprises a mutation, a deletion or an insertion inactivating its activity and /or expression said gene selected from a gene encoding aryl hydrocarbon receptor (AHR), Transforming growth factor beta receptor) (TGF beta receptor), Program cell death protein 1, a combination thereof.

Gene in which said CAR may be inserted are described below in Table 9

**Table 9:** List of genes encoding immune checkpoint proteins that may be inactivated according to the present invention in the CD22 CAR engineered T cells of the invention

Pathway	Genes that can be inactivated In the pathway	
Co-inhibitory receptors	CTLA4 (CD152)	
	PDCD1 (PD-1, CD279)	
	CD223 (lag3)	
	HAVCR2 (tim3)	
	BTLA(cd272)	
	CD160(by55)	
	IgSF family	TIGIT
		CD96
		CRTAM
	LAIR1(cd305)	
Death receptors	SIGLECs	LAIR1
		SIGLEC7
	CD244(2b4)	SIGLEC9
Death receptors	TRAIL	CD244
		TNFRSF10B, TNFRSF10A, CASP8,

		CASP10, CASP3, CASP6, CASP7
	FAS	FADD, FAS
Cytokine signalling	TGF-beta signalling	<b>TGFBRII, TGFBRI, SMAD2, SMAD3, SMAD4, SMAD10, SKI, SKIL, TGIF1</b>
	IL10 signalling	<b>IL10RA, IL10RB, HMOX2</b>
	IL6 signalling	IL6R, IL6ST
Prevention of TCR signalling		CSK, PAG1
		SIT1
Induced Treg	induced Treg	FOXP3
Transcription factors controlling exhaustion	transcription factors controlling exhaustion	PRDM1 (=blimp1, heterozygotes mice control chronic viral infection better than wt or conditional KO)
		BATF
Hypoxia mediated tolerance	iNOS induced guanylated cyclase	GUCY1A2, GUCY1A3, GUCY1B2, GUCY1B3

In bold are the preferred gene inactivated in the UCART of the invention

The UCART22 as above comprising an anti-CD22 CAR (UCART22) according to any one of the

above and a polynucleotide coding said anti-CD22 CAR (UCART22) inserted into the genome,

5 into the CD25 gene.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR or a multi-chain CAR.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain

10 CAR comprising an additional scfv specific for any one of the following tumor-associated surface antigens selected from CD19, CD20, CD30, a major histocompatibility complex (MHC) molecule, an Immunoglobulin (Ig), CD3, CD5, CD34, CD79, preferably CD79b, CD138, B7-1 (CD80), BCMA (CD269, TNFRSF 17), FLT-3, or PAX5, preferably CD19.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain

15 CAR comprising an additional scfv specific for CD19.

The UCART22 according to any one of the above expressing an anti-CD22 CAR and an anti-CD19CAR, preferably of SEQ ID N°94 or of SEQ ID N°95.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD20.

20 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD30.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for a major histocompatibility complex (MHC) molecule.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain

5 CAR comprising an additional scfv specific for an Immunoglobulin (Ig).

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD3.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD5.

10 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD34.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD79, preferably CD79b.

15 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD138.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for CD80.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for BCMA (CD269).

20 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for TNFRSF 17,

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a single-chain CAR comprising an additional scfv specific for FLT-3.

25 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD19.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain

30 CAR, comprising an additional scfv specific for CD79 a or CD79b.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain (mc) CAR comprising an additional scfv specific for CD19.

The UCART22 according to any one of the above expressing an anti-CD22 mcCAR and an anti-CD19CAR, preferably of SEQ ID N°94 or of SEQ ID N°95.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD20.

5 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD30.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for a major histocompatibility complex (MHC) molecule.

10 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for an Immunoglobulin (Ig).

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD3.

15 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD5.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD34.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD138.

20 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for CD80.

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for BCMA (CD269).

25 The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for TNFRSF 17,

The UCART22 according to any one of the above wherein the anti-CD22 CAR is a multi-chain CAR comprising an additional scfv specific for FLT-3.

A population of cells comprising the UCART 22 according to any one of the above.

30 A population of cells comprising the UCART 22 according to any one of the above and wherein cells expressing said anti-CD22 CAR also express an anti-CD19 CAR, preferably said anti-CD19 CAR comprises a sequence of SEQ ID N°25 or SEQ ID N°26 at the cell surface.

A CD22 CAR T cell (UCART22), optionally combined to a protein kinase C inhibitor such as bryostatin 1 as a pharmaceutical composition of the invention, is particularly useful in for the treatment of CLL, ALL, Multiple myeloma, (MM), Blastic plasmacytoid dendritic cell neoplasm (BPDCN), especially refractory / relapse ALL, refractory / relapse CLL and or 5 aggressive forms of these diseases, more preferably refractory or relapse B-ALL.

A CD22 CAR T cell (UCART22), derived from m971, optionally combined to a protein kinase C inhibitor such as bryostatin 1 as a pharmaceutical composition of the invention, is particularly useful in for the treatment of CLL, ALL, Multiple myeloma, (MM), Blastic 10 plasmacytoid dendritic cell neoplasm (BPDCN), especially refractory / relapse ALL, refractory / relapse CLL and or aggressive forms of these diseases, more preferably refractory or relapse B-ALL.

The engineered immune cells of the present invention not only display high level of in vivo 15 activity toward malignant cells, less cytokine release but also their number and activity is controlled conferring safety and efficiency for immunotherapy.

The present invention provides an engineered human T Cell Receptor Knock Out (TCR KO) cell endowed with a Chimeric Antigen Receptor specific for CD22 (CD22 CAR) (UCART 22), 20 preferably expressed at the cell surface,

wherein said CD22 CAR comprises:

i) at least one extracellular domain comprising :

- a hinge domain from CD8alpha,  
- an antigen binding domain specific for CD22, optionally a leader sequence,

25 ii) a transmembrane domain from CD8alpha, and

iii) an intracellular signaling domain.

said UCART22 comprising at least one additional edited gene, preferably a deletion in the CD52 gene.

The present invention also provides the UCART CD22 as above wherein the antigen 30 binding domain comprises a scfv specific for CD22, derived from a m917 antibody

(m971), preferably said scfv comprises a sequence selected from SEQ ID N° 12, SEQ ID N° 13, SEQ ID N° 14 and from SEQ ID N° 15, more preferably a sequence from SEQ ID N°.15.

In one embodiment the present invention also provides an engineered human T Cell Receptor Knock Out (TCR KO) cell endowed with a Chimeric Antigen Receptor specific for CD22 (CD22 CAR) (UCART 22), preferably expressed at the cell surface,

wherein said CD22 CAR comprises:

i) at least one extracellular domain comprising :

- a hinge domain from CD8alpha,

- an antigen binding domain specific for CD22, optionally a leader sequence,

ii) a transmembrane domain from CD8alpha, and

iii) an intracellular signaling domain.

said UCART22 comprising at least one additional edited gene, preferably a deletion in the CD52 gene

and wherein the antigen binding domain comprises a scfv specific for the distal part of CD22, said CAR having a SEQ IDN°20.

The UCART CD22 according to the above comprising the following sequences :

QVQLQQSGPGLVKPSQTLSTCAISGDSVSSNSAAWNWIRQSPSRGLEWLGRYYRSKWYNDYAV  
SVKSRITINPDTSKNQFSLQLNSVTPEDTAVYYCAREVTGDLEAFDIWGQGTMVTVSS and  
DIQMTQSPSSLSASVGDRVTITCRASQTIWSYLNWYQQRPGKAPNLLIYAASSLQSGVPSRFSGRGS  
GTDFTLTSSLQAEDFATYYCQQSYSIPQTFGQGTKLEIK or having 80 to 99 % homology with each of said sequences.

The present invention also provides a UCART 22 as above comprising a polypeptide of SEQ ID NO15 and a safety switch comprising :

. a RQR8 temporarily linked to the CD22 CAR by a peptide 2A or  
. at least two rituximab mAb-specific epitopes, preferably 3 rituximab mAb-specific epitopes and more preferably 3 rituximab mAb-specific epitopes and a QBEN-10 mAb-specific epitopes linked to the CD22 CAR.

[allowing both sorting and/or depletion of the immune cells endowed with said CD22 CAR].

The present invention also provides a UCART 22 as above comprising at least one additional edited gene, preferably a deletion in CD52 gene, or in a dCK gene or a deletion in a beta2 microglobulin gene or in CTIIA gene, even more preferably a deletion in CD52 gene, and/or an insertion in the HIF-1alpha gene, conferring resistance to hypoxia.

The present invention provides a UCART 22 as above comprising a deletion in CD52 gene, in combination with alemtuzumab.

10 The present invention also provides a UCART 22 as above wherein said CD22 CAR is expressed under hypoxia (low O<sub>2</sub> concentration that is less than 5% O<sub>2</sub>, preferably less than 1% O<sub>2</sub>).

15 The present invention also provides a UCART 22 as above comprising a polynucleotide encoding a polypeptide comprising a CD22 CAR and a safety switch. In a preferred embodiment, the present invention provides a UCART 22 as above comprising a polynucleotide of SEQ ID NO. 22 and of SEQ IDN°18 in the same gene, preferably in the TRAC gene.

20 The present invention also provides a UCART 22 as above comprising a polynucleotide encoding a polypeptide comprising a CD22 CAR and a safety switch. In a preferred embodiment, the present invention provides a UCART 22 as above comprising a polynucleotide of SEQ ID NO. 20 and of SEQ IDN°18 in the same gene, preferably in the TRAC gene.

The present invention provides a population of cells comprising a UCART 22 as above.

25 The present invention provides a pharmaceutical composition comprising either the UCART 22 as above or a population of cells comprising said UCART 22 any of the above and a pharmaceutically acceptable excipient.

In particular embodiments, a pharmaceutical composition comprising the UCART 22 according to the invention or a population of cells comprising said UCART 22 in

combination with a UCART CD19 and a pharmaceutically acceptable excipient is provided. UCART 19 and UCART 22 may be given at the same time, concomitantly or successively starting by UCART 19 or by UCART 22 as a function of CD19 and CD22 expression level a cancer cells of patients.

5 In particular embodiments, a pharmaceutical composition comprising the UCART 22/19 or UCART 19/22 (bispecific CAR single chain or multichain CAR or cells expressing both CD19CAR and CD22 CAR) and a pharmaceutically acceptable excipient, is provided. The present invention provides a pharmaceutical composition as above further comprising a compound of the bryostatin family, preferably bryostatin 1.

10 The present invention provides a therapeutically effective amount of UCART 22 as above or of the pharmaceutical composition comprising said UCART 22 as above for use as a medication for treating a patient.

15 The present invention provides a therapeutically effective amount of UCART 22 as above or of the pharmaceutical composition as above for use as a medication for treating a patient wherein treating a patient comprises administering at least two times (re dosing) said therapeutically effective amount of UCART CD22 or said pharmaceutical composition for avoiding a relapsing.

20 In a particular embodiment, the present invention provides a UCART CD22 according to any one of the above or the pharmaceutical composition according to any one of the above for use as a medication for treating a patient wherein treating a patient comprises administering a UCART 22 as above or a pharmaceutical composition as above at least two times for avoiding the relapsing.

25 The present invention provides a therapeutically effective amount of UCART 22 as above or of the pharmaceutical composition as above for use as a medication for treating a patient as above for the treatment of a CD22-related pathology, preferably a CD22-related B-cell malignancy (eg CD22-related hematological cancer).

In a particular embodiment, the present invention provides:

The therapeutically effective amount of UCART 22 as above or of the pharmaceutical composition as above for use as a medication for the treatment of a hematological

cancer such as a hematological cancer selected from (lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, preferably a CD22-expressing hematological cancer, more preferably a relapse refractory CD22-expressing hematological cancer, even more preferably an aggressive form of said CD22-related hematological cancer.

5 Preferably the UCART22 is used for treating patients with relapse refractory B ALL.

The present invention provides a therapeutically effective amount of UCART 22 as above 10 or of a pharmaceutical composition as above for use as a medication for treating a patient wherein said patient suffers from a cancer selected from alveolar rhabdomyosarcoma, bladder cancer (e.g., bladder carcinoma), bone cancer, brain cancer (e.g., medulloblastoma), breast cancer, cancer of the anus, anal canal, or anorectum, cancer of the eye, cancer of the intrahepatic bile duct, cancer of the joints, 15 cancer of the neck, cancer of the gallbladder, cancer of the pleura, cancer of the nose, cancer of the nasal cavity, cancer of the middle ear, cancer of the oral cavity, cancer of the vulva, chronic lymphocytic leukemia, chronic myeloid cancer, colon cancer, esophageal cancer, cervical cancer, fibrosarcoma, gastrointestinal carcinoid tumor, head and neck cancer (e.g., head and neck squamous cell carcinoma), hypopharynx cancer, 20 kidney cancer, larynx cancer, liver cancer, lung cancer (e.g., non-small cell lung carcinoma), malignant mesothelioma, mastocytoma, melanoma, nasopharynx cancer, ovarian cancer, pancreatic cancer, peritoneum cancer, omentum cancer, mesentery cancer, pharynx cancer, prostate cancer, rectal cancer, renal cancer, skin cancer, small intestine cancer, soft tissue cancer, solid tumors, stomach cancer, testicular cancer, 25 thyroid cancer, ureter cancer.

The present invention provides:

1. An engineered human T Cell Receptor Knock Out (TCR KO) cell endowed with a Chimeric Antigen Receptor (CAR) specific for CD22 (UCART 22), preferably expressed at the cell surface,

30 wherein said anti-CD22 CAR comprises:

i) at least one extracellular domain comprising :

- a hinge domain from CD8alpha,
- an antigen binding domain specific for CD22, optionally a leader sequence,

ii) a transmembrane domain from CD8alpha, and

iii) an intracellular signaling domain.

said UCART22 comprising at least one additional edited gene, preferably a CD52 inactivated gene, a dCK inactivated gene, a beta 2 microglobulin inactivated gene or an inserted HIF-1alpha gene.

The UCART CD22 according to 1 wherein the antigen binding domain comprises a scfv specific for CD22, said scfv is derived from a m917 antibody (m971), preferably said scfv comprises a sequence selected from SEQ ID N° 12, SEQ ID N° 13, SEQ ID N° 14 or from SEQ ID N° 15, more preferably a sequence from SEQ ID N° 15.

The UCART 22 according to any one of 1 to 2 comprising a polypeptide of SEQ ID NO15 and a safety switch, said safety switch comprising :

- a RQR8 temporarily linked to the CD22 CAR by a peptide 2A,
- at least two rituximab mAb-specific epitopes, preferably 3 rituximab mAb-specific epitopes and more preferably 3 rituximab mAb-specific epitopes and a QBEN-10 mAb-specific epitopes linked to the CD22 CAR

[allowing both sorting and/or depletion of the immune cells endowed with said CD22 CAR].

The UCART 22 according to any one of 1 to 3 comprising a CD52 inactivated gene, even more preferably a CD52 inactivated gene and HIF-1alpha inserted gene conferring resistance alemtuzumab and to hypoxia.

The UCART 22 according to any one of 1 to 4 wherein said anti-CD22 CAR is expressed at the cell surface under low O2 concentration( <5% O2).

The UCART 22 according to any one of 1 to 5 comprising a polynucleotide encoding a polypeptide comprising an anti-CD22 CAR as in 1 to 5.

UCART 22 according to any one of the above comprising an anti-CD22 CAR at the cell surface, a polynucleotide encoding said anti-CD22 CAR inserted into the TRAC gene and anogenous polynucleotide sequence encoding IL-12 inserted into the CD25 genomic sequence, the B2M genomic sequence or into the PD1 genomic sequence.

The UCART 22 according to any one of the above comprising an anti-CD22 CAR at the cell surface, a polynucleotide encoding said anti-CD22 CAR inserted into the TRAC gene and an exogenous polynucleotide sequence encoding IL-12 inserted into the CD25 genomic sequence or into the PD1 genomic sequence and further comprising genomic KO gene

5 selected from IL-10Receptor, TGFbeta receptor, TIM-3, LAG-3, (see table 9 above).

7. The UCART 22 according to any one of 1 to 6 further comprising a polynucleotide of SEQ ID NO. 22, preferably comprising a sequence of SEQ ID N°18 and 22 in the same TRAC gene.

8. A population of cells comprising said UCART 22 according to any one of 1 to 7.

10 9. A pharmaceutical composition comprising the UCART 22 according to any one of 1 to 7 or a population of cells comprising said UCART 22 according to 8 and a pharmaceutically acceptable excipient.

10. The pharmaceutical composition according to 9 further comprising a bryostatin, preferably bryostatin-1.

15 11. A therapeutically effective amount of UCART 22 according to any one of 1 to 7 or of the pharmaceutical composition according to 9 or 10 for use as a medication for treating a patient.

20 12. The therapeutically effective amount of UCART 22 according to any one of 1 to 7 or of the pharmaceutical composition according to 9 or 10 for use as a medication for treating a patient according to 11 wherein treating a patient comprises administering at least two times (re dosing) said therapeutically effective amount of UCART CD22 or said pharmaceutical composition for avoiding a relapsing.

25 13. The therapeutically effective amount of UCART 22 according to any one of 1 to 7 or of the pharmaceutical composition according to 9 or 10 for use as a medication for treating a patient according to 11 or 12 for the treatment of a CD22-related pathology, preferably a CD22-related B-cell malignancy.

30 14. The therapeutically effective amount of UCART 22 according to any one of 1 to 7 or of the pharmaceutical composition according to 9 or 10 for use as a medication for treating a patient according to any one of 11 to 13 for use in the treatment of a hematological cancer selected from (lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma,

leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, preferably a CD22-expressing hematological cancer, more preferably a relapse or refractory CD22-expressing hematological cancer, even more preferably an aggressive form of said CD22-related hematological cancer.

5

15. The therapeutically effective amount of UCART 22 according to any one of 1 to 7 or of the pharmaceutical composition according to 9 or 10 for use as a medication for treating a patient according to any one of 11 to 13 for use in the treatment of relapsed and/or  
10 refractory CD22 positive B-ALL.

10

16. The therapeutically effective amount of UCART 22 according to any one of 1 to 7 or of the pharmaceutical composition according to 9 or 10 for use as a medication for treating a patient according to any one of 11 to 13 wherein said patient suffers from a cancer, 15 preferably mediated by CD22+cells, selected from alveolar rhabdomyosarcoma, bladder cancer (e.g., bladder carcinoma), bone cancer, brain cancer (e.g., medulloblastoma), breast cancer, cancer of the anus, anal canal, or anorectum, cancer of the eye, cancer of the intrahepatic bile duct, cancer of the joints, cancer of the neck, cancer of the gallbladder, cancer of the pleura, cancer of the nose, cancer of the nasal cavity, cancer 20 of the middle ear, cancer of the oral cavity, cancer of the vulva, chronic lymphocytic leukemia, chronic myeloid cancer, colon cancer, esophageal cancer, cervical cancer, fibrosarcoma, gastrointestinal carcinoid tumor, head and neck cancer (e.g., head and neck squamous cell carcinoma), hypopharynx cancer, kidney cancer, larynx cancer, liver cancer, lung cancer (e.g., non-small cell lung carcinoma), malignant mesothelioma, 25 mastocytoma, melanoma, nasopharynx cancer, ovarian cancer, pancreatic cancer, peritoneum cancer, omentum cancer, mesentery cancer, pharynx cancer, prostate cancer, rectal cancer, renal cancer, skin cancer, small intestine cancer, soft tissue cancer, solid tumors, stomach cancer, testicular cancer, thyroid cancer, ureter cancer, preferably liver cancer and lung cancer.

20

25

30

#### **Brief description of the figures**

**Figure 1:** Schematic representation of an engineered immune cell according to the invention

The engineered immune cell presented in figure 1 may be a T-cell endowed with a polynucleotide encoding a CAR of the invention. This T-cell is further engineered to allow a better and safer engraftment into the patient. X, or Y is an edited gene that may be mutated, deleted and/or having an insertion. For instance a gene expressing a component of the T cell receptor (TCR) for example the TCRalpha or TCRbeta may be deleted or may comprise an insertion, Y may be a gene involved into the sensitivity of T-cells to immune-suppressive drugs like dCK (with respect to resistance to purine nucleotide analogues) or CD52 (with respect to Campath) or HPRT (with respect to 6-Thioguanine).

**Figure 2:** Representation of a single chain and of a multichain CD22 CAR

Figure 2 illustrates examples of CD22 CAR according to the invention, comprising a scfv specific for CD22, optionally comprising a safety switch, a hinge and a transmembrane domain from CD8 alpha, an intracellular domains from 4-1BB and CD3 zeta, optionally a domain conferring resistance to hypoxia.

**Figure 3:** Examples of CD22 CAR constructs of the invention comprising a safety switch.

At least a rituximab (R) mAb-specific epitopes (black box), preferably 3 rituximab mAb-specific epitopes and more preferably 3 rituximab mAb-specific epitopes and a QBEN-10 (Q) mAb-specific epitopes (grey box) are inserted into the CD22 CAR

R may be inserted into the scfv, between a VH and a VL domain (or a VL and a VH domain) and/or into the hinge.

**Figure 4:** Example of a polypeptide coded by a polynucleotide

Figure 4 represents one example of polypeptide which will be cleaved so that a safety switch (RQR8) and a CD22 CAR will be expressed at the cell surface.

R=CD20 mimotope (bound by Rituximab), Q=CD34 epitope (bound by QBEnd10)

**Figure 5:** Degranulating activity of UCART22

Degranulating activity of UCART22 (scfv-V1 against the proximal domain of CD22) as compared to the degranulating activity of non transduced (NT) or that of T cells transduced with a CAR targeting the distal part of CD22 (scfv-V2), in the presence of CD22-positive NALM-16 cells as compared to CD22 negative SUP-T1 cells.

5 **Figure 6:** Cytotoxic activity of UCART22

Cytotoxic activity of UCART22 (scfv-V1 against the proximal domain of CD22) as compared to the cytotoxic activity of non transduced (NT) or that of T cells transduced with a CAR targeting the distal part of CD22 (scfv-V2) cells in the presence of CD22-positive NALM-16 cells as compared to CD22 negative SUP-T1 cells.

10 **Figure 7:** Interferon gamma production of UCART22

**Figure 8:** Mice survival in the presence of control cells, UCART22 (scfv-V1 against the proximal domain of CD22) or CART22 (no TRAC deletion).

**Figure 9:** General Strategy to insert a gene into the TRAC gene using TALEN.

15

### Detailed description of the invention

Unless specifically defined herein, all technical and scientific terms used have the same meaning as commonly understood by a skilled artisan in the fields of gene therapy, biochemistry, genetics, immunology and molecular biology.

5 All methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, with suitable methods and materials being described herein. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will prevail. Further, the  
10 materials, methods, and examples are illustrative only and are not intended to be limiting, unless otherwise specified.

The practice of the present invention will employ, unless otherwise indicated, conventional techniques of cell biology, cell culture, molecular biology, transgenic biology, microbiology, recombinant DNA, and immunology, which are within the skill of the art. Such techniques are explained fully in the literature. See, for example, Current  
15 Protocols in Molecular Biology (Frederick M. AUSUBEL, 2000, Wiley and son Inc, Library of Congress, USA); Molecular Cloning: A Laboratory Manual, Third Edition, (Sambrook et al, 2001, Cold Spring Harbor, New York: Cold Spring Harbor Laboratory Press); Oligonucleotide Synthesis (M. J. Gait ed., 1984); Mullis et al. U.S. Pat. No. 4,683,195;  
20 Nucleic Acid Hybridization (B. D. Harries & S. J. Higgins eds. 1984); Transcription And Translation (B. D. Hames & S. J. Higgins eds. 1984); Culture Of Animal Cells (R. I. Freshney, Alan R. Liss, Inc., 1987); Immobilized Cells And Enzymes (IRL Press, 1986); B. Perbal, A Practical Guide To Molecular Cloning (1984); the series, Methods In  
25 ENZYMOLOGY (J. Abelson and M. Simon, eds.-in-chief, Academic Press, Inc., New York), specifically, Vols.154 and 155 (Wu et al. eds.) and Vol. 185, "Gene Expression Technology" (D. Goeddel, ed.); Gene Transfer Vectors For Mammalian Cells (J. H. Miller and M. P. Calos eds., 1987, Cold Spring Harbor Laboratory); Immunochemical Methods In Cell And Molecular Biology (Mayer and Walker, eds., Academic Press, London, 1987);  
30 Handbook Of Experimental Immunology, Volumes I-IV (D. M. Weir and C. C. Blackwell, eds., 1986); and Manipulating the Mouse Embryo, (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., 1986).

## CD22 specific Chimeric Antigen Receptors

The present invention relates to new designs of anti-CD22 chimeric antigen receptor (CAR or CD22 CAR or anti-CD22 CAR) which are chimeric antigen receptor capable of binding to CD22 in particular to the proximal domain of CD22.

5 The CD22 specific Chimeric Antigen Receptors of the invention comprises an extracellular domain comprising an extracellular ligand-binding domain and a hinge, optionally a suicide domain, a transmembrane domain and an intracellular domain comprising a signaling transducing domain.

10 Expressed at a cell surface, a CD22 CAR according to the present invention comprises an extracellular domain that comprises an extracellular ligand-binding domain.

15 The term “extracellular ligand-binding domain” as used herein is defined as an oligo- or polypeptide that is capable of binding at least one epitope of CD22. Preferably, the extracellular ligand-binding domain will be capable of interacting at least partially with a cell surface molecule interacting with CD22 and with another cell surface antigen or another membrane bound antigen, or of interacting directly with CD22, or of interacting with human CD22, more precisely of interacting directly with the proximal region of human CD22 (from amino acid 243 to amino acid 687).

20 In one embodiment, a CD22 CAR according to the present invention comprises an extracellular domain that comprises an extracellular ligand-binding domain capable of interacting with the proximal region of CD22 (from amino acid 243 to amino acid 687) and with the distal part of CD22 (from aa 20 to aa 425).

25 In the present invention, the full length extracellular domain of CD22 is from amino acid (aa) 20-to aa 687, the membrane proximal domain of CD22 is from aa 243 to aa 687, the membrane distal domain of CD22 is from aa 20 to aa 425.

In one embodiment, the extracellular ligand-binding domain may be chosen to recognize a particular form (glycosylated) CD22 that acts as a cell surface marker on target cells associated with a particular disease state.

5

In a preferred embodiment, said extracellular ligand-binding domain comprises at least one single chain antibody fragment (scFv) comprising the light ( $V_L$ ) and the heavy ( $V_H$ ) variable fragment of a target antigen specific monoclonal anti CD22 antibody joined by a linker, in particular a flexible linker. Said  $V_L$  and  $V_H$  are preferably from the antibody m971 as in Table 2 below. They are preferably linked together by a flexible linker comprising for instance the sequence SEQ ID NO.10.

10

For the purpose of the present invention, specific parts of the fully human anti-CD22 antibody, m971 antibody (m971) previously identified using phage display methodology and characterized. (Xiao X, Ho M, Zhu Z, Pastan I, Dimitrov DS. Identification and characterization of fully human anti-CD22 monoclonal antibodies. *mAbs*. 2009;1(3):297-303) were combined to specific sequences to produce new CD22 CARs, according to the invention. See also WO 2014065961 which is incorporated by reference.

15

A preferred embodiment of the invention provides CARs comprising an antigen-binding domain comprising, consisting of, or consisting essentially of, a single chain variable fragment (scFv) of the antigen binding domain of m971 with the following moieties as in table 1

Table 1: Sequence of different domains in CD22 CAR

Functional domains	SEQ ID #	Raw amino acid sequence
CD8 $\alpha$ signal peptide (or sequence leader)	SEQ ID NO.1	MALPV TALLLPLALLHAARP
Alternative signal peptide	SEQ ID NO.2	METDTLLWVLLLWVPGSTG
Fc $\gamma$ RIII $\alpha$ hinge	SEQ ID NO.3	GLAVSTI SSFFPPPGYQ
CD8 $\alpha$ hinge	SEQ ID NO.4	TTTPAPRPPTPAPTIASQPLSLRPEACRPAAGGAVHTR GLDFACD
IgG1 hinge	SEQ ID NO.5	EPKSPDKTHTCPPCPAPPVAGPSVFLPPKPKDTLMIA RTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTK PREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNK

		ALPAPIEKTIKAKGQPREPVYTLPPSRDELTKNQVSL TCLVKGFYPSDIAVEWESNGQPENNYKTPPVLDSDG SFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQ KSLSLSPGK
CD8 $\alpha$ transmembrane domain	SEQ ID NO.6	IYIWAPLAGTCGVLLSLVITLYC
41BB transmembrane domain	SEQ ID NO.7	IISFFLALTSTALLFLLFLTLRFSVV
41BB intracellular domain	SEQ ID NO.8	KRGRKKLLYIFKQPFMRPVQTTQEEEDGCSCRFPEEEE GGCEL
CD3 $\zeta$ intracellular domain	SEQ ID NO.9	RVKFSRSADAPAYQQGQNQLYNELNLGRREYDVLD KRRGRDPEMGGKPRRKNPQEGLYNELQKDKMAEAY SEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHM QALPPR
Linker	SEQ ID NO.10	GGGGSGGGGSG GGGS

Table 2: Sequence of the different CD22 scfv VH and VL

ScFv sequences	SEQ ID #	Raw amino acid sequence
m971- heavy chain variable region	SEQ ID NO.12	QVQLQQSGPGLVKPSQTLSTCAISGDSVSSNSAAWNWIR QSPSRGLEWLGRYYRSKWYNDYAVSVKSRTINPDTSKN QFSQLQLNSVTPEDTAVYYCAREVTGDLEDAFDIWGQGTM VTVSS
m971- light chain variable region	SEQ ID NO.13	DIQMTQSPSSLSASVGDRVTITCRASQTIWSYLNWYQQRP GKAPNLLIYAASSLQSGVPSRFSGRGSGTDFLTISLQAEDF ATYYCQQSYSIPQTFGQGKLEIK

Table 3: CD22 CAR of structure V-1

CAR Designation	CAR Structure							
V-1	signal peptide	VH	VL	Fc $\gamma$ RIII $\alpha$ hinge	CD8 $\alpha$ TM	41BB -IC	CD3 $\zeta$ CD	
m971 (SEQ ID NO.14)	SEQ ID NO.1	SEQ ID NO.12	SEQ ID NO.13	SEQ ID NO.3	SEQ ID NO.6	SEQ ID NO.8	SEQ ID NO.9	

Table 4: CAR of structure V-3

CAR Designation	CAR Structure							
V-3	signal peptide	VH	VL	CD8 $\alpha$ hinge	CD8 $\alpha$ -TM	41BB-IC	CD3 $\zeta$ CD	
m971(SEQ ID NO.15)	SEQ ID NO.1	SEQ ID NO.12	SEQ ID NO.13	SEQ ID NO.4	SEQ ID NO.6	SEQ ID NO.8	SEQ ID NO.9	

5 In a preferred embodiment, the CD22 CAR of the invention comprises a sequence of SEQ ID N°15.

10 In a preferred embodiment, the CD22 CAR of the invention comprises a sequence of SEQ ID N°23.

15 Sequences of CD22 CARs of the invention comprise a peptide signal, a TM domain from CD8alpha and a linker between the VH and VL domain from m971.

#### SCFV

20 In the present invention, a scfv is a fusion protein of the variable region of the heavy ( $V_H$  domain) and light chain ( $V_L$  domain) of an immunoglobulin or a part of an immunoglobulin specific for CD22, connected with a short linker peptide of 10 to 25 amino acids, preferably of SEQ ID NO. 10.

25 In a preferred embodiment, said CARs preferentially comprise an extracellular ligand-binding domain comprising a polypeptide sequence displaying at least 90 %, 95 %, 96%, 97 %, 98%, 99 % or 100% identity with an amino acid sequence SEQ ID NO: 12.

20 In a preferred embodiment, said CARs preferentially comprise an extracellular ligand-binding domain comprising a polypeptide sequence displaying at least 90 %, 95 %, 96%, 97 %, 98%, 99 % or 100% identity with an amino acid sequence SEQ ID NO: 13.

25 In a preferred embodiment, said CARs preferentially comprise an extracellular ligand-binding domain comprising a polypeptide sequence displaying at least 90 %, 95 %, 96%, 97 %, 98%, 99 % or 100% identity with an amino acid sequence SEQ ID NO: 12.

and a polypeptide sequence displaying at least 90 %, 91%, 92% 93% 94%, 95 %, 96%, 97 %, 98%, 99 % or 100% identity with an amino acid sequence selected from the group consisting of SEQ ID NO: 13.

#### HINGE

5 The extracellular domain can further comprise a hinge region between said extracellular ligand-binding domain and said transmembrane domain. The term "hinge region" used herein generally means any oligo- or polypeptide that functions to link the transmembrane domain to the extracellular ligand-binding domain. In particular, hinge region is used to provide more flexibility and accessibility for the extracellular ligand-binding domain. A hinge region may comprise up to 300 amino acids, preferably 10 to 100 amino acids and most preferably 10 to 50 amino acids. Hinge region may be derived from all or part of naturally occurring molecules, such as from all or part of the extracellular region of CD8, or CD4, or from all or part of an antibody constant region. Alternatively the hinge region may be a synthetic sequence that corresponds to a naturally occurring hinge sequence, or may be an entirely synthetic hinge sequence. In a preferred embodiment said hinge domain comprises a part of a human CD8 alpha chain, FcRIII $\alpha$  receptor or IgG1, respectively referred to in this specification as SEQ ID NO. 4, SEQ ID NO. 5 and SEQ ID NO.6, or in a more preferred embodiment, a hinge polypeptide which display at least 80%, preferably at least 90 %, 95 % 97 % 99 % or 100% sequence identity with SEQ ID N°4, even more preferably 100% sequence identity with SEQ ID N°4.

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A Hinge from IgG4 or from PD1 is part of the present invention and disclosed in WO2016120216 and may be used in the construction of a CD22 CAR according to the invention.

25 A CD22 CAR according to the present invention is anchored into the membrane of the cell. Thus, such CD22 CAR further comprises a transmembrane domain. The distinguishing features of appropriate transmembrane domains comprise the ability to be expressed at the surface of a cell, preferably in the present invention an immune cell, in particular lymphocyte cells or Natural killer (NK) cells, and to interact together for directing cellular response of immune cell against a predefined target cell.

30 The transmembrane domain can be derived either from a natural or from a synthetic

source. The transmembrane domain can be derived from any membrane-bound or transmembrane protein. As non-limiting examples, the transmembrane polypeptide can be a subunit of the T-cell receptor such as  $\alpha$ ,  $\beta$ , or  $\delta$ , polypeptide constituting CD3 complex, IL2 receptor p55 ( $\alpha$  chain), p75 ( $\beta$  chain) or  $\gamma$  chain, subunit chain of Fc receptors, in particular Fc receptor III or CD proteins. Alternatively, the transmembrane domain can be synthetic and can comprise predominantly hydrophobic residues such as leucine and valine.

In a preferred embodiment said transmembrane domain is derived from the human CD8 alpha chain (e.g. NP\_001139345.1).

A CD22CAR according to the invention generally further comprises a transmembrane domain (TM) more particularly from CD8 $\alpha$ , showing identity with the polypeptides of SEQ ID NO. 6 or SEQ ID NO.7. Preferably, a CAR according to the invention comprises a TM showing at least 70%, preferably at least 80%, more preferably at least 90 %, 91%, 92%, 93%, 94%, 95 %, 96%, 97 %, 98%, 99 % or 100% sequence identity with the polypeptides of SEQ ID NO. 6.

A CD22 CAR according to the invention generally further comprises a transmembrane domain (TM) from CD8 $\alpha$  showing identity with the polypeptides of SEQ ID NO. 6. Preferably, a CAR according to the invention comprises a TM showing at least 70%, preferably at least 80%, more preferably at least 90 %, 91%, 92%, 93%, 94%, 95 %, 96%, 97 %, 98%, 99 % or 100% sequence identity with the polypeptides of SEQ ID NO. 6.

A CD22 CAR according to the present invention comprises an intracellular domain that comprises a signal transducing domain or intracellular signaling domain.

The signal transducing domain or intracellular signaling domain of a CD22 CAR according to the present invention is responsible for intracellular signaling following the binding of extracellular ligand binding domain to the target resulting in the activation of the immune cell and immune response (cytolytic activity against the target cell). In other words, the signal transducing domain is responsible for the activation of at least one of the normal effector functions of the immune cell in which the CAR is expressed. For example, the effector function of a T cell can be a cytolytic activity or helper activity including the secretion of cytokines. Thus, the term "signal transducing domain" refers

to the portion of a protein which transduces the effector signal function signal and directs the cell to perform a specialized function.

Preferred examples of signal transducing domain in a CD22 CAR of the invention can be the cytoplasmic sequences of the T cell receptor and co-receptors that act in concert to initiate signal transduction following antigen receptor engagement, as well as any derivate or variant of these sequences and any synthetic sequence that has the same functional capability. Signal transduction domain comprises two distinct classes of cytoplasmic signaling sequence, those that initiate antigen-dependent primary activation, and those that act in an antigen-independent manner to provide a secondary or co-stimulatory signal. Primary cytoplasmic signaling sequence can comprise signaling motifs which are known as immunoreceptor tyrosine-based activation motifs of ITAMs. ITAMs are well defined signaling motifs found in the intracytoplasmic tail of a variety of receptors that serve as binding sites for syk/zap70 class tyrosine kinases. Examples of ITAM used in the invention can include as non-limiting examples those derived from TCRzeta, FcRgamma, FcRbeta, FcRepsilon, CD3gamma, CD3delta, CD3epsilon, CD5, CD22, CD79a, CD79b and CD66d. In a preferred embodiment, the signaling transducing domain of the CAR can comprise the CD3zeta signaling domain which has amino acid sequence with at least 70%, preferably at least 80%, more preferably at least 90 %, 95 % 97 % 99 % or 100% sequence identity with amino acid sequence selected from the group consisting of (SEQ ID NO: 9). Optionally said CD3zeta signaling domain is comprising a polypeptide sequence displaying at least 90 %, 91%, 92% 93% 94%, 95 %, 96%, 97 %, 98%, 99 % or 100% identity with SEQ ID NO: 9.

In a more preferred embodiment, the signaling transducing domain of the CD22 CAR consists in a CD3zeta signaling domain of SEQ ID NO: 9 and excludes any sequence from human CD28 signaling domain. In particular embodiment the signal transduction domain of the CAR of the present invention comprises a co-stimulatory signal molecule. A co-stimulatory molecule is a cell surface molecule other than an antigen receptor or their ligands that is required for an efficient immune response. "Co-stimulatory ligand" refers to a molecule on an antigen presenting cell that specifically binds a cognate co-stimulatory molecule on a T-cell, thereby providing a signal which, in addition to the primary signal provided by, for instance, binding of a TCR/CD3 complex with an MHC

molecule loaded with peptide, mediates a T cell response, including, but not limited to, proliferation activation, differentiation and the like. A co-stimulatory ligand can include but is not limited to CD7, B7-1 (CD80), B7-2 (CD86), PD-L1, PD-L2, 4-1BBL, OX40L, inducible costimulatory ligand (ICOS-L), intercellular adhesion molecule (ICAM, CD30L, 5 CD40, CD70, CD83, HLA-G, MICA, M1CB, HVEM, lymphotoxin beta receptor, 3/TR6, ILT3, ILT4, an agonist or antibody that binds Toll ligand receptor and a ligand that specifically binds with B7-H3. A co-stimulatory ligand also encompasses, *inter alia*, an antibody that specifically binds with a co-stimulatory molecule present on a T cell, such as but not limited to, CD27, 4-1BB, OX40, CD30, CD40, PD-1, ICOS, lymphocyte function-associated 10 antigen-1 (LFA-1), CD2, CD7, LTGHT, NKG2C, B7-H3, a ligand that specifically binds with CD83.

A “co-stimulatory molecule” refers to the cognate binding partner on a T-cell that specifically binds with a co-stimulatory ligand, thereby mediating a co-stimulatory response by the cell, such as, but not limited to proliferation. Co-stimulatory molecules include, but are not limited to, an MHC class I molecule, BTLA and Toll ligand receptor. Examples of costimulatory molecules include CD27, CD8, 4-1BB (CD137), OX40, CD30, 15 CD40, PD-1, ICOS, lymphocyte function-associated antigen-1 (LFA-1), CD2, CD7, LIGHT, NKG2C, B7-H3 and a ligand that specifically binds with CD83 and the like.

In a preferred embodiment, the signal transduction domain of the CAR of the 20 present invention comprises a part of co-stimulatory signal molecule consisting of fragment of 4-1BB (GenBank: AAA53133.) In particular the signal transduction domain of the CAR of the present invention comprises amino acid sequence which comprises at least 70%, preferably at least 80%, more preferably at least 90 %, 95 % 97 % 99 % or 100% sequence identity with amino acid sequence selected from the group consisting of 25 SEQ ID NO: 8.

In a more preferred embodiment, the signal transduction domain of the CAR of the present invention comprises no sequence from CD28 (NP\_006130.1).

In an even more preferred embodiment, all the embodiments of the present invention comprise no sequence from CD28 (NP\_006130.1).

In an even more preferred embodiment the signal transduction domain of the CD22 CAR of the present invention comprises a part of co-stimulatory signal molecule 4-1BB (GenBank: AAA53133) and no sequence from CD28 (NP\_006130.1).

The present invention provides a CD22 specific chimeric antigen receptor (CD22 CAR) comprising:

An extracellular domain comprising :

- a binding domain specific for CD22, preferably a binding domain specific for human CD22, more preferably said binding domain specific for human CD22 is a single-chain variable fragment (scFv),

- a hinge, preferably from CD8 alpha

- a transmembrane domain, preferably from CD8 alpha

- an intracellular domain comprising:

- a co-stimulatory signal molecule from human 4-1BB, and

an intracellular signaling domain comprising a human CD3zeta signaling domain.

In a preferred embodiment the CD22 CAR of the invention has no sequence from CD28.

In a preferred embodiment, the CD22 CAR of the invention does not contain any sequence from CD28 and comprises a sequence leader, a TM domain and a hinge from CD8  $\alpha$ , preferably no sequence from CD28 and comprises a sequence leader of SEQ ID NO. 1, a TM domain of SEQ ID NO. 6 of and a hinge of SEQ ID NO. 4 from CD8  $\alpha$ .

In one embodiment, the CD22 CAR of the invention comprises a leader sequence from human CD8  $\alpha$  (SEQ ID NO.1.) or a leader sequence having at least 95% identity with SEQ ID NO.1.

In another embodiment, The CD22 CAR of the invention comprises a leader sequence of SEQ ID NO.2 or a leader sequence having at least 95% identity with SEQ ID NO.2.

In one embodiment the present invention provides a CD22 specific chimeric antigen receptor (CD22 CAR) comprising:

- a binding domain specific for CD22, preferably a binding domain specific for human CD22, more preferably said domain specific for human CD22 is a single-chain variable fragment (*scFv*), even more preferably comprising a VH and an VL from m971,

- a hinge from human CD8 alpha (from CD8  $\alpha$ )

5 - a transmembrane domain from human CD8alpha( $\alpha$ )

- a co-stimulatory signal molecule from human 4-1BB

-an intracellular signaling domain comprising a human CD3zeta signaling domain.

In one embodiment the present invention provides a CD22 specific chimeric antigen receptor (CD22 CAR) comprising:

10 - a binding domain specific for CD22, preferably a binding domain specific for human CD22, more preferably said domain specific for human CD22 is a single-chain variable fragment (*scFv*), even more preferably comprising a VH and an VL from m971,

- a hinge from human FcRIII $\alpha$

- a transmembrane domain from human CD8alpha( $\alpha$ )

15 - a co-stimulatory signal molecule from human 4-1BB

-an intracellular signaling domain comprising a human CD3zeta signaling domain.

The present invention also provides a CD22 specific chimeric antigen receptor (CD22 CAR) comprising:

20 - a binding domain specific for CD22, preferably a binding domain specific for human CD22, more preferably said domain specific for human CD22 is a single-chain variable fragment (*scFv*), even more preferably comprising a VH and an VL from m971.

- a hinge from human IgG1

- a transmembrane domain from human CD8alpha( $\alpha$ )

- a co-stimulatory signal molecule from human 4-1BB

25 -an intracellular signaling domain comprising a human CD3zeta signaling domain.

These three last embodiments encompass a CD22 CAR with a signal peptide of SEQ ID NO 1 or of SEQ ID NO 2, preferably of SEQ ID NO 1

More preferably, said CD22 CAR has no sequence from CD28.

A scfv of the invention is derived from an antibody specific for CD22, it comprises a VH domain separated to a VL domain by a linker, said VH and/or VL domains contributing to the binding to CD22.

5 In a preferred embodiment the UCART 22 of the invention comprises a scfv from m971 antibody with one GS4 linker between the VH and the VL and 2R between the VL and the CD8alpha hinge.

10 In the present invention, a scfv is a fusion protein of the variable regions of the heavy ( $V_H$  domain) of SEQ ID NO.12: and light chains ( $V_L$  domain) of SEQ ID NO.13: of an immunoglobulin specific for CD22, m971, connected with a linker peptide, preferably a linker of SEQ ID NO10.

In one embodiment said scfv of the invention further comprises a leader sequence (or signal peptide), preferably said leader sequence is linked to the VH domain.

15 An embodiment wherein said leader sequence is linked to the VL domain is part of the present invention.

In one embodiment, a VH domain is linked to a hinge, in another embodiment a VL domain is linked to said hinge.

20 The present invention provides a scfv linked to a hinge having different length preferably a hinge from CD8 $\alpha$ , IgG1 or FcRIII $\alpha$  (See figure 2), more preferably from CD8 $\alpha$ .

Preferably, the present invention provides a CD22 CAR comprising:

- a signal peptide, for example a signal peptide of SEQ ID NO. 2 or from CD8alpha of SEQ ID NO. 1.
- a (scFv) comprising a VH domain separated from a VL domain by a linker, said VH and VL and linker contributing to the binding to CD22,
- a hinge from human CD8 alpha chain or a Hinge from human IgG1 or a hinge from FcRIII $\alpha$ , preferably from CD8 alpha.
- a transmembrane domain (TM) from CD8alpha( $\alpha$ )

- a co-stimulatory signal molecule from human 4-1BB
- an intracellular signaling domain comprising the CD3zeta signaling domain.

One of the CD22 CAR of the invention consists in :

- a leader sequence (for example a CD8  $\alpha$  leader sequence or a CD8 $\alpha$  signal peptide)
- 5 - an anti-CD22 scfv comprising a VH, a linker, and a VL, or a VL, a linker, and a VH, said VH and VL are derived from m971
  - a CD8  $\alpha$  hinge
  - a CD8  $\alpha$  TM
  - a co-stimulatory signal molecule from 4-1BB
- 10 • an intracellular CD3zeta signaling domain.

One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,
- an epitope recognized by QBEN10 and an epitope recognized by rituximab,
- an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971 two successive epitopes recognized by rituximab,
  - a CD8  $\alpha$  hinge
  - a CD8  $\alpha$  TM
  - a co-stimulatory signal molecule from 4-1BB
  - an intracellular CD3zeta signaling domain

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One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,
- an epitope recognized by QBEN10 and an epitope recognized by rituximab,
- an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971 two successive epitopes recognized by rituximab,

25

- a CD8  $\alpha$  TM
- a co-stimulatory signal molecule from 4-1BB
- an intracellular CD3zeta signaling domain

5 One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,
- an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971 two successive epitopes recognized by rituximab,

- a CD8  $\alpha$  hinge

10 • a CD8  $\alpha$  TM

- a co-stimulatory signal molecule from 4-1BB
- an intracellular CD3zeta signaling domain

One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,

15 - an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971

two successive epitopes recognized by rituximab,

- a CD8  $\alpha$  TM
- a co-stimulatory signal molecule from 4-1BB
- an intracellular CD3zeta signaling domain

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One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,

- an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971, an anti-CD19 scfv

25 two successive epitopes recognized by rituximab,

- a CD8  $\alpha$  hinge
- a CD8  $\alpha$  TM
- a co-stimulatory signal molecule from 4-1BB
- an intracellular CD3zeta signaling domain

5 One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,
- an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971, an anti-CD19 scfv
- two successive epitopes recognized by rituximab,

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- a CD8  $\alpha$  TM
- a co-stimulatory signal molecule from 4-1BB
- an intracellular CD3zeta signaling domain

One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,

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- an anti-CD19 scfv and an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971,
- two successive epitopes recognized by rituximab,

- a CD8  $\alpha$  hinge
- a CD8  $\alpha$  TM

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- a co-stimulatory signal molecule from 4-1BB
- an intracellular CD3zeta signaling domain

One of the CD22 CAR of the invention comprises successively :

- a CD8 $\alpha$  signal peptide, removable upon expression at the cell surface,
- an anti-CD19 scfv and an anti-CD22 scfv comprising a VH, a linker, and a VL, said VH and VL from m971,

two successive epitopes recognized by rituximab,

- a CD8  $\alpha$  TM
- a co-stimulatory signal molecule from 4-1BB
- an intracellular CD3zeta signaling domain.

5 LINKER -SCFV

A linker according to the invention may be for example, a multimer of the pentapeptide (GGGGS)n or (G4S)n or (Gly4Ser)n with n= 1 to 4, preferably n=3 , the 18-mer GGSSRSSSSGGGGSGGG (Andris-Widhopf et al., 2011) and the 20-mer (G4S)4 (Schaefer et al., 2010). A linker according to the invention may include sequences with added functionalities, e.g. an epitope tag (Sblattero & Bradbury, 2000 Nature Biotechnology 18, 75 - 80), at least on sequence of SEQ ID NO. 20, preferably 2, separated by a linker, sequences improving scFv properties of the present invention, often in the context of particular antibody sequences.

Amongst other linkers suitable within the present invention is the 15-mer peptide linker (RGRGRGRGRSRGGGS) (Zhihong Shen, Heping Yan, Ying Zhang, Raymond L. Mernaugh, and Xiangqun Zeng (2008), Anal Chem. 80(6): 1910–1917).

In a preferred embodiment, a linker linking the VH to the VL sequence of m971 (or the VL to the VH sequence) is a linker of formula (G4S)n wherein n is 1 to 3; preferably n=3 of sequence (G4S)3 ( SEQ ID NO. 10).

20 In one embodiment the present invention provides:

A CD22 CAR comprising

- a human CD8 $\alpha$  leader sequence (CD8  $\alpha$  leader or CD8 $\alpha$  signal peptide) of SEQ ID NO. 1  
- an anti-CD22 scfv comprising a VH of SEQ ID NO. 12, a linker of SEQ ID N°10, and a VL of SEQ ID NO 13

25 a human CD8  $\alpha$  hinge of SEQ ID NO.4,

- a human CD8  $\alpha$  TM of SEQ ID NO.6
- a co-stimulatory signal molecule from 4-1BB of SEQ ID NO.8

- an intracellular CD3zeta signaling domain of SEQ ID NO. 9.

In one embodiment the present invention also provides:

A CD22 CAR comprising

- a human CD8 $\alpha$  leader sequence (CD8  $\alpha$  leader or CD8 $\alpha$  signal peptide) of SEQ ID NO. 1

5 - an anti-CD22 scfv comprising a VH of SEQ ID NO. 12, a linker of SEQ ID N°10, and a VL of SEQ ID NO 13

a human Fc $\gamma$ RIII $\alpha$  hinge of SEQ ID NO.3,

- a human CD8  $\alpha$  TM of SEQ ID NO.6
- a co-stimulatory signal molecule from 4-1BB of SEQ ID NO.8
- 10 • an intracellular CD3zeta signaling domain of SEQ ID NO. 9.

In one embodiment, the present invention provides

An CD22 CAR comprising

- a human CD8 $\alpha$  leader sequence (CD8  $\alpha$  leader or CD8 $\alpha$  signal peptide) of SEQ ID NO. 1

an anti-CD22 scfv comprising a VL of SEQ ID NO 13, a linker of SEQ ID N°10, and a VH of 15 SEQ ID NO. 12,

a human Fc $\gamma$ RIII $\alpha$  hinge of SEQ ID NO.3,

- a human CD8  $\alpha$  TM of SEQ ID NO.6
- a co-stimulatory signal molecule from 4-1BB of SEQ ID NO.8
- 20 • an intracellular CD3zeta signaling domain of SEQ ID NO. 9.

In one embodiment, the present invention provides

An CD22 CAR comprising

- a human CD8 $\alpha$  leader sequence (CD8  $\alpha$  leader or CD8 $\alpha$  signal peptide) of SEQ ID NO. 1

an anti-CD22 scfv comprising a VL of SEQ ID NO 13, a linker of SEQ ID N°10, and a VH of 25 SEQ ID NO. 12,

a human CDA alpha hinge of SEQ ID NO.4,

- a human CD8  $\alpha$  TM of SEQ ID NO.6
- a co-stimulatory signal molecule from 4-1BB of SEQ ID NO.8
- an intracellular CD3zeta signaling domain of SEQ ID NO. 9.

5 In one embodiment, the present invention provides a CD22 specific chimeric antigen receptor (CD22 CAR) comprising:

- a signal peptide having an amino acid sequence with at least 80%, more preferably at least 90 %, 95 % 97 %, 99 % or 100% sequence identity with the polypeptide of SEQ ID NO. 1 or 2; preferably the signal peptide has an amino acid sequence with at least 80%, more preferably at least 90 %, 95 % 97 %, 99 % or 100% sequence identity with the 10 polypeptide of SEQ ID NO 1.

- a VH domain separated to a VL domain by a linker, said VH and VL contributing to the binding to CD22; said linker having at least 90 %, 95 % 97 %, 99 % or 100% sequence identity with the polypeptide of SEQ ID NO 10.

Said VH domain having at least 90 %, 95 % 97 %, 99 % or 100% sequence identity with 15 the polypeptide of SEQ ID NO 12.

Said VL domain having at least 90 %, 95 % 97 %, 99 % or 100% sequence identity with the polypeptide of SEQ ID NO 13.

- - a hinge derived from human CD8 alpha chain having an amino acid sequence with at least 80%, more preferably at least 80%, 90 %, 95 % 97 %, 99 % or 100% sequence 20 identity with the polypeptide of SEQ ID NO. 4.

- a transmembrane domain derived from CD8alpha( $\alpha$ ) having an amino acid sequence with at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identity with the polypeptide of SEQ ID NO. 6;

- a co-stimulatory signal molecule derived from human 4-1BB (or 4-1BB intracellular 25 domain) having an amino acid sequence with at least 70%, preferably at least 80%, more preferably at least 90 %, 95 % 97 %, 99 % or 100% sequence identity with amino acid sequence selected from the group consisting of SEQ ID NO: 8

-an intracellular signaling domain comprising the CD3zeta signaling domain having an amino acid sequence with at least 70%, preferably at least 80%, more preferably at least

90%, 95% 97%, 99 % or 100 % sequence identity with amino acid sequence selected from the group consisting of SEQ ID NO: 9.

In a preferred embodiment, the CD22 specific chimeric antigen receptor (CD22 CAR) of the present invention does not comprise any sequence from human CD28, in particular from human CD28 intra signaling domain. In a more preferred embodiment, the CD22 specific chimeric antigen receptor (CD22 CAR) of the present invention does not comprise any sequence from human CD28, in particular from human CD28 intra signaling domain and further contains a signal peptide from CD8 $\alpha$ , preferably fused to the VH domain of a scfv specific for CD22.

In one embodiment, the present invention provides a CD22 CAR of SEQ ID NO. 15.

In one embodiment, the present invention provides a CD22 CAR having an amino acid sequence with at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identity with the polypeptide of SEQ ID N°15.

In one embodiment the present invention provides a CD22 CAR having a sequence with at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identity with the polynucleotide of SEQ ID N°22.

The CD22 CAR of the invention encompasses the following sequences:

v1-m971 (Fc $\gamma$ RIII $\alpha$ -CD8 $\alpha$ TM-41BB.IC-CD3 $\zeta$ .IC)

MALPV TALLPL ALLLHAARPQVQLQQSGPGLVKPSQTL SLTCAISGDSVSSNSAAWNWIRQSPSRGL  
EWLGRTYYRSK WYNDYAVSVKS RITINPDT SKNQFSLQLNSVT PEDA TAVYYCAREVTGDLEAFDIW  
GQGTMVTVSSGGGGSGGGGSGGGSDIQMTQSPSSL SASVGDRV TICRASQTIWSYLNWYQQR  
PGKAPNLLIYAASSLQSGVPSRFSGRGS GTDFTLTISSLQAEDFATYYCQQSYSIPQTFGQGT KLEIKGL  
AVSTI SFFPPGYQIYIWAPLAGTCGVLLSLVITLYCKRGRKKLLYIFKQPFMRPVQTTQEE DGCSCR F  
PEEEEGGCELRVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPEMGGKPRRKNPQ  
EGLYNELQDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQALPPR (SEQ ID  
N°14).

V3-m971 (CD8 $\alpha$ -CD8 $\alpha$ TM-41BB.IC-CD3 $\zeta$ .IC)

MALPV TALLPL ALLLHAARPQVQLQQSGPGLVKPSQTL SLTCAISGDSVSSNSAAWNWIRQSPSRGL  
EWLGRTYYRSK WYNDYAVSVKS RITINPDT SKNQFSLQLNSVT PEDA TAVYYCAREVTGDLEAFDIW

GQGTMVTVSSGGGGSGGGGGSDIQMTQSPSSLASVGDRVITCRASQTIWSYLNWYQQR  
PGKAPNLLIYAASSLQSGVPSRFSGRGSGTDFLTISLQAEDFATYYCQQSYSIPQTFGQGTKLEIKTT  
TPAPRPTPAPTIASQPLSLRPEACRPAAGGAHVTRGLDFACDIYIWAPLAGTCVLLSLVITLYCKR  
GRKKLLYIFKQPFMRPVQTTQEEDGCSRFPEEEQEGGCELRVKFSRSADAPAYQQGQNQLYNELNL  
5 GRREYDVLDKRRGRDPEMGGKPRRKNPQEGLYNELQDKMAEAYSEIGMKGERRRGKGDGLY  
QGLSTATKDTYDALHMQALPPR (SEQ ID N°15).

In a preferred embodiment the CD22 CAR of the invention comprises the following sequence.

MALPV TALLPL ALLLHAARPQVQLQQSGPGLVKPSQTL SLTCAISGDSVSSNSA AWNWIRQSPSRGL  
10 EWLGRTYYRSK WYNDYAVSVKS RITINPDT SKNQFSLQLNSVT PEDA VYYCAREV TGDLEAFDIW  
GQGTMVTVSSGGGGSGGGGGSDIQMTQSPSSLASVGDRVITCRASQTIWSYLNWYQQR  
PGKAPNLLIYAASSLQSGVPSRFSGRGSGTDFLTISLQAEDFATYYCQQSYSIPQTFGQGTKLEIKTT  
TPAPRPTPAPTIASQPLSLRPEACRPAAGGAHVTRGLDFACDIYIWAPLAGTCVLLSLVITLYCKR  
GRKKLLYIFKQPFMRPVQTTQEEDGCSRFPEEEQEGGCELRVKFSRSADAPAYQQGQNQLYNELNL  
15 GRREYDVLDKRRGRDPEMGGKPRRKNPQEGLYNELQDKMAEAYSEIGMKGERRRGKGDGLY  
QGLSTATKDTYDALHMQALPPR (SEQ ID N°15).

Sequences of CD22 CAR with a peptide signal from SEQ ID NO.2, a TM domain from CD8 $\alpha$  and a linker between the VH and VL domain :

20 METDTLLWVLLLWVPGSTG  
EVQLVQSGGGVVRPGGLRLPCAASGFTFDDYGMSWVRQAPGKGLEWVSGINWNGGSTGYADS  
VKGRFTISRDNAKNSLYLQMNSLRAEDTALYHCARGGDDAFDIWGQGTMVTVSS —  
GGGGSGGGGGSGGGGS—  
RIVMTQSPGTLSVSPGETATLSCRASQFSNMLAWYQQKSGQPPRLLIYGVSTRAAGVPARFSGSG  
25 SGTEFTLTISNLQSEDFAVYYCQQYGDWPRYTFGQGTKVERK —  
GLAVSTISSLFFPPGYQIYIWAPLAGTCVLLSLVITLYCKRGRKKLLYIFKQPFMRPVQTTQEEDGSC  
RFPEEEQEGGCELRVKFSRSADAPAYQQGQNQLYNELNLRREYDVLDKRRGRDPEMGGKPRRK  
PQEGLYNELQDKMAEAYSEIGMKGERRRGKGDGLYQGLSTATKDTYDALHMQALPPR  
METDTLLWVLLLWVPGSTG  
30 EVQLVQSGGGVVRPGGLRLPCAASGFTFDDYGMSWVRQAPGKGLEWVSGINWNGGSTGYADS  
VKGRFTISRDNAKNSLYLQMNSLRAEDTALYHCARGGDDAFDIWGQGTMVTVSS—

GGGGSGGGGGGGGS—

RIVMTQSPGTLSVSPGETATLSCRASQSFSNMLAWYQQKSGQPPRLLIYGVSTRAAGVPARFSGSG  
SGTEFTLTISNLQSEDFAVYYCQQYGDWPRYTFGQGTKVERK—

TTTPAPRPPTPAPTIASQPLSLRPEACRPAAGGAHVTRGLDFACDIYIWAPLAGTCGVLLSLVITLYC  
5 KRGRKKLLYIFKQPFMRPVQTTQEEDGCSRFPEEESEGCELRVKFSRSADAPAYQQGQNQLYNEL  
NLGRREYDVLDRGRDPEMGGKPRRKNPQEGLYNELQDKMAEAYSEIGMKGERRRGKGHDG  
LYQGLSTATKDTYDALHMQALPPR

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METDTLLWVLLLWVPGSTG

10 QVQLQQSGPGLVKPSQTLSLTCAISGDSVSSNSAAWNWIRQSPSRGLEWLGRYYRSKWYNDYAV  
SVKSRTINPDTSKNQFSLQLNSVTPEDTAVYYCAREVTGDLEAFDIWGQGTMVTVSS  
GGGGSGGGGGGGSDIQMTQSPSSLSASVGDRVITCRASQTIWSYLNWYQQRPGKAPNLLIYA  
ASSLQSGVPSRFSGRGSQTDFTLTISLQAEDFATYYCQQSYSIPQTFGQGTKLEIK  
GLAVSTISSFFPPGYQIYIWAPLAGTCGVLLSLVITLYCKRGRKKLLYIFKQPFMRPVQTTQEEDGSC  
15 RFPEEESEGCELRVKFSRSADAPAYQQGQNQLYNELNLGRREYDVLDRGRDPEMGGKPRRKNPQEGLYNELQDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQALPPR

M971 V3

METDTLLWVLLLWVPGSTGQVQLQQSGPGLVKPSQTLSLTCAISGDSVSSNSAAWNWIRQSPSR  
GLEWLGRYYRSKWYNDYAVSVKSRTINPDTSKNQFSLQLNSVTPEDTAVYYCAREVTGDLEAFDI  
20 IWGQGTMVTVSSGGGGGGGGGGSDIQMTQSPSSLSASVGDRVITCRASQTIWSYLNWYQQRPGKAPNLLIYA  
ASSLQSGVPSRFSGRGSQTDFTLTISLQAEDFATYYCQQSYSIPQTFGQGTKLEIK  
KTTTPAPRPPTPAPTIASQPLSLRPEACRPAAGGAHVTRGLDFACDIYIWAPLAGTCGVLLSLVITLY  
CKRGRKKLLYIFKQPFMRPVQTTQEEDGCSRFPEEESEGCELRVKFSRSADAPAYQQGQNQLYNE  
25 LNLRREYDVLDRGRDPEMGGKPRRKNPQEGLYNELQDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQALPPR.

In one embodiment the present invention provides the following sequences:

QVQLQQSGPGLVKPSQTLSLTCAISGDSVSSNSAAWNWIRQSPSRGLEWLGRYYRSKWYNDYAV  
SVKSRTINPDTSKNQFSLQLNSVTPEDTAVYYCAREVTGDLEAFDIWGQGTMVTVSSGGGGGGSGG

GGSGGGGSDIQMTQSPSSLSASVGDRVITCRASQTIWSYLNWYQQRPGKAPNLLIYAASSLQSGV  
PSRFSGRSGTDFLTISLQAEDFATYYCQQSYSIPQTFGQGTKLEIKTTTPAPRPPPTAPTIASQPLS  
LRPEACRPAAGGAVHTRGLDFACDIYIWAPLAGTCVLLSLVITLYCKRGRKKLLYIFKQPFMRPVQ  
TTQEEDGCSCRFPEEEEGGCELRVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLKDRRGRDPE  
5 MGGKPRRKNPQEGLYNELQDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQ  
ALPPR. In this CD22CAR the signal peptide is absent.

In one embodiment, the UCART22 of the present invention comprises a sequence of

SEQ	ID	N°
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20

:ATGGCTCTGCCGTACCGCTCTGCTGCCACTGGCCCTGCTGCTGCACGCAGCAAGACCAC  
10 AGGTGCAGCTGCAGCAGAGCGGCCCTGGCCTGGTGAAGCCAAGCCAGACACTGTCCCTGACCT  
GCGCCATCAGCGCGATTCCGTGAGCTCCAACTCCGCCGCTGGAATTGGATCAGGCAGTCCCC  
TTCTCGGGGCCTGGAGTGGCTGGGAAGGACATACTATCGGTCTAAGTGGTACAACGATTATGC  
CGTGTCTGTGAAGAGCAGAACATCAACCTGACACCTCCAAGAACATCAGTTCTCTGCAG  
15 CTGAATAGCGTGACACCAGAGGACACCGCCGTGTACTATTGCGCCAGGGAGGTGACCGGCGAC  
CTGGAGGATGCCTTGACATCTGGGCCAGGGCACAATGGTGACCGTGTAGCGGAGGAGG  
AGGATCCGGAGGAGGAGGATCTGGCGGCCGGCAGCGATATCCAGATG (SEQ ID N° 20)

In one embodiment, the UCART22 of the present invention comprises a sequence of

SEQ ID N° 22

In a preferred embodiment the UCART22 of the present invention comprises a sequence

20 of SEQ ID N° 22 inserted into a human TRAC gene (such as in human TRAC gene Chromosome 14 - NC\_000014.9) and expresses at the cell surface an anti-CD22 CAR specific for the proximal part of CD22.

In a more preferred embodiment the UCART22 of the present invention comprises a

sequence of SEQ ID N° 20 inserted into a human TRAC gene (such as in human TRAC 25 gene Chromosome 14 - NC\_000014.9) and expresses at the cell surface an anti-CD22 CAR specific for the distal part of CD22.

In one aspect, an anti-CD22 binding domain of the CD22 CAR of the invention is an anti-CD22 binding domain specific for the distal portion of CD22.

HA22-CAR

Accordingly the present invention provides a CD22 CAR with the following sequence :

MALPV TALLPLALLLHAARPEVQLVESGGGLVKPGGSLKLSCAASGFAFSIYDMSWVRQTPEKRLE  
WVAYISSGGGTYYPDTVKGRFTISRDNAKNTLYLQMSSLKSEDTAMYYCARHSGYGTWGVLFAY  
5 KPDGTVKLLIYYTSILHSGVPSRFSGS GSGTDYSLTISNLEQEDFATYFCQQGNTLPWTFGGGT KLEIK  
ATTPAPR PPTPAPTIASQPLSLRPEACRPAAGGA VHTRGLDFACDIYIWAPLAGTCGVLLSLVITLY  
CKRGRKKLLYIFKQPFMRPVQTTQEDGCSCRFPEEEEGGCEL RVKFSRSADAPAYQQQQNQLYNE  
LNLRREEYDVLKRRGRDPEMGGKPRRKNPQEGLYNE LQKDKMAEAYSEIGMKGERRRGKGHD  
GLYQGLSTATKDTYDALHMQALPPR (SEQ ID N°23).

10 Preferably the UCART22 of the present invention comprises a sequence :

ATGGCTCTGCCCGTCACCGCTCTGCTGCCACTGGCCCTGCTGCTGCACGCAGCAAGGCCTGAGGTGC  
AGCTGGT GGAATCCGGAGGAGGCCTGGTGAAGCCTGGCGCTCTGAAGCTGAGCTGTGCCGCCTCCG  
GCTTCGCCTTCCATCTACGACATGTCTGGTGAGGCAGACCCCAGAGAAGCGCCTGGAGTGGTGG  
15 CCTATATCAGCTCCGGCGCCGACCTACTATCCCACACAGTGAAGGGCCGGTTACCACATCTAGAGA  
TAACGCCAAGAATACACTGTACCTGCAGATGTCTAGCCTGAAGAGCGAGGATACCGCCATGTACTATTG  
GCAAGGC ACTCCGGATACGGAACACACTGGGGCGTGTCTGCCTATTGGGCCAGGGCACCCCTGGT  
ACAGTGAGCGCCGGAGGAGGAGGAAGCGCGGAGGAGGCTCCGGCGCGCGCTTGACATCCAGA  
TGACCCAGACCACATCCTCTTGAGCGCCTCCCTGGCGACAGGGTACAATCTTGAGAGCCAGCCA  
GGATATCTCCA ACTACCTGAATTGGTATCAGCAGAACGCTGATGGCACCGTGAAGCTGCTGATCTACTAT  
20 ACATCTATCCTGCACAGCGGAGTGCCTACCGGTTCTCTGGAAGCGGATCCGAACCGACTACTCTCTGA  
CAATCAGCAACCTGGAGCAGGAGGATTCGCCACCTATTTTGCCAGCAGGGCAATACCCCTGCCTGGAC  
ATTGGCGCGGCACAAAGCTGGAGATCAAGGCCACCACAACCCCTGCACCAAGGCCACCAACACCAGC  
ACCTACCACATCGCATCTCAGCCTCTGAGCCTGAGACCAAGAGGGCATGTAGGCCAGCAGCAGGAGGAGCAGT  
25 GCACACAAAGGGACTGGATTTGCCCTGTGATATCTACATCTGGCACCTCTGGCAGGAACATGTGGCGT  
GCTCCTGCTCAGCCTGGTCATCACCTGTACTGCAAGAGAGGGAGGAAGAGCTGCTGTATATCTCAAG  
CAGCCCTCATGAGACCCGTGCAGACAACCCAGGAGGAGGACGGCTGCTCCTGTAGGTTCCAGAAGAG  
GAGGAGGGAGGATGTGAGCTGCGCGTGAAGTTTCCC GGCTGCCATGCACCTGCATACCAAGCAGGG  
30 ACAGAACATCAGCTGTATAACGAGCTGAATCTGGCCGGAGAGAGGGAGTACGACGTGCTGGATAAGAGGA  
GGGAAAGGGACCCAGAGATGGGAGGCAAGCCTCGGAGAAAGAACCCACAGGGAGGGCTGTACAATGA  
GCTGCAGAAGGACAAGATGCCAGGGCTATTCTGAGATGGCATGAAGGGAGAGAGGCCGGGGC  
AAGGGACACGATGCCCTGTACCAGGGCCTGTCCACAGCCACCAAGGACACCTATGATGCCCTGCATATG  
CAGGCACTGCCCTCAAGGTGA (SEQ ID N° 24).

35 An anti- CD22 binding domain specific for the distal portion of CD22 may be expressed alone or with an anti- CD22 binding domain specific for the proximal portion of CD22 in the UCART22 of the invention.

In one aspect, the anti-CD22 binding domain of the CD22 CAR of the invention is an optimized anti- CD22 binding domain.

As used herein, "optimized" antibody (or scfv) refers to forms of antibodies (or scfv) that are chimeric immunoglobulins, immunoglobulin chains, or fragments thereof (such as Fv, Fab, Fab', F(ab')<sub>2</sub> or other antigen binding subsequences of antibodies) that contain minimal sequences derived from immunoglobulin. Preferably, antibodies are 5 human immunoglobulins (recipient antibody) in which residues from a complementary determining region (CDR) are replaced by residues from a CDR to achieve the desired specificity, affinity, and capacity.

10 The donor CDR may undergo few amino acid changes that may significantly affect or alter the binding characteristics of the CD22 CAR of the invention. Indeed, one of the invention provided here is a CD22 CAR which binding to CD22-expressing cell (and cytolytic activity) is maintained but the affinity is modified to reduce the intensity of the response (cytokine release).

15 Amino acid modifications are usually conservative modifications including amino acid substitutions, additions and deletions in said antibody fragment in said CAR and/or any of the other parts of said CAR molecule. Modifications can be introduced into an antibody, into an antibody fragment or in any of the other parts of the CAR molecule of the invention by standard techniques known in the art, such as site-directed mutagenesis, PCR-mediated mutagenesis or by employing optimized germline sequences.

20 In general, the optimized CAR will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the CDR regions correspond to the original human immunoglobulin.

25 Conservative amino acid substitutions mean substitutions in which the amino acid residue is replaced with an amino acid residue having a similar side chain. Families of amino acid residues having similar side chains have been defined in the art. These families include amino acids with basic side chains (e.g., lysine, arginine, histidine), acidic side chains (e.g., aspartic acid, glutamic acid), uncharged polar side chains (e.g., glycine, asparagine, glutamine, serine, threonine, tyrosine, cysteine, tryptophan), nonpolar side chains (e.g., alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine), 30 beta-branched side chains (e.g., threonine, valine, isoleucine) and aromatic side chains

(e.g., tyrosine, phenylalanine, tryptophan, histidine). Thus, one or more amino acid residues within a CAR of the invention can be replaced with other amino acid residues from the same side chain family and the altered CAR can be tested using the functional assays described herein.

5 In a preferred embodiment, the present invention provides a CD22 CAR having conservative sequence modifications (or an amino acid sequence change) as compared to the amino acid sequence of the polypeptide of SEQ ID N°15.

10 In a preferred embodiment, the present invention provides a CD22 CAR having an amino acid sequence with 2 amino acid changes as compared to the amino acid sequence of the polypeptide of SEQ ID N°15.

15 In a preferred embodiment, the present invention provides a CD22 CAR having an amino acid sequence with 3 amino acid changes as compared to the amino acid sequence of the polypeptide of SEQ ID N°15.

20 In a preferred embodiment, the present invention provides a CD22 CAR having an amino acid sequence with 4 amino acid changes as compared to the amino acid sequence of the polypeptide of SEQ ID N°15

25 In a preferred embodiment, the present invention provides a CD22 CAR having an amino acid sequence with 5 amino acid changes as compared to the amino acid sequence of the polypeptide of SEQ ID N°15, optionally comprising at least one sequence of SEQ ID NO 20.

30 In a more preferred embodiment, the present invention provides a CD22 CAR having an amino acid sequence with 5 amino acid changes as compared to the amino acid sequence of the polypeptide of SEQ ID N°15 and at least one CDR in SEQ ID N°15 is conserved.

35 In a more preferred embodiment, the present invention provides a CD22 CAR having an amino acid sequence with from 1 to 15 amino acid changes as compared to the amino acid sequence of the polypeptide of SEQ ID N°15 and at least one CDR in SEQ ID N°15, is conserved.

In a preferred embodiment, the sequence of CD22 CAR of the invention is modified by changing 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 amino acids as compared to the wt CD22 CAR, to reduce the HAMA (human anti-mouse response), without affecting the binding capacity of said CAR to its target (CD22).

5 In a preferred embodiment, the present invention provides a CD22 CAR having an amino acid sequence with at least 1 amino acid change as compared to the amino acid sequence of wt (wt is m971) said at least 1 amino acid change having no impact or improving the binding and/or activity of said CD22 CAR in primary T cells.

10 Binding characteristics may be modified using adapted technique initially described in Mitchell Ho, Satoshi Nagata, and Ira Pastan. Isolation of anti-CD22 Fv with high affinity by Fv display on human cells *PNAS 2006 103 (25) 9637-9642; published ahead of print June 8, 2006, doi:10.1073/pnas.0603653103 which is incorporated herein by reference.*

15 Those optimized scfv also bear at least one mutations equivalent to mutations Pro-91–Thr-92 (PT) Gly-91–Ala-92 and Val-91–Phe-92.

In one embodiment the present invention provides an anti CD22 CAR comprising :

- An extracellular domain comprising

a signal peptide

20 a ligand binding-domain optionally optimized comprising a VH domain and a VL domain from a monoclonal anti-CD22 antibody having one of the following Pro-91–Thr-92 (PT), Gly-91–Ala-92, Val-91–Phe-92, mutations or equivalent,

a hinge, comprising a CD8 alpha ( $\alpha$ ) hinge

- a CD8 alpha transmembrane domain and

25 - a cytoplasmic domain comprising a CD3 zeta signaling domain and a co-stimulatory domain from 4-1BB.

In a preferred embodiment the present invention provides an anti CD22 CAR as above wherein said monoclonal anti-CD22 antibody is from m971 antibody with hots

spot in CDRs. Preferably, one of the following Pro-91–Thr-92 (PT), Gly-91–Ala-92, Val-91–Phe-92, mutations.

In a more preferred embodiment the present invention provides an isolated engineered (TCR and dCK KO) immune T cell comprising an anti CD22 CAR comprising

- 5     • An extracellular domain comprising,  
a signal peptide, a ligand binding-domain comprising a VH domain and a VL domain from  
a monoclonal anti-CD22 antibody having at least one of the following Pro-91–Thr-92,  
Gly-91–Ala-92 mutation; Val-91–Phe-92 mutation,  
a hinge, comprising a CD8 alpha ( $\alpha$ ) hinge  
10    - a CD8 alpha transmembrane domain and  
- a cytoplasmic domain comprising a CD3 zeta signaling domain and a co-stimulatory  
domain from 4-1BB.

In a more preferred embodiment the present invention provides an isolated engineered (TCR and CD52 KO) immune T cell comprising an anti CD22 CAR comprising

- 15    • An extracellular domain comprising,  
a signal peptide, a ligand binding-domain comprising a VH domain and a VL domain from  
a monoclonal anti-CD22 antibody having at least one of the following Pro-91–Thr-92,  
Gly-91–Ala-92 mutation; Val-91–Phe-92 mutation,  
a hinge, comprising a CD8 alpha ( $\alpha$ ) hinge  
20    - a CD8 alpha transmembrane domain and  
- a cytoplasmic domain comprising a CD3 zeta signaling domain and a co-stimulatory  
domain from 4-1BB.

25           In a more preferred embodiment the present invention provides an isolated engineered (TCR, CD52 and dCK KO) immune T cell comprising an anti CD22 CAR comprising

- An extracellular domain comprising,

a signal peptide, a ligand binding-domain comprising a VH domain and a VL domain from a monoclonal anti-CD22 antibody having at least one of the following Pro-91–Thr-92, Gly-91–Ala-92 mutation; Val-91–Phe-92 mutation,

a hinge, comprising a CD8 alpha ( $\alpha$ ) hinge

5           - a CD8 alpha transmembrane domain and

          - a cytoplasmic domain comprising a CD3 zeta signaling domain and a co-stimulatory domain from 4-1BB.

In one aspect, the CAR 22 may be coexpressed at the cell surface with at least one, preferably two, more preferably three, monoclonal antibody (mAb)-specific epitopes, said mAb-specific epitope may be fused to a transmembrane domain of CD8. In one embodiment said mAb –specific epitope is an epitope recognized by rituximab, and/or from QBEN10 and the peptide coexpressed with the cD22 CAR is RQR8.

10           In another embodiment, at least one, preferably two, more preferably three, monoclonal antibody (mAb)-specific epitopes, may be inserted into the linker L of the scfv (binding the VH to the VL) specific for CD22 and/or into the hinge of the CD22 CAR.

15           Molecular antibody (mAb)-specific epitope, may be one of the following a mAb-specific epitope specifically recognized by an monoclonal antibody selected from ibritumomab, tiuxetan, muromonab-CD3, tosimumab, abciximab, basiliximab, brentuximab vedotin, cetuximab, infliximab, rituximab, alemtuzumab, bevacizumab, certolizumab pegol, daclizumab, eculizumab, efalizumab, gemtuzumab, natalizumab, omalizumab, palivizumab, ranibizumab, tocilizumab, trastuzumab, vedolizumab, adalimumab, 20        belimumab, canakinumab, denosumab, golimumab, ipilimumab, ofatumumab, panitumumab, QBEND-10 and ustekinumab, preferably from rituximab (R) and/or from QBEN10 (Q).

25           The epitope-specific mAb may be used for *in vitro* cell sorting and/or *in vivo* cell depletion of immune cells expressing a CD22.

30           In particular embodiments, the extracellular binding domain of the CD22 CAR of the invention may comprises one of the following sequences :

V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-(  
V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-(  
V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>-(  
(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>;  
5 (L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>;  
Epitope1-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>;  
(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-(  
(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>-(  
(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>-Epitope4-(L)<sub>x</sub>-(  
10 (L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>-(  
(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>-Epitope4-(L)<sub>x</sub>-(  
V<sub>1</sub>-(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>2</sub>;

V<sub>1</sub>-(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>;

V<sub>1</sub>-(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>;

15 V<sub>1</sub>-(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>-Epitope4-(L)<sub>x</sub>-(  
(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>1</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-V<sub>2</sub>; or,

(L)<sub>x</sub>-Epitope1-(L)<sub>x</sub>-V<sub>1</sub>-(L)<sub>x</sub>-Epitope2-(L)<sub>x</sub>-V<sub>2</sub>-(L)<sub>x</sub>-Epitope3-(L)<sub>x</sub>;

wherein,

V1 is VL, preferably of SEQ ID N°12 and V2 is VH, preferably of SEQ ID N°13 or V1 is VH

20 and V2 is VL;

L1 is a linker suitable to link the VH chain to the VL chain; preferably of SEQ ID N°10

L is a linker comprising glycine and serine residues, and each occurrence of L in the extracellular binding domain can be identical or different to other occurrence of L in the same extracellular binding domain, and,

25 x is 0 or 1 and each occurrence of x is selected independently from the others; and,

Epitope 1, Epitope 2 and Epitope 3 are mAb-specific epitopes and can be identical or different.

In one embodiment, the extracellular binding domain comprises one of the following 30 sequences

V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-L-Epitope1; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-L-Epitope1-L; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-L-Epitope1-L-Epitope2; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-L-Epitope1-L-Epitope2-L; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-L-Epitope1-L-Epitope2-L-Epitope3; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-L-Epitope1-

L-Epitope2-L-Epitope3-L; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-Epitope1; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-Epitope1-L; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-Epitope1-L-Epitope2; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-Epitope1-L-Epitope2-L; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-Epitope1-L-Epitope2-L-Epitope3; V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-Epitope1-L-Epitope2-L-Epitope3-L; Epitope1-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; Epitope1-L-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; L-Epitope1-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; L-Epitope1-L-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; Epitope1-L-Epitope2-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; Epitope1-L-Epitope2-L-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; L-Epitope1-L-Epitope2-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; L-Epitope1-L-Epitope2-L-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; Epitope1-L-Epitope2-L-Epitope3-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; Epitope1-L-Epitope2-L-Epitope3-L-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; L-Epitope1-L-Epitope2-L-Epitope3-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; L-Epitope1-L-Epitope2-L-Epitope3-L-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>; V<sub>1</sub>-L-Epitope1-L-V<sub>2</sub>; L-Epitope1-L-V<sub>1</sub>-L-Epitope2-L-V<sub>2</sub>; V<sub>1</sub>-L-Epitope1-L-V<sub>2</sub>-L-Epitope2-L; V<sub>1</sub>-L-Epitope1-L-V<sub>2</sub>-L-Epitope2-L-Epitope3; V<sub>1</sub>-L-Epitope1-L-V<sub>2</sub>-L-Epitope2-L-Epitope3-Epitope4; L-Epitope1-L-V<sub>1</sub>-L-Epitope2-L-V<sub>2</sub>-L-Epitope3-L; Epitope1-L-V<sub>1</sub>-L-Epitope2-L-V<sub>2</sub>-L-Epitope3-L; L-Epitope1-L-V<sub>1</sub>-L-Epitope2-L-V<sub>2</sub>-L-Epitope3; L-Epitope1-L-V<sub>1</sub>-L-V<sub>2</sub>-L-Epitope2-L-Epitope3; L-Epitope1-L-V<sub>1</sub>-L-V<sub>2</sub>-L-Epitope2-Epitope3, or Epitope1-L-V<sub>1</sub>-L<sub>1</sub>-V<sub>2</sub>-L-Epitope2-L-Epitope3-Epitope4 wherein

15 V<sub>1</sub> is V<sub>L</sub> and V<sub>2</sub> is V<sub>H</sub> or V<sub>1</sub> is V<sub>H</sub> and V<sub>2</sub> is V<sub>L</sub>; and VH, and VL are optimized VH and VL from m971.

L<sub>1</sub> is any linker suitable to link the V<sub>H</sub> chain to the V<sub>L</sub> chain;

20 L is a linker comprising glycine and serine residues, and each occurrence of L in the extracellular binding domain can be identical or different to other occurrences of L in the same extracellular binding domain, and,

Epitope 1, Epitope 2 and Epitope 3 are mAb-specific epitopes and can be identical or different.

25 L<sub>1</sub> is a linker comprising Glycine and/or Serine, preferably, L<sub>1</sub> is a linker comprising the amino acid sequence (Gly-Gly-Gly-Ser)<sub>n</sub> or (Gly-Gly-Gly-Gly-Ser)<sub>n</sub>, where n is 1, 2, 3, 4 or 5 or a linker comprising the amino acid sequence (Gly<sub>4</sub>Ser)<sub>4</sub> or (Gly<sub>4</sub>Ser)<sub>3</sub>.

Similarly, L is a linker comprising Glycine and/or Serine, preferably L is a linker having an amino acid sequence selected from SGG, GGS, SGGS, SSGGS, GGGG, SGGGG, GGGGS, SGGGGS, GGGGGS, SGGGGGS, SGGGGG, GSGGGGS, GGGGGGGS, SGGGGGGG, SGGGGGGGGS, and SGGGGSGGGGS, preferably L is a SGGGG, GGGGS or SGGGGS.

30 In a preferred embodiment, Epitope 1, Epitope 2, Epitope 3 and Epitope 4 are independently selected from mAb-specific epitopes specifically recognized by

ibritumomab, tiuxetan, muromonab-CD3, tosimumomab, abciximab, basiliximab, brentuximab vedotin, cetuximab, infliximab, rituximab, alemtuzumab, bevacizumab, certolizumab pegol, daclizumab, eculizumab, efalizumab, gemtuzumab, natalizumab, omalizumab, palivizumab, ranibizumab, tocilizumab, trastuzumab, vedolizumab, 5 adalimumab, belimumab, canakinumab, denosumab, golimumab, ipilimumab, ofatumumab, panitumumab, QBEND-10 and ustekinumab, preferably Epitope 1, Epitope 2, Epitope 3 and Epitope 4 are recognized by rituximab or QBEND-10.

10 Epitope 1, Epitope 2, Epitope 3 and Epitope 4 are mAb-specific epitopes specifically recognized by :

Antibody	Indication	Drug bank accession n° (or other n° if stated)	Target/ Antigen
Ibritumoma b tiuxetan	Non-Hodgkin lymphoma (with yttrium-90 or indium-111)	DB00078	CD20
Muromona b-CD3	Transplant rejection	DB00075	T cell CD3 Receptor
Tositumom ab	Non-Hodgkin lymphoma	DB00081	CD20
Abciximab	Cardiovascular disease	DB00054	inhibition of glycoprotein IIb/IIIa
Basiliximab	Transplant rejection	DB00074	IL-2R $\alpha$ receptor (CD25)
Brentuxima b vedotin	Anaplastic large cell lymphoma	DB08870	CD30
Cetuximab	Colorectal cancer, Head and neck cancer	DB00002	epidermal growth factor receptor
Infliximab	Several autoimmune disorders	DB00065	inhibition of TNF- $\alpha$ signaling
Rituximab	Non-Hodgkin lymphoma	DB00073	CD20
Alemtuzum ab	Chronic lymphocytic	DB00087	CD52

	leukemia		
Bevacizumab	Colorectal cancer, Age related macular degeneration (off-label)	DB00112	Vascular endothelial growth factor (VEGF)
Certolizumab pegol	Crohn's disease	DB08904	inhibition of TNF- $\alpha$ signaling
Daclizumab	Transplant rejection	DB00111	IL-2R $\alpha$ receptor (CD25)
Eculizumab	Paroxysmal nocturnal hemoglobinuria	DB01257	Complement system protein
Efalizumab	Psoriasis	DB00095	CD11a
Gemtuzumab	Acute myelogenous leukemia (with calicheamicin)	DB00056	CD33
Natalizumab	Multiple sclerosis and Crohn's disease	DB00108	alpha-4 ( $\alpha$ 4) integrin
Omalizumab	mainly allergy-related asthma	DB00043	immunoglobulin E (IgE)
Palivizumab	Respiratory Syncytial Virus	DB00110	an epitope of the RSV F protein
Ranibizumab	Macular degeneration	DB01270	Vascular endothelial growth factor A (VEGF-A)
Tocilizumab ( or Atlizumab )	Rheumatoid arthritis	DB06273	Anti- IL-6R
Trastuzumab	Breast cancer	DB00072	ErbB2
Vedolizumab	Crohn's disease, ulcerative colitis	CAS n°943609-66-3	integrin $\alpha_4\beta_7$
Adalimumab	Several autoimmune disorders	DB00051	inhibition of TNF- $\alpha$ signaling

Belimumab	Systemic lupus erythematosus	DB08879	inhibition of B- cell activating factor
Canakinumab	Cryopyrin-associated periodic syndrome (CAPS)	DB06168	IL-1 $\beta$
Denosumab	Postmenopausal osteoporosis, Solid tumor's bony metastases	DB06643	RANK Ligand inhibitor
Golimumab	Rheumatoid arthritis, Psoriatic arthritis, and Ankylosing spondylitis	DB06674	TNF-alpha inhibitor
Ipilimumab ( MDX-101 )	Melanoma	DB06186	blocks CTLA-4
Ofatumumab	Chronic lymphocytic leukemia	CAS n° 679818-59-8	CD20
Panitumumab	Colorectal cancer	DB01269	epidermal growth factor receptor
Ustekinumab	Psoriatic Arthritis, Plaque Psoriasis	DB05679	IL-12, IL-23
Nivolumab	renal cell carcinoma, lung cancer, melanoma, and advanced or metastatic solid tumors	CAS n°946414-94-4	PD-1

The mAb-specific epitope may therefore comprise one polypeptide selected from :

CPYSNPSLC, NSELLSLINDMPITNDQKKLMSNN, CQFDLSTRRLKC, CQYNLSSRALKC,  
 CVWQRWQKSYVC, CVWQRWQKSYVC, SFVLNWYRMSPSNQTDKLAAPEDR,  
 5 SGTYLCGAISLAPKAQIKE, ELPTQGTFSNVSTNVSPAKPTTTA, ELPTQGTFSNVSTNVSPAKPTTTA,  
 GQNDTSQTSSPS.

5

Antibody

mAb-specific epitope

Rituximab		
Mimotope		CPYSNPSLC
Palivizumab		
Epitope		NSELLSLINDMPITNDQKKLMSNN
Cetuximab		
Mimotope 1		CQFDLSTRRLKC
Mimotope 2		CQYNLSSRALKC
Mimotope 3		CVWQRWQKSYVC
Mimotope 4		CMWDRFSRWYKC
Nivolumab		
Epitope 1		SFVLNWYRMSPSNQTDKLAAPEDR
Epitope 2		SGTYLCGAISLAPKAQIKE
QBEND-10		
Epitope		ELPTQGTFSNVSTNVSPAKPTTTA
Alemtuzumab		
Epitope		GQNDTSQTSSPS

In a preferred embodiment, the mAb-specific epitope is a mAb-specific epitope having an amino acid sequence of ELPTQGTFSNVSTNVSPAKPTTTA and/or CPYSNPSLC (SEQ ID NO19).

5

In a more preferred embodiment, the CD22 CAR of the invention comprises 3 mAb-specific epitopes having an amino acid sequence of CPYSNPSLC (R) and one having an amino acid sequence of ELPTQGTFSNVSTNVSPAKPTTTA (Q).

10 In an even more preferred embodiment, the CD22 CAR of the invention comprises 2 mAb-specific epitopes having an amino acid sequence of CPYSNPSLC (R) located at the NT part of the hinge, just after the VL.

15 In one aspect, at least one sequence to which rituximab binds to (R) and/or a sequence to which QBEN10 binds to (Q) may be inserted into the linker GGGGSGGGGSGGGGS and/or into the Hinge as previously described in (WO2016120216).

20 In a particular embodiment, the CD22 CAR of the present invention is a single chain CAR (scCAR).

In particular embodiments, the single chain anti-CD22 CAR of the invention comprises a scfv from m971 and at least one other binding domain, preferably specific for the distal part of CD22, alternatively for another B cell antigen, especially if expressed by B cells malignancies such as CD34, CD10, CD79a, CD20, IgD, CD5, CD23, CD19, STAT5, CD3,

CD30, BCMA. In a particular embodiment, the CD22 CAR of the present invention is a multichain CAR (mcCAR). Multichain CD22 CARs are part of the present invention and may be produced as described in details in WO2014039523, which is incorporated herein by reference. In a particular embodiment, the  $V_H$  domain and the  $V_L$  domain of an immunoglobulin or a part of an immunoglobulin specific for CD22, may be carried by two different and isolated (non covalently bound) chains of a multichain CAR.

In a multichain version, the CD22 CAR of the invention comprises at least two, preferably 3 transmembrane domains (non covalently bound to each other) with at least one of the transmembrane domain comprising a scfv specific for CD22 of the invention.

10 In a particular embodiment, the  $V_H$  domain and the  $V_L$  domain of an immunoglobulin specific for CD22, preferably from m971 may be carried by one chain of a multichain CAR.

An example of sc CD22 CAR and of mc CD22 CAR of the invention is provided figure 2.

15 In a particular embodiment, the  $V_H$  domain and the  $V_L$  domain of an immunoglobulin specific for CD22, preferably from m971 may be carried by one chain of a multichain CAR and the  $V_H$  domain and the  $V_L$  domain of another immunoglobulin specific for CD22, may be carried by another chain of the mc CAR.

20 Downregulation or mutation of target antigens is commonly observed in cancer cells, creating antigen-loss escape variants. Thus, to offset tumor escape and render immune cell more specific to target, the CD22 specific CAR according to the invention can comprise another extracellular ligand-binding domain, to simultaneously bind other elements in target thereby augmenting immune cell activation and function. In one embodiment, the extracellular ligand-binding domains can be placed in tandem on the same transmembrane polypeptide, and optionally can be separated by a linker.

25 In another embodiment, said different extracellular ligand-binding domains can be placed on different transmembrane polypeptides composing the multichain CAR. In another embodiment, the present invention relates to a population of CARs comprising different extracellular ligand binding domains, one of each is specific for CD22.

In one embodiment the extracellular binding domain specific for CD22 and the second extracellular binding domain are on the same scCAR,

In another embodiment, the extracellular binding domain specific for CD22 and the second extracellular binding domain are on the same mc CAR and belong to the same or to two different and non covalently bound transmembrane domains of said mc CAR.

5 As other second extracellular binding domain may be any extracellular binding domain binding specific to an antigen associated (coexpressed – even temporarily) to CD22 on pathological cells, such as CD34, CD10, CD79a, CD20, IgD, CD5, CD23, CD19, STAT5, CD3, CD30, BCMA, PAX5, CD19, CD20, CD30, glycosphingolipids, a major histocompatibility complex (MHC) molecule, an Ig, CD3, CD34, CD79, preferably CD79a, CD138, B7-1  
10 (CD80), B7-2 (CD86), a major histocompatibility complex (MHC) molecule, BCMA (CD269, TNFRSF 17) or FLT-3, Pax5.

15 The invention also provides related CD22 CAR nucleic acids, CD22 CAR recombinant expression vectors, engineered TCR KO cells, preferably T cells comprising at least another edited gene endowed with the CD22 CAR, populations of said TCR KO cells endowed with a CD22 CAR, and pharmaceutical compositions relating to the CD22  
CARs, protein, expression vector, engineered TCR KO CD52 KO cells expressing said CD22CAR of the invention.

20 The invention provides the following objects : a CD22 CAR of the invention - related nucleic acids, -recombinant expression vectors, engineered TCR KO cells comprising at least another edited gene selected from a gene conferring resistance to hypoxia, a gene conferring resistance to alemtuzumab, to protease inhibitor, such as bortezomib, a gene conferring resistance to PNA (dCK) and endowed with a CD22 CAR, and related nucleic acid, populations of engineered TCR KO cells comprising at least another edited gene as below, endowed with said CD22 CAR and pharmaceutical  
25 compositions comprising said same objects as a medicament.

### **Polynucleotides, vectors:**

The present invention relates to polynucleotides, vectors encoding the above described CD22 CAR according to the invention.

5

A polynucleotide may consist in an expression cassette or expression vector (e.g. a plasmid for introduction into a bacterial host cell, or a viral vector such as a baculovirus vector for transfection of an insect host cell, or a plasmid or viral vector such as a lentivirus or an adeno associated virus for introduction into a mammalian, preferably human host cell.

10

In a particular embodiment, the different nucleic acid sequences can be included in one polynucleotide or vector which comprises a nucleic acid sequence encoding ribosomal skip sequence such as a sequence encoding a 2A peptide. 2A peptides, which were identified in the Aphthovirus subgroup of picornaviruses, causes a ribosomal "skip" from one codon to the next without the formation of a peptide bond between the two amino acids encoded by the codons (see (Donnelly and Elliott 2001; Atkins, Wills et al. 2007; Doronina, Wu et al. 2008)).

Accordingly the present invention provides a vector as in figure 4 coding for a RQR8 and an anti-CD22CAR linked by a peptide 2A.

15

20

By "codon" is meant three nucleotides on an mRNA (or on the sense strand of a DNA molecule) that are translated by a ribosome into one amino acid residue. Thus, two polypeptides can be synthesized from a single, contiguous open reading frame within an mRNA when the polypeptides are separated by a 2A oligopeptide sequence that is in frame. Such ribosomal skip mechanisms are well known in the art and are known to be used by several vectors for the expression of several proteins encoded by a single messenger RNA.

25

A vector allowing a CD22 CAR of the invention to be expressed in a cell is another object of the present invention. In a preferred embodiment, said vector allows a transient expression of the CD22 CAR of the invention. In a more preferred embodiment said vector allows a constitutive and stable expression of a CD22 CAR of the invention by insertion of the sequence coding said CD22 CAR into the genome of a cell.

The expression of a CD22 CAR of the invention and/or the survival of the cell expressing the CD22 CAR of the invention may be controlled using a gene under the control of an inducible promoter as described in (R. Kuhn, F. Schwenk, M. Aguet, K.

Rajewsky. Inducible gene targeting in mice. Science 8 September 1995: Vol. 269 no. 5229 pp. 1427-1429 DOI:10.1126/science.7660125, and cited references.

5 In one embodiment, a CD22 CAR is provided wherein the extracellular domain comprises at least two CD20 mimotopes of SEQ ID NO 19 (CPYSNPSLC) located between m971 scfv domains and the hinge from human CD8alpha. Document Patent WO2016120216A1 discloses a method for preparing such constructions and is incorporated herein by reference.

In one embodiment, the present invention provides a vector comprising a sequence coding a CD22 CAR selected from SEQ ID NO. 22.

10 To direct transmembrane polypeptide into the secretory pathway of a host cell, a secretory signal sequence (also known as a leader sequence, prepro sequence or pre sequence) is provided in polynucleotide sequence or vector sequence. The secretory signal sequence is operably linked to the transmembrane nucleic acid sequence, i.e., the two sequences are joined in the correct reading frame and positioned to direct the 15 newly synthesized polypeptide into the secretory pathway of the host cell. Secretory signal sequences are commonly positioned 5' to the nucleic acid sequence encoding the polypeptide of interest, although certain secretory signal sequences may be positioned elsewhere in the nucleic acid sequence of interest (see, e.g., Welch et al., U.S. Patent No. 5,037,743; Holland et al., U.S. Patent No. 5,143,830). In a preferred embodiment the 20 signal peptide comprises the amino acid sequence SEQ ID NO: 1 and 2.

In a more preferred embodiment, the signal peptide of the CAR of the invention comprises the amino acid sequence of SEQ ID NO: 1 from human CD8 alpha.

25 Those skilled in the art will recognize that, in view of the degeneracy of the genetic code, considerable sequence variation is possible among these polynucleotide molecules. Preferably, the nucleic acid sequences of the present invention are codon-optimized for expression in mammalian cells, preferably for expression in human cells. Codon-optimization refers to the exchange in a sequence of interest of codons that are generally rare in highly expressed genes of a given species by codons that are generally frequent in highly expressed genes of such species, such codons encoding the amino 30 acids as the codons that are being exchanged.

Methods of engineering immune cells endowed with CD22 CARs:

5 The present invention encompasses a method of preparing immune cells for immunotherapy comprising introducing *ex-vivo* into said immune cells a polynucleotide or a vector encoding one of the CD22 CAR of the invention, preferably of SEQ ID NO. 15 as previously described.

10 In a preferred embodiment, said polynucleotides are included into a vector in view of being stably expressed in the immune cells.

15 According to further embodiments, said method further comprises the step of 10 genetically modifying said cell to make it more suitable for adoptive transfer, and/or for use with a drug affecting said immune cell survival, in particular for transplant (also called allograft, or homograft) alone or in combination with the drug for which the immune cell is made resistant to.

20 In this later case, engineered cells may be initially isolated from a donor and used 15 for a reinjection into the same donor in combination with a drug to which it is made resistant to.

25 For editing a gene, which means here, modifying a gene, or inactivating a gene, for example mutating a gene, deleting a gene, inserting a sequence in a gene, modifying the methylation of said gene (this includes the promotor of a gene), etc, methods 20 described in PA201670503 are incorporated here by reference and illustrated in the examples below.

30 Methods described in MacLeod et al., Integration of a CD19 CAR into the TCR Alpha Chain Locus Streamlines Production of Allogeneic Gene-Edited CAR T Cells, Molecular Therapy (2017), <http://dx.doi.org/10.1016/j.ymthe.2017.02.005>, incorporated herein by reference are also a possible alternatives to the method used in the present invention for preparing a TCR KO CD22 CAR or a cell endowed with a CD22 CAR resistant to hypoxia by over expressing HIF-1a.

35 The method of the present invention is based on cellular homology-directed repair (HDR) mechanisms to “knock in” a CD22 CAR in the TRAC gene (encoding the TCR alpha subunit of the TCR) resulting in a more efficient product.

5

HDR with an exogenous DNA sequence has been described previously in T cells using short oligonucleotides paired with CRISPR/Cas9. Others have shown that adeno-associated virus (AAV) vectors can be used as a template in conjunction with a site-specific nuclease Crispr/Cas9 or MegaTAL to achieve gene insertion via HDR. In the present invention is provided a new method combining adeno-associated virus (AAV) vectors and TALEN to insert a CAR into the TCR gene.

In UCART22, AAV6 vector may be used after genetic editing using specific TALEN of a gene such as the TRAC gene (gene encoding the alpha subunit or the TCR) or any gene disclosed in PCT/EP2017/076798.

10

15

Because TALEN are specific for a DNA sequence and allow integrating a sequence into a gene, preferably a TRAC gene, the present invention also provides an engineered immune cells comprising a sequence coding a CAR, preferably a CD22 CAR as described above located in a precise region of the TRAC gene determined by the TALEN used. The sequence in the TRAC gene of said engineered immune cell, is unique due to the TALEN specificity.

Accordingly the present invention provides an engineered immune cell comprising the following sequence;

(YYY)<sub>n</sub>-ZZZ-(XXX)<sub>m</sub>.

20

with n is =1 to at least 10

and m is = 1 to 100 preferably m is > 100 and represents the number of base pair of the sequence to be integrated,

wherein ZZZ codes a self-cleaving peptide, such as a 2A peptide, in frame with the TRAC encoding sequence,

25

Y is A or T or G or C and flanking or comprising a sequence of the TRAC gene targeted by a TALEN comprising at least **ttgtcccacagATATC**, preferably **ttgtcccacagATATCCAG** and (XXX)<sub>n</sub> is A or T or G or C and part of an exogenous sequence to be inserted into the TRAC gene, preferably a sequence encoding a CAR, more preferably a sequence encoding a CD22 CAR.

In one embodiment the TRAC gene is deleted and the inserted gene is expressed under the control of the TRAC promotor.

Additional or alternative sequences, such as IRES internal ribosome entry site; maybe interposed between the TALEN target and XXX.

5 In the present invention, the TALEN target is SEQ ID N° 21 and the CAR CD22 is SEQ ID N° 22.

In one embodiment the sequence cleaved by said TALEN is AGAACCTGACCCCTG. The sequence AGAACCTGACCCCTG may be conserved at least in part (see figure 9) in an engineered cell of the invention depending on the insert sequence.

10 The present invention provides an engineered immune cell comprising a TRAC gene comprising a SEQ ID N° 22.

The present invention provides an engineered immune cell comprising a sequence encoding a CAR specific for CD19 or a sequence encoding a CAR specific for CD22 inserted into the TRAC gene, preferably anywhere at the locus :AGAACCTGACCCCTG.

15 Thus,in particular embodiments, the engineered immune cell of the invention comprises two different sequences encoding a CAR and express said two different CARs. At the cell surface, undetectable level of TCR.

20 Thus,in particular embodiments, the engineered immune cell of the invention comprises two different sequences encoding a CAR and express said two different CARs. At the cell surface, undetectable level of TCR and of MHC Class I.

25 the engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD19 is inserted.

the engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD34 is inserted.

the engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD79a is inserted.

5 the engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD79b is inserted.

The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD10 is inserted.

10 The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for IgD is inserted.

15 The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD5 is inserted

The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD23 is inserted.

20 The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD30 is inserted.

The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for BCMA is inserted.

25 The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for FLT3 is inserted.

The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD138 is inserted.

5 The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD80 is inserted.

The engineered immune cell of the invention comprises into its genomic TRAC gene a sequence coding CD22, preferably of SEQ ID N°22, and another genomic sequence in which another exogenous gene coding for a CAR specific for CD86 is inserted.

10 Another genomic sequence in which another exogenous gene coding for a second CAR is inserted may be any one of the genes disclosed in PCT/EP2017/076798 or in WO2017069958A2.

15 The other exogenous gene encoding a CAR may be inserted into the TRAC gene in frame with a self cleaving peptide and with the CD22 CAR sequence, preferably SEQ ID N° or into another geneencoding a protein as those disclosed in PCT/EP2017/076798, or chosen among PD1 (Uniprot Q15116), CTLA4 (Uniprot P16410), PPP2CA (Uniprot P67775), PPP2CB (Uniprot P62714), PTPN6 (Uniprot P29350), PTPN22 (Uniprot Q9Y2R2), LAG3 (Uniprot P18627), HAVCR2 (Uniprot Q8TDQ0), BTLA (Uniprot Q7Z6A9), CD160 (Uniprot O95971), TIGIT (Uniprot Q495A1), CD96 (Uniprot P40200), CRTAM (Uniprot O95727), LAIR1 (Uniprot Q6GTX8), SIGLEC7 (Uniprot Q9Y286), SIGLEC9 (Uniprot Q9Y336), CD244 (Uniprot Q9BZW8), TNFRSF10B (Uniprot O14763), TNFRSF10A (Uniprot O00220), CASP8 (Uniprot Q14790), CASP10 (Uniprot Q92851), CASP3 (Uniprot P42574), CASP6 (Uniprot P55212), CASP7 (Uniprot P55210), FADD (Uniprot Q13158), FAS (Uniprot P25445), TGFBRII (Uniprot P37173), TGFRBRI (Uniprot Q15582), SMAD2 (Uniprot Q15796), SMAD3 (Uniprot P84022), SMAD4 (Uniprot Q13485), SMAD10 (Uniprot B7ZSB5), SKI (Uniprot P12755), SKIL (Uniprot P12757), TGIF1 (Uniprot Q15583), IL10RA (Uniprot Q13651), IL10RB (Uniprot Q08334), HMOX2 (Uniprot P30519), IL6R (Uniprot P08887), IL6ST (Uniprot P40189), EIF2AK4 (Uniprot Q9P2K8), CSK (Uniprot P41240), PAG1 (Uniprot Q9NWQ8), SIT1 (Uniprot Q9Y3P8), FOXP3 (Uniprot Q9BZS1), PRDM1 (Uniprot Q60636), BATF (Uniprot Q16520), GUCY1A2 (Uniprot P33402), GUCY1A3 (Uniprot Q02108), GUCY1B2 (Uniprot Q8BXH3) and GUCY1B3 (Uniprot Q02153).

Preferred edited (KO) genes in UCART 22 are TNFRSF10B (Uniprot O14763), TNFRSF10A (Uniprot O00220), IL10RA (Uniprot Q13651), IL10RB (Uniprot Q08334, TGFBRII (Uniprot P37173), TGFRBRI (Uniprot Q15582), PD1 (Uniprot Q15116), CTLA4 (Uniprot P16410), LAG3 (Uniprot P18627), HAVCR2 (Uniprot Q8TDQ0), TIGIT (Uniprot Q495A1).

5 Preferably the gene in which the second CAR is inserted is a genomic gene active during T cell activation selected from any one of those described in table A:

Table A

Symbol	Gene description
CD3G	CD3 gamma
Rn28s1	28S ribosomal RNA
Rn18s	18S ribosomal RNA
Rn7sk	RNA, 7SK, nuclear
Actg1	actin, gamma, cytoplasmic 1
B2m	beta-2 microglobulin
Rpl18a	ribosomal protein L18A
Pabpc1	poly(A) binding protein, cytoplasmic 1
Gapdh	glyceraldehyde-3-phosphate dehydrogenase
Rpl19	ribosomal protein L19
Rpl17	ribosomal protein L17
Rplp0	ribosomal protein, large, P0
Cfl1	cofilin 1, non-muscle
Pfn1	profilin 1

10 or in safe harbor loci as disclosed in PCT/EP2017/076798 or in Table AA

Table AA:

Zfp640	zinc finger protein 640
LOC100038422	uncharacterized LOC100038422
Zfp600	zinc finger protein 600
Serpib3a	serine (or cysteine) peptidase inhibitor, clade B (ovalbumin), member 3A
Tas2r106	taste receptor, type 2, member 106
Magea3	melanoma antigen, family A, 3
Omt2a	oocyte maturation, alpha
Cpxcr1	CPX chromosome region, candidate 1
Hsf3	heat shock transcription factor 3
Pbsn	Probasin
Sbp	spermine binding protein
Wfdc6b	WAP four-disulfide core domain 6B
Meiob	meiosis specific with OB domains
Dnm3os	dynamin 3, opposite strand
Skint11	selection and upkeep of intraepithelial T cells 11

5 The other gene in which the second CAR may be inserted may be a gene encoding any one of the protein in Table B selected from ...

Table B

interleukin 21
interleukin 3
isopentenyl-diphosphate delta isomerase 2
granzyme C
chemokine (C-C motif) receptor 8
interleukin 2
interleukin 1 receptor, type I
tumor necrosis factor (ligand) superfamily, member 4

neuronal calcium sensor 1
CDK5 and Abl enzyme substrate 1
transmembrane and tetratricopeptide repeat containing 2
LON peptidase N-terminal domain and ring finger 1
glycoprotein 49 A
polo-like kinase 2
lipase, endothelial
cyclin-dependent kinase inhibitor 1A (P21)
grainyhead-like 1 (Drosophila)
cellular retinoic acid binding protein II
adenylate kinase 4
microtubule-associated protein 1B
acyl-CoA synthetase long-chain family member 6
zinc finger E-box binding homeobox 2
CD200 antigen
carboxypeptidase D
thioredoxin reductase 3
myosin IE
RNA binding protein with multiple splicing 2
mitogen-activated protein kinase kinase 3, opposite strand
PERP, TP53 apoptosis effector
myosin X
immediate early response 3
folliculin interacting protein 2
leukocyte immunoglobulin-like receptor, subfamily B, member 4
circadian associated repressor of transcription
RAR-related orphan receptor gamma
proline-serine-rich coiled-coil 1
cysteine rich protein 2
cAMP responsive element modulator
chemokine (C-C motif) ligand 4
nuclear receptor subfamily 4, group A, member 2
transglutaminase 2, C polypeptide
synapse defective 1, Rho GTPase, homolog 2 (C, elegans)
sprouty homolog 1 (Drosophila)
activating transcription factor 3
pogo transposable element with KRAB domain
tumor necrosis factor receptor superfamily, member 21
cytokine inducible SH2-containing protein
lymphotoxin A
FBJ osteosarcoma oncogene
signaling lymphocytic activation molecule family member 1
syndecan 3
mitochondrial ribosomal protein L47
Ladinin
E2F transcription factor 5

ISG15 ubiquitin-like modifier
aryl-hydrocarbon receptor
diacylglycerol O-acyltransferase 2
FBJ osteosarcoma oncogene B
pleckstrin homology-like domain, family A, member 3
potassium voltage-gated channel, subfamily Q, member 5
tumor necrosis factor receptor superfamily, member 10b
Mir17 host gene 1 (non-protein coding)
glucose-fructose oxidoreductase domain containing 1
plexin A1
heat shock factor 2
carbohydrate sulfotransferase 11
growth arrest and DNA-damage-inducible 45 gamma
solute carrier family 5 (sodium-dependent vitamin transporter), member 6
interferon induced transmembrane protein 3
DENN/MADD domain containing 5A
plasminogen activator, urokinase receptor
solute carrier family 19 (thiamine transporter), member 2
ubiquitin domain containing 2
nuclear receptor subfamily 4, group A, member 3
zinc finger protein 52
SH3 domain containing ring finger 1
dihydrouridine synthase 2
cyclin-dependent kinase 5, regulatory subunit 1 (p35)
processing of precursor 7, ribonuclease P family, (S, cerevisiae)
growth factor independent 1
interleukin 15 receptor, alpha chain
BCL2-like 1
protein tyrosine phosphatase, receptor type, S
plasmacytoma variant translocation 1
fos-like antigen 2
BCL2-associated X protein
solute carrier family 4, sodium bicarbonate cotransporter, member 7
tumor necrosis factor receptor superfamily, member 4
chemokine (C-X-C motif) ligand 10
polo-like kinase 3
CD3E antigen, epsilon polypeptide associated protein
tumor necrosis factor (ligand) superfamily, member 11
polymerase (RNA) III (DNA directed) polypeptide D
early growth response 2
DnaJ (Hsp40) homolog, subfamily C, member 2
DNA topoisomerase 1, mitochondrial
tripartite motif-containing 30D
DnaJ (Hsp40) homolog, subfamily C, member 21
SAM domain, SH3 domain and nuclear localization signals, 1

solute carrier family 5 (inositol transporters), member 3
mitochondrial ribosomal protein L15
dual specificity phosphatase 5
apoptosis enhancing nuclease
ets variant 6
DIM1 dimethyladenosine transferase 1-like (S, cerevisiae)
2'-5' oligoadenylate synthetase-like 1
UTP18, small subunit (SSU) processome component, homolog (yeast)
BRCA2 and CDKN1A interacting protein
synaptotagmin-like 3
5-methyltetrahydrofolate-homocysteine methyltransferase reductase
URB2 ribosome biogenesis 2 homolog (S, cerevisiae)
ubiquitin-conjugating enzyme E2C binding protein
lysine (K)-specific demethylase 2B
queuine tRNA-ribosyltransferase domain containing 1
ubiquitin specific peptidase 31
eukaryotic translation initiation factor 2-alpha kinase 2
ATPase family, AAA domain containing 3A
adhesion molecule, interacts with CXADR antigen 1
SUMO/sentrin specific peptidase 3
ESF1, nucleolar pre-rRNA processing protein, homolog (S, cerevisiae)
deoxynucleotidyltransferase, terminal, interacting protein 2
TGFB-induced factor homeobox 1
eukaryotic translation initiation factor 1A
interferon-stimulated protein
pleiomorphic adenoma gene-like 2
PWP2 periodic tryptophan protein homolog (yeast)
furin (paired basic amino acid cleaving enzyme)
tumor necrosis factor
apoptosis antagonizing transcription factor
interferon, alpha-inducible protein 27 like 2A
ST6 (alpha-N-acetyl-neuraminy-2,3-beta-galactosyl-1,3)-N-acetylgalactosaminide alpha-2,6-sialyltransferase 4
methyltransferase like 1
notchless homolog 1 (Drosophila)
mitochondrial ribosomal protein L3
UBX domain protein 2A
guanine nucleotide binding protein-like 2 (nucleolar)
programmed cell death 11
cyclin-dependent kinase 8
eukaryotic translation initiation factor 5B
RNA terminal phosphate cyclase-like 1
NSFL1 (p97) cofactor (p47)
nuclear factor of kappa light polypeptide gene enhancer in B cells

inhibitor, delta
M-phase phosphoprotein 10 (U3 small nucleolar ribonucleoprotein)
GRAM domain containing 1B
ERO1-like (S. cerevisiae)
nuclear receptor subfamily 4, group A, member 1
surfeit gene 2
N(alpha)-acetyltransferase 25, NatB auxiliary subunit
yrdC domain containing (E.coli)
La ribonucleoprotein domain family, member 4
SDA1 domain containing 1
importin 4
inducible T cell co-stimulator
solute carrier family 7 (cationic amino acid transporter, y+ system), member 1
arsA arsenite transporter, ATP-binding, homolog 1 (bacterial)
polymerase (RNA) I polypeptide C
spermatogenesis associated 5
ubiquitin specific peptidase 18
placenta-specific 8
general transcription factor IIF, polypeptide 1
nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, beta
PHD finger protein 6
RRN3 RNA polymerase I transcription factor homolog (yeast)
cytotoxic and regulatory T cell molecule
COP9 (constitutive photomorphogenic) homolog, subunit 6 (Arabidopsis thaliana)
asparagine-linked glycosylation 3 (alpha-1,3-mannosyltransferase)
tryptophanyl-tRNA synthetase
hypoxia up-regulated 1
family with sequence similarity 60, member A
bone marrow stromal cell antigen 2
nuclear factor of kappa light polypeptide gene enhancer in B cells 2, p49/p100
UTP20, small subunit (SSU) processome component, homolog (yeast)
CD274 antigen
proviral integration site 1
signal transducer and activator of transcription 5A
CD69 antigen
pitrilysin metallopeptidase 1
cyclin-dependent kinase 6
DEAD (Asp-Glu-Ala-Asp) box polypeptide 27
polymerase (RNA) I polypeptide B
tumor necrosis factor, alpha-induced protein 3
nodal modulator 1
NOP14 nucleolar protein

ribosomal protein L7-like 1
methionyl aminopeptidase 1
hypoxia inducible factor 1, alpha subunit
Janus kinase 2
nuclear factor of kappa light polypeptide gene enhancer in B cells 1, p105
reticuloendotheliosis oncogene
septin 2
nucleolar protein interacting with the FHA domain of MKI67
elongation factor Tu GTP binding domain containing 2
myelocytomatosis oncogene
dyskeratosis congenita 1, dyskerin
carnitine deficiency-associated gene expressed in ventricle 3
GTP binding protein 4
HEAT repeat containing 1
proteaseome (prosome, macropain) activator subunit 3 (PA28 gamma, Ki)
La ribonucleoprotein domain family, member 1
DNA segment, Chr 19, Brigham & Women's Genetics 1357 expressed
eukaryotic translation initiation factor 3, subunit D
TSR1 20S rRNA accumulation
MYB binding protein (P160) 1a
T cell activation Rho GTPase activating protein
RAB8B, member RAS oncogene family
DEAD (Asp-Glu-Ala-Asp) box polypeptide 21
chaperonin containing Tcp1, subunit 4 (delta)
coiled-coil-helix-coiled-coil-helix domain containing 2
WD repeat domain 43

UCART22 may be prepared using, AAV vector, preferably AAV6 vector and even more preferably AAV6 /2 vector for inserting the CD22 CAR or another gene as disclosed herein. AAV vector(s) may be used after genetic editing of a gene such as the TRAC gene (gene encoding the alpha subunit or the TCR) or any gene disclosed in PCT/EP2017/076798, using a specific endonuclease.

Adoptive cell transfer is the transfer of cells into a patient. The cells may have originated from the patient him- or herself and then been altered before being transferred back (syngenic transfer) or, they may have come from another individual. The cells are most commonly derived from the immune system, with the goal of transferring improved immune functionality and characteristics along with the cells back to the patient. Transferring autologous cells, or cells from the patient, minimizes graft-

versus-host disease (GVHD) or tissue or organ rejection. Similarly transferring TCR-deficient T cells CD22 CART cells minimizes GVHD. Transferring TCR-deficient MHC I deficient CD22CART minimizes GVHD and HVGD.

In one embodiment, the step of genetically modifying (engineering) said immune cell takes place before the step of introducing the polynucleotides or vectors encoding one of the CD22 CAR of the invention into said cells. According to a first aspect, the immune cell can be made less allogeneic, for instance, by inactivating at least one gene expressing one or more component of T-cell receptor (TCR) as described in WO 2013/176915, which can be combined with the inactivation of a gene encoding or regulating HLA expression such as  $\beta$ 2m gene as described in WO2008102199 or in WO2015136001 or in WO2016201047 which are all incorporated herein by reference. Accordingly, the risk of graft versus host syndrome and the risk of graft rejection are significantly reduced.

According to another aspect, the immune cells of the invention can be further genetically engineered to improve the resistance of engineered immune cells to an immunosuppressive drug or a chemotherapy treatment, which are used as standard care for treating CD22 positive malignant cells as disclosed in WO201575195 which is incorporated herein by reference.

#### **Resistance to Campath (alemtuzumab)**

In one preferred embodiment, the genes which can be inactivated to confer drug resistance to the T-cell is a glucocorticoid receptor (GR) and CD52. Genes are inactivated to make the cells resistant to these treatments and give them a competitive advantage over patient's own T-cells not endowed with specific CD22 CARs.

The inactivation of the CD52 and TRAC gene in the engineered immune cell according to the invention is performed using a TALE nuclease or a CRISPR CAS9 system.

In one more preferred embodiment, the gene which can be inactivated to confer drug resistance to the T-cell is the CD52 in TCR KO immune T cells endowed with a CD22 CAR.

In one preferred embodiment, the gene which can be inactivated to confer drug resistance to the T-cell is a glucocorticoid receptor (GR).

5

Expression of CD3 gene can also be suppressed or reduced to confer resistance to Teplizumab, which is another immune suppressive drug. Expression of HPRT can also be suppressed or reduced according to the invention to confer resistance to 6-thioguanine, a cytostatic agent commonly used in chemotherapy especially for the treatment of acute lymphoblastic leukemia.

**Resistance to purine nucleotide analogs by deletion of human deoxycytidine kinase (dCK) gene.**

10

In one preferred embodiment, the gene which can be inactivated to confer drug resistance to the T-cell is the human deoxycytidine kinase (dCK) gene. This enzyme is required for the phosphorylation of the deoxyribonucleosides deoxycytidine (dC), deoxyguanosine (dG) and deoxyadenosine (dA). Purine nucleotide analogs (PNAs) are metabolized by dCK into mono-, di- and tri-phosphate PNA. Their triphosphate forms and particularly clofarabine triphosphate compete with ATP for DNA synthesis, acts as proapoptotic agent and are potent inhibitors of ribonucleotide reductase (RNR) which is involved in trinucleotide production.

15

The inactivation of the dCK gene in the engineered immune cell according to the invention is mediated by a TALE nuclease or a CRISPR CAS9 system. To achieve this goal, several pairs of dCK TALE-nuclease have been designed, assembled at the polynucleotide level and validated by sequencing. Examples of TALE-nuclease pairs which can be used according to the present invention are depicted in PCT/EP2014/075317.

20

This dCK inactivation in engineered immune cells of the invention confers resistance to purine nucleoside analogs (PNAs) such as clofarabine and fludarabine.

25

In another preferred embodiment, the dCK inactivation in engineered immune cells of the invention is combined with an inactivation of TRAC genes rendering these double knock out (KO) (TCR or TRAC KO and dCK KO) cells both resistant to drug such as clofarabine and less allogeneic.

In another preferred embodiment, the CD52 inactivation in engineered immune cells of the invention is combined with an inactivation of TRAC gene rendering these

double knock out (KO) (TCR or TRAC KO and CD52 KO) cells both resistant to drug such as CAMPATH (alemtuzumab) and less allogeneic.

This double feature is particularly useful for a therapeutic goal, allowing “off-the-shelf” allogeneic cells (UCART22) for immunotherapy in conjunction with chemotherapy to treat patients with cancer in need thereof. This double KO inactivation dCK/TRAC or CD52/TRAC can be performed simultaneously or sequentially. One example of TALE-nuclease dCK/TRAC pairs which gave success in the invention is described in PCT/EP2014/075317, in particular, the target sequences in the 2 loci (dCK and TRAC). Document PCT/EP2014/075317 is incorporated herein in its entirety.

The present invention provides a primary T cells expressing a CD22 CAR of SEQ ID NO.15, wherein, wherein the CD52 and TRAC genes are inactivated by deletion for their use in the treatment of CLL, ALL, preferably their aggressive, relapsing refractory forms, optionally in lymphodepleted patients, more preferably relapsing refractory forms of B-ALL.

According to a further aspect of the invention, the immune cells can be further manipulated to make them more active or limit exhaustion, by inactivating genes encoding proteins that act as “immune checkpoints” that act as regulators of T-cells activation, such as PDCD1 or CTLA-4. Examples of genes, which expression could be reduced or suppressed are indicated in Table 9.

The present invention also provides a primary T cells expressing a CD22 CAR of SEQ ID NO.15, wherein the CD52, TRAC and dCK genes were deleted.

In another embodiment the present invention also provides a primary T cells expressing a CD22 CAR that were made resistant to hypoxia.

The present invention also provides a primary T cells expressing a CD22 CAR of SEQ ID NO.15, wherein the CD52, TRAC and dCK genes were deleted and sequences of HIF-1a were inserted to make cells resistant to hypoxia.

### **Engineered cells resistant to hypoxia**

In particular embodiments, the expression and cytolytic activity of CD22 CAR T cell of the invention is maintained, or the expression of CD22 CAR T cell induced and the

activity maintained under low oxygen condition (hypoxia), (as compared to normal oxygen condition 20% O<sub>2</sub> vs 1 to 5 % O<sub>2</sub>) and said cell still target and destroy tumor cells when embedded into tissues.

5 Examples of hypoxia- inducible CAR in T cell are described (in WO2013123061 or in Juillerat, A. *et al.* An oxygen sensitive self-decision making engineered CAR T-cell *Sci. Rep.* 7, 39833; doi: 10.1038/srep39833 (2017), both incorporated by reference): A synthetic promoter specific for the OxiTF driving the expression of the CD22 CAR was constructed. The OxiTF is design to activate a synthetic genetic element encoding a CD22 CAR. Upon 10 tumor encounter, (creating hypoxia), engineered T cells can “detect” a decrease in oxygen level (as compared to the mean level of O<sub>2</sub> in the blood) and trigger the expression of the CD22 CAR. Cell surface exposure of CD22 CAR enables the recognition of tumor antigen under hypoxia that eventually triggers T cells activation and proliferation via the activation and co-stimulatory domains present within said CD22 15 CAR. Ultimately, tumor antigen expressing cells are lysed by the UCART22 of the invention.

20 In the present invention, immune cells may be also engineered to remain efficient under low O<sub>2</sub> condition (low oxygen concentration means 1–5%) by overexpressing at least one, preferably all of the following factors : Oct3, Oct4, Sox2, Klf4 and c-Myc , or by 25 editing a HIF-1a factor.

25 In the present invention, an oxygen sensitive CD22 single chain CAR –expressing engineered cell and a hypoxia resistant CD22 CAR –expressing engineered cell were constructed and tested successfully.

30 Because CD22 is mainly expressed on CD22-expressing B cell malignancies, which are “liquid” tumors” and therefore are not supposed to create hypoxia in contrast to solid tumor, it was not expected that a CD22 CAR engineered immune cells resistant to hypoxia would be more efficient than CD22 CAR engineered immune cells which are not 35 resistant to hypoxia against B-ALL from patient. In fact, the UCART22 of the invention

reaching the nested cancer cells clustered or homing in tissues may be able to lyse these cells.

5 Other genes may be edited in the UCART22 of the present invention such as those in the above table 5:

Table 5: List of genes encoding immune checkpoint proteins that may be inactivated according to the present invention in the CD22 CAR engineered T cells of the invention

Pathway		Genes that can be inactivated In the pathway
Co-inhibitory receptors	CTLA4 (CD152)	CTLA4, PPP2CA, PPP2CB, PTPN6, PTPN22
	PDCD1 (PD-1, CD279)	PDCD1
	CD223 (lag3)	LAG3
	HAVCR2 (tim3)	HAVCR2
	BTLA(cd272)	BTLA
	CD160(by55)	CD160
	IgSF family	TIGIT
		CD96
		CRTAM
	LAIR1(cd305)	LAIR1
Death receptors	SIGLECs	SIGLECT7
		SIGLEC9
	CD244(2b4)	CD244
Death receptors	TRAIL	TNFRSF10B, TNFRSF10A, CASP8, CASP10, CASP3, CASP6, CASP7
	FAS	FADD, FAS
Cytokine signalling	TGF-beta signalling	TGFBRII, TGFBRI, SMAD2, SMAD3, SMAD4, SMAD10, SKI, SKIL, TGIF1
	IL10 signalling	IL10RA, IL10RB, HMOX2
	IL6 signalling	IL6R, IL6ST
Prevention of TCR signalling		CSK, PAG1
		SIT1
Induced Treg	induced Treg	FOXP3
Transcription factors controlling exhaustion	transcription factors controlling exhaustion	PRDM1 (=blimp1, heterozygotes mice control chronic viral infection better than wt or conditional KO)

		BATF
Hypoxia mediated tolerance	iNOS induced guanylated cyclase	GUCY1A2, GUCY1A3, GUCY1B2, GUCY1B3

The present invention provides an isolated engineered immune T cells expressing a CD22 CAR of SEQ ID NO.15, wherein, the dCK and/or CD52 and TRAC genes are edited, that is, inactivated by deletion, for their use in the treatment of CLL, ALL, preferably their aggressive, relapsing refractory forms, in lymphodepleted patients.

The present invention provides an isolated engineered immune T cells expressing a CD22 CAR of SEQ ID NO.15, wherein, the b2m and TRAC genes are edited, that is, inactivated by deletion, for their use in the treatment of CLL, ALL, preferably their aggressive, relapsing refractory forms, in lymphodepleted patients.

10 The present invention provides an isolated engineered immune T cells expressing a CD22 CAR of SEQ ID NO.15, wherein TRAC and IL-10R genes are edited, that is, inactivated by deletion, for their use in the treatment of CLL, ALL, preferably their aggressive, relapsing refractory forms, in lymphodepleted patients. The present invention provides an engineered immune T cells expressing a CD22 CAR (UCART22) comprising a deficient TCR alpha gene (so that 15 the cell surface expression of the TCR is compromised), a B2M deficient gene (so that the expression of MHC class I molecules at the cell surface is compromised), and in addition a TGFbeta receptor KO gene.

20 The present invention provides an engineered immune T cells expressing a CD22 CAR (UCART22) comprising a deficient TCR alpha gene (so that the cell surface expression of the TCR is compromised), a B2M deficient gene (so that the expression of MHC class I molecules at the cell surface is compromised), and in addition an IL-10 receptor KO gene.

25 The present invention provides an engineered immune T cells expressing a CD22 CAR (UCART22) comprising a deficient TCR alpha gene (so that the cell surface expression of the TCR is compromised), a B2M deficient gene (so that the expression of MHC class I molecules at the cell surface is compromised), and in addition an AHR KO gene.

The present invention provides an engineered immune T cells expressing a CD22 CAR (UCART22) comprising a deficient TCR alpha gene (so that the cell surface expression of the TCR is compromised), a B2M deficient gene (so that the expression of MHC class I molecules at the cell surface is compromised), and in addition a PD1 KO gene.

30 The present invention provides an engineered immune T cells expressing a CD22 CAR (UCART22) comprising a deficient TCR alpha gene (so that the cell surface expression of the TCR is compromised), a B2M deficient gene (so that the expression of MHC class I molecules at the cell surface is compromised), and in addition a LAG-3 KO gene.

The present invention provides an engineered immune T cells expressing a CD22 CAR (UCART22) comprising a deficient TCR alpha gene (so that the cell surface expression of the TCR is compromised), a B2M deficient gene (so that the expression of MHC class I molecules at the cell surface is compromised), and in addition a TIM-3 KO gene.

5

The present invention provides an isolated engineered immune T cells expressing a CD22 CAR of SEQ ID NO.15 wherein, wherein the CD52, and TRAC genes are inactivated by deletion for their use in the treatment of relapsing refractory forms of BALL, in lymphodepleted patients.

10

In a preferred embodiment a method of engineering the immune cells involves introducing into said T cells polynucleotides, in particular mRNAs, encoding specific rare-cutting endonuclease to selectively inactivate the genes, as those mentioned above, by DNA cleavage.

15

In a more preferred embodiment said rare-cutting endonucleases are TALE-nucleases or Cas9 endonuclease. TAL-nucleases have so far proven higher specificity and cleavage efficiency over the other types of rare-cutting endonucleases, making them the endonucleases of choice and preferred for producing of the engineered immune cells on a large scale with a constant turn-over.

20

### **Delivery methods**

The different methods described above involve introducing a CD22 CAR of the invention into a cell. As non-limiting examples, said CD22 CAR can be introduced as a transgene encoded by one plasmid vector of the invention. Said plasmid vector encoding a CD22 CAR of the invention can also contain a selection marker which provides for identification and/or selection of cells which received said vector.

25

A method allowing a CD22 CAR according to the invention to be introduced and then expressed into an isolated immune cell was described elsewhere, for example in WO2013126720 or in WO2015121454 which are incorporated herein by reference in entirety.

Polypeptides corresponding to the CD22 CAR of the invention may be synthesized *in situ* in the cell as a result of the introduction of polynucleotides encoding said polypeptides into the cell. Alternatively, said polypeptides could be produced outside the cell and then introduced thereto. Methods for introducing a polynucleotide construct into cells are known in the art and including as non-limiting examples stable transformation methods wherein the polynucleotide construct is integrated into the genome of the cell, transient transformation methods wherein the polynucleotide construct is not integrated into the genome of the cell and virus mediated methods. Said polynucleotides may be introduced into a cell by for example, recombinant viral vectors (e.g. retroviruses, such as lentiviruses, adenoviruses, adeno associated virus), liposome and the like. For example, transient transformation methods include for example microinjection, electroporation or particle bombardment. Said polynucleotides may be included in vectors, more particularly plasmids or virus, in view of being expressed in cells.

In a preferred embodiment said polynucleotide encoding a CD22 CAR is inserted into an AAV6 vector and introduced into a given gene. Methods for preparing a vector allowing the CD22 CAR of the invention to be introduced and then expressed into an isolated T cell were described elsewhere, for example in WO2013126720 which is incorporated herein by reference.

### 20      **Engineered immune cells (UCART)**

An engineered immune cell endowed with a CD22 CAR (UCART 22) is another object of the present invention.

Preferably said immune cell is an isolated immune cell, more preferably an isolated immune T cell, more preferably an isolated primary immune T cell.

25      The UCART 22 is provided as a medicament, thus a therapeutically efficient amount of UCART 22 is provided as a medicament.

“A primary immune cell” according to the invention means a “cell originating from a tissue such as a blood sample or from peripheral blood mononuclear cells (PBMCs) and that may be in culture for a few passages, eventually frozen before use, said primary immune cell has a limited capacity of division (Raulf-Heimsoth M. T cell - primary culture

from peripheral blood. *Methods Mol Med.* 2008;138:17-30. doi: 10.1007/978-1-59745-366-0) as compared to a transformed or cancerous cell.

An immune cell according to the invention is preferably an immune T or NK cell. Accordingly, an engineered immune cell according the invention is isolated from a blood sample, is a primary cell and derived from an immune T cell selected from inflammatory T-lymphocytes, cytotoxic T-lymphocytes, regulatory T-lymphocytes or helper T-lymphocytes, Natural Killer T –cell, preferably from cytotoxic T-lymphocytes and further engineered.

Engineered means that primary immune cells are modified so that they will be endowed with a CD22 CAR and at least one gene is edited, preferably said cells are modified so that they will be endowed with a CD22 CAR and will neither express a TCR nor die in the presence of purine nucleotide analogs.

In other word, engineered immune cells means a TCR KO isolated immune T cells comprising at least one other edited gene, expressing CD22 CAR.

In a particular embodiment, engineered means that primary immune cells are modified so that they will be endowed with a CD22 CAR, preferably said cells are modified so that they will be endowed with a CD22 CAR and will not die in the presence of purine nucleotide analogs '1 to 5 micromol/L) or in the presence of alemtuzumab (50 microgram/mL). Valton et al., *Molecular Therapy* vol. 23 no. 9, 1507–1518 sep. 2015)

Preferably, said T cell is endowed with a CD22 CAR of SEQ ID NO. 15.

More preferably, said T cell is endowed with a CD22 CAR of SEQ ID NO. 15 and comprises at least one sequence of SEQ ID NO. 22.

More preferably, said T cell is endowed with a CD22 CAR of SEQ ID NO. 15 and comprises at least one sequence of SEQ ID NO. 22 and at least part of the sequence .

More preferably, said T cell is endowed with a CD22 CAR of SEQ ID NO. 18 that includes at least one sequence of SEQ ID NO. 20.

The present invention provides a primary immune T cell expressing a CD22 CAR of the invention and exhibiting a CTL and/or degranulating activity towards a CD22-expressing cell.

5 The present invention also provides a primary T cell expressing a CD22 CAR of the invention for lysing a CD22-expressing cell, in particular a CD22-expressing cancerous cell.

10 Preferably cells targeted by a T cell endowed with a CD22 CAR of SEQ ID NO. 16 of the invention are efficient in the treatment of relapse/refractory/aggressive ALL or CLL, preferably

15 The present invention also relates to isolated cells or cell lines susceptible to be obtained by said method to engineer cells. In particular said isolated cell comprises at least one CD22 CAR of the invention as described above. In another embodiment, said isolated cell comprises a population of CARs each one comprising different extracellular ligand binding domains. In particular, said isolated cell comprises exogenous polynucleotide sequence encoding CAR. Genetically modified immune cells of the present invention are activated and can proliferate independently of antigen binding 20 mechanisms.

25 In the scope of the present invention is also encompassed an isolated immune cell, preferably an isolated immune T cell (T-cell), more preferably an engineered isolated immune T cell obtained according to any one of the methods previously described. Said immune cell refers to a cell of hematopoietic origin functionally involved in the initiation and/or execution of innate and/or adaptative immune response. Said immune cell according to the present invention can be derived from a stem cell. The stem cells can be adult stem cells, non-human embryonic stem cells, more particularly non-human stem cells, cord blood stem cells, progenitor cells, bone marrow stem cells, induced pluripotent stem cells, totipotent stem cells or hematopoietic stem cells. 30 Representative human cells are CD34+ cells. Said isolated cell can also be a dendritic

cell, a killer dendritic cell, a mast cell, a NK-cell, a B-cell or a T-cell selected from the group consisting of inflammatory T-lymphocytes, cytotoxic T-lymphocytes, regulatory T-lymphocytes or helper T-lymphocytes. In another embodiment, said cell can be derived from the group consisting of CD4+ T-lymphocytes and CD8+ T-lymphocytes.

5 Prior to expansion and genetic modification of the cells of the invention, a source of cells can be obtained from a subject through a variety of non-limiting methods. Cells can be obtained from a number of non-limiting sources, including peripheral blood mononuclear cells, bone marrow, lymph node tissue, cord blood, thymus tissue, tissue, ascites, pleural effusion, spleen tissue, and tumors. In certain embodiments of the 10 present invention, any number of T cell lines available and known to those skilled in the art, may be used. In another embodiment, said cell can be derived from a healthy donor, from a patient diagnosed with cancer or from a patient diagnosed with an infection. In another embodiment, said cell is part of a mixed population of cells which present different phenotypic characteristics. In the scope of the present invention is also 15 encompassed a cell line obtained from an engineered T- cell according to the method described. Modified cells resistant to an immunosuppressive treatment and susceptible to be obtained by the previous method are encompassed in the scope of the present invention.

20 As a preferred embodiment, the present invention provides T-cells or a population of T-cells endowed with a CD22 CAR of the invention as described above, that do not express functional TCR and that are reactive towards CD22 positive cells, for their adoptive transfer into patients.

25 As a more preferred embodiment the present invention provides T-cells or a population of T-cells endowed with a CD22 CAR as described above, that do not express functional TCR and that were made resistant to chemotherapy, in particular to purine nucleotide analogues (PNAs).

30 According to a preferred embodiment of the invention, the immune cells endowed with an CD22 CAR are engineered to be resistant to chemotherapy drugs, in particular to purine nucleotide analogues (PNAs), making them suitable for cancer treatments combining adoptive immunotherapy and chemotherapy.

Purine nucleotide analogues enter chemotherapy compositions for many cancer treatments. It is used as a standard of care against leukemia or lymphoma. The most widely used PNAs are clofarabine, fludarabine and cytarabine alone or in combination. PNAs are metabolized by enzymes having deoxycytidine kinase (dCK) activity [EC 2.7.1.74] into mono, -di and tri-phosphate PNA. Their tri-phosphate forms and particularly clorofarabine triphosphate compete with ATP for DNA synthesis, acts as pro-apoptotic agent and are potent inhibitors of ribonucleotide reductase (RNR), which is involved in trinucleotide production.

The present invention thus includes a method of producing *ex-vivo* immune cells, preferably primary T-cells expressing no TCR, which are resistant to a purine analogue drug and that can target CD22 positive malignant cells.

A Method for preparing a UCART22 according to the invention can be also that disclosed in WO 2013176915 or in WO 2014191128 which are incorporated herein by reference in entirety.

A method for preparing a UCART22 comprises the following steps:

(a) Providing an immune cell from a donor, preferably an isolated T cell or an isolated population of T cells,

(b) introducing into said immune cell (preferably by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting

- a gene expressing an enzyme having deoxycytidine kinase activity (dCK – EC 2.7.1.74), in particular the human deoxycytidine kinase gene (NCBI Gene ID: 1633) and /or

- a gene coding one of the TCR subunit alpha and/or beta, preferably alpha, and/or

- a gene coding human CD52

(c) expressing said endonuclease into said immune cells to obtain targeted inactivation of said gene(s);

(d) Expanding the engineered immune cells obtained in step c), optionally in the presence of a purine analogue drug;

(e) Introducing into said immune cell a CD22 CAR of the invention, preferably of SEQ ID SEQ ID NO:15.

A method for preparing a UCART22 comprises the following steps:

(a) Providing an immune cell from a donor, preferably an isolated T cell or an isolated population of T cells,

(b) introducing into said immune cell (preferably by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting

- a gene expressing an enzyme having deoxycytidine kinase activity (dcK – EC 2.7.1.74), in particular the human deoxycytidine kinase gene (NCBI Gene ID: 1633) and /or

- a gene coding one of the TCR subunit alpha and/or beta, preferably alpha, and/or

- a gene coding human beta2microglobulin (B2M)

(c) expressing said endonuclease into said immune cells to obtain targeted inactivation of said gene(s);

(d) Expanding the engineered immune cells obtained in step c), optionally in the presence of a purine analogue drug;

(e) Introducing into said immune cell a CAR of the invention, preferably a CD22 CAR, alone or in combination with a CD19 CAR, even more preferably a CD22 CAR of SEQ ID NO:15, alone or in combination with a CD19 CAR.

In a preferred embodiment, the present invention includes a method of producing *ex-vivo* immune cells, preferably primary T-cells expressing no TCR, which are resistant to a purine analogue drug and that can target CD22 positive malignant cells. Said method comprises the following steps:

- Providing an immune cell from a donor, preferably an isolated T cell (or an isolated population of T cells)
- Introducing into said immune cell a CD22 CAR of the invention, preferably of SEQ ID selected from SEQ ID NO: 15.
- Expanding the engineered immune cells obtained in step b)

(d) introducing into said immune cell (by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting

a gene expressing an enzyme having deoxycytidine kinase activity (dcK – EC 2.7.1.74), in particular the human deoxycytidine kinase gene (NCBI Gene ID: 1633) and /or a gene expressing one of the TCR subunit alpha or beta,

5 (e) expressing said endonuclease into said immune cells to obtain targeted inactivation of said gene(s);

(f) Expanding the engineered immune cells obtained in step e), optionally in the presence of a purine analogue drug.

10 The method of producing *ex-vivo* immune cells, preferably primary T-cells expressing no TCR, which are resistant to a purine analogue drug and that can target CD22 positive malignant cells optionally comprises another step of introducing into said immune cell (by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting one of the gene cited in Table 9, preferably PD-1 ,

15 CD279 and more preferably PDCD1 (PD-1, CD279) or CTLA4 (CD152).

The present inventors have successfully created CD22 CAR expressing primary T cells resistant to purine nucleotide analogues (dCK-KO), more particularly to clorofarabine and/or fludarabine, by mediating the inactivation (deletion) of dcK gene expression into said cells particularly by using nucleases, in particular TAL- nucleases.

20 Transfection of the T-cells using mRNA encoding specific TAL-nuclease directed against dCK genes, preferably by using electroporation as described in WO2013176915, induced a significant resistance to the drugs, while maintaining T-cells cytotoxic activity towards CD22 bearing cells.

25 The present application also provides a TCR –KO, CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, which expression of deoxycytidine kinase has been repressed or inactivated (dCK-KO) for the treatment of leukemia or lymphoma, preferably of their aggressive, resistant, relapsing form more preferably B-ALL.

5 According to a preferred embodiment of the invention, the immune cells endowed with an CD22 CAR are engineered to be resistant to chemotherapy drugs, in particular to alemtuzumab (CAMPATH), making them suitable for cancer treatments combining adoptive immunotherapy and chemotherapy.

10 Alemtuzumab is used for many cancer treatments. It is used as a standard of care against leukemia or lymphoma, in particular in the treatment of chronic lymphocytic leukemia (CLL), cutaneous T-cell lymphoma (CTCL) and T-cell lymphoma. It is known under the trade names Campath, MabCampath and Campath-1H. It is also used in some conditioning regimens for bone marrow transplantation, kidney transplantation and islet cell transplantation.

15 It is a monoclonal antibody that binds to CD52, a protein present on the surface of mature lymphocytes, but not on the stem cells from which these lymphocytes are derived. After treatment with alemtuzumab, these CD52-bearing lymphocytes are targeted for destruction.

Alemtuzumab is also used as second-line therapy for CLL. It was approved by the US Food and Drug Administration for CLL patients who have been treated with alkylating agents and who have failed fludarabine therapy.

20 The present invention thus includes a method of producing *ex-vivo* UCART22, thus expressing no TCR, that are resistant to alemtuzumab.

A method for preparing a UCART22 CD52 KO comprises the following steps:

- (a) Providing an immune cell from a donor, preferably an isolated T cell or an isolated population of T cells,
- (b) introducing into said immune cell (preferably by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting
  - a gene coding one of the TCR subunit alpha and/or beta, preferably alpha, and/or
  - a gene coding the CD52 ,
- (c) expressing said endonuclease into said immune cells to obtain targeted inactivation of said gene(s);

(d) Expanding the engineered immune cells obtained in step c), optionally in the presence of alemtuzumab,

(e) Introducing into said immune cell a CD22 CAR of the invention, preferably of SEQ ID NO:15.

5 In a preferred embodiment, the present invention includes a method of producing *ex-vivo* immune cells, preferably primary T-cells expressing no TCR, which are resistant to alemtuzumab and that can target CD22 positive malignant cells. Said method comprises the following steps:

10 • Providing an immune cell from a donor, preferably an isolated T cell (or an isolated population of T cells)

• Introducing into said immune cell a CD22 CAR of the invention, preferably of SEQ ID NO: 15.

• Expanding the engineered immune cells obtained in step b)

15 (d) introducing into said immune cell (by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting

a gene expressing CD52 and a gene expressing one of the TCR subunit alpha or beta,

(e) expressing said endonuclease into said immune cells to obtain targeted inactivation of said gene(s);

(f) Expanding the engineered immune cells obtained in step e), optionally in the presence of a purine analogue drug.

20 In one embodiment, a method for preparing a UCART22 comprises the following steps:

(a) Providing an immune cell from a donor, preferably an isolated T cell or an isolated population of T cells,

25 (b) introducing into said immune cell (preferably by transfection or transduction)

- a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting a gene coding one of the TCR subunit alpha and/or beta, preferably alpha, and

- a nucleic acid encoding a sequence to be inserted, preferably coding HIF-1alpha,

(c) Expressing said endonuclease into said immune cells to obtain targeted

5 insertion of said sequence to be inserted,

(d) Expanding the engineered immune cells obtained in step c), optionally in the presence of low O<sub>2</sub> concentration (5% O<sub>2</sub>, preferably 1% O<sub>2</sub>);

(e) Introducing into said immune cell a CD22 CAR of the invention, preferably of SEQ ID NO:15.

10 In a preferred embodiment, the present invention includes a method of producing *ex-vivo* immune cells, preferably primary T-cells expressing no TCR, which are resistant to a hypoxia and that can target CD22 positive malignant cells. Said method comprises the following steps:

15 • Providing an immune cell from a donor, preferably an isolated T cell (or an isolated population of T cells),

• Introducing into said immune cell a CD22 CAR of the invention, preferably of SEQ ID NO: 15,

• Expanding the engineered immune cells obtained in step b)

(d) introducing into said immune cell (preferably by transfection or transduction)

20 - a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting a gene coding one of the TCR subunit alpha and/or beta, preferably alpha, and

- a nucleic acid encoding a sequence to be inserted coding HIF-1alpha,

(e) expressing said endonuclease into said immune cells to obtain targeted insertion of said gene(s);

25 (f) Expanding the engineered immune cells obtained in step e), optionally in the presence of low O<sub>2</sub> concentration (5% O<sub>2</sub>, preferably 1% O<sub>2</sub>);

The method of producing *ex-vivo* immune cells, preferably primary T-cells expressing no TCR, which are resistant to either a purine analogue drug, alemtuzumab or hypoxia and that can target CD22 positive malignant cells optionally comprises another step of introducing into said immune cell (by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting one of the gene cited in Table 9, preferably (PD-1, CD279) and more preferably PDCD1 (PD-1, CD279) and CTLA4 (CD152).

The present inventors have successfully created CD22 CAR expressing primary T cells resistant to purine nucleotide analogues (dCK-KO), more particularly to clorofarabine and/or fludarabine, by mediating the inactivation (deletion) of dCK gene expression into said cells particularly by using nucleases, in particular TAL- nucleases.

Transfection of the T-cells using mRNA encoding specific TAL-nuclease directed against dCK genes, preferably by using electroporation as described in WO2013176915, induced a significant resistance to the drugs, while maintaining T-cells cytotoxic activity towards CD22 bearing cells.

The same method applies to deletion of human CD52 using specific TALEN as described by the present inventors.

The present application also provides a TCR-KO, CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, which expression of deoxycytidine kinase has been repressed or inactivated (dCK-KO) for the treatment of leukemia or lymphoma, preferably of their aggressive, resistant, relapsing form; more preferably relapsing B-ALL.

Such cells are “universal” T cells (or UCART).

In one embodiment, the present application provides a CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, which expression of deoxycytidine kinase has been repressed or inactivated (dCK-KO) for the treatment of leukemia or lymphoma, preferably of their aggressive, resistant, relapsing form; more preferably relapsing B-ALL after autologous transfer.

In one embodiment, the present application provides a CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, which expression of CD52 has been repressed or inactivated (CD52-KO) for the treatment of leukemia or lymphoma, preferably of their

aggressive, resistant, relapsing form; more preferably relapsing B-ALL after autologous transfer.

In one embodiment, the present application provides a CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, which expression of HIF-1Alpha has been increased by insertion of the coding sequence into the TRAC sequence without knocking out the TCR.

5 for the treatment of leukemia or lymphoma, preferably of their aggressive, resistant, relapsing form; more preferably relapsing B-ALL after autologous transfer

In one embodiment, the present application provides a CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, which expression of deoxycytidine kinase and CD52 have been repressed or inactivated (dCK-and CD52KO) for the treatment of leukemia or lymphoma, preferably of their aggressive, resistant, relapsing form; more preferably relapsing B-ALL after autologous transfer.

10 In one embodiment, the present application provides a CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, which expression of deoxycytidine kinase and CD52 have been repressed or inactivated (dCK-and CD52KO) and the expression of HIF-1alpha increased by insertion of the HIF1alpha coding sequence into the TRAC sequence without knocking out the TCR, for the treatment of leukemia or lymphoma, preferably of their aggressive, resistant, relapsing form; more preferably relapsing B-ALL after autologous transfer.

15 The method of producing *ex-vivo* immune cells, preferably primary T-cells expressing no TCR, which are resistant to a purine analogue drug and/or to alemtuzumab and/or to hypoxia, that can target CD22 positive malignant cells optionally comprises another step of introducing into said immune cell (by transfection or transduction) a nucleic acid sequence encoding a rare-cutting endonuclease specifically targeting one of the gene cited in Table 9, preferably PD-1 , CD279 and more preferably PDCD1 (PD-1, CD279) or CTLA4 (CD152).

20 The present inventors have successfully created CD22 CAR expressing primary T cells resistant to purine nucleotide analogues (dCK-KO), more particularly to clorofarabine and/or fludarabine, by mediating the inactivation (deletion) of dcK gene expression into said cells particularly by using nucleases, in particular TAL- nucleases.

The present inventors have successfully created CD22 CAR expressing primary T cells resistant to hypoxia, by a targeted insertion of the HIF-1alpha gene into said cells particularly by using nucleases, in particular TAL- nucleases.

Transfection of the T-cells using mRNA encoding specific TAL-nuclease directed 5 against dCK genes, preferably by using electroporation as described in WO2013176915, induced a significant resistance to the drugs, while maintaining T-cells cytotoxic activity towards CD22 bearing cells.

10 The present application also provides a TCR –KO, CD22 CAR (preferably of SEQ ID NO 15) primary T-cells, resistant to hypoxia for the treatment of leukemia or lymphoma, preferably of their aggressive, resistant, relapsing form; more preferably B-ALL.

#### Activation and expansion of T cells

15 Whether prior to or after genetic modification of the T cells, even if the genetically modified immune cells of the present invention are activated and proliferate independently of antigen binding mechanisms, the immune cells, particularly T-cells of the present invention can be further activated and expanded generally using methods as described, for example, in U.S. Patents 6,352,694; 6,534,055; 6,905,680; 6,692,964; 5,858,358; 6,887,466; 6,905,681; 7,144,575; 7,067,318; 7,172,869; 7,232,566; 20 7,175,843; 5,883,223; 6,905,874; 6,797,514; 6,867,041; and U.S. Patent Application Publication No. 20060121005. T cells can be expanded *in vitro* or *in vivo*.

25 Generally, the T cells of the invention are expanded by contact with an agent that stimulates a CD3 TCR complex and a co-stimulatory molecule on the surface of the T cells to create an activation signal for the T-cell. For example, chemicals such as calcium ionophore A23187, phorbol 12-myristate 13-acetate (PMA), or mitogenic lectins like phytohemagglutinin (PHA) can be used to create an activation signal for the T-cell.

30 As non-limiting examples, T cell populations may be stimulated *in vitro* such as by contact with an anti-CD3 antibody, or antigen-binding fragment thereof, or an anti-CD2 antibody immobilized on a surface, or by contact with a protein kinase C activator (e.g., bryostatin) in conjunction with a calcium ionophore. For co-stimulation of an accessory molecule on the surface of the T cells, a ligand that binds the accessory molecule is

used. For example, a population of T cells can be contacted with an anti-CD3 antibody and an anti-CD28 antibody, under conditions appropriate for stimulating proliferation of the T cells. Conditions appropriate for T cell culture include an appropriate media (e.g., Minimal Essential Media or RPMI Media 1640 or, X-vivo 5, (Lonza)) that may contain factors necessary for proliferation and viability, including serum (e.g., fetal bovine or human serum), interleukin-2 (IL-2), insulin, IFN- $\gamma$ , 1L-4, 1L-7, GM-CSF, -10, -2, 1L-15, TGF $\beta$ , and TNF- or any other additives for the growth of cells known to the skilled artisan. Other additives for the growth of cells include, but are not limited to, surfactant, plasmanate, and reducing agents such as N-acetyl-cysteine and 2-mercaptopethanol. Media can include RPMI 1640, A1M-V, DMEM, MEM, a-MEM, F-12, X-Vivo 1, and X-Vivo 20, Optimizer, with added amino acids, sodium pyruvate, and vitamins, either serum-free or supplemented with an appropriate amount of serum (or plasma) or a defined set of hormones, and/or an amount of cytokine(s) sufficient for the growth and expansion of T cells. Antibiotics, e.g., penicillin and streptomycin, are included only in experimental cultures, not in cultures of cells that are to be infused into a subject. The target cells are maintained under conditions necessary to support growth, for example, an appropriate temperature (e.g., 37° C) and atmosphere (e.g., air plus 5% CO<sub>2</sub>). T cells that have been exposed to varied stimulation times may exhibit different characteristics

In another particular embodiment, said cells can be expanded by co-culturing with tissue or cells. Said cells can also be expanded *in vivo*, for example in the subject's blood after administrating said cell into the subject.

### **Pharmaceutical composition**

A pharmaceutical composition comprising an engineered (TCR and dCK KO) or (TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) and a pharmaceutically acceptable vehicle is another object of the present invention.

In another embodiment the present invention provides a composition comprising the UCART22 of the present invention (as any one of the above embodiments) with a compound of the family of the bryostatin compounds, preferably bryostatin-1.

Bryostatins are a group of macrolide lactones from bryozoan, Bugula neritina. The structure of bryostatin 1 was determined in 1980's. To date 20 different bryostatins have been isolated; further, certain analogs of bryostatin have been referred to as "bryologs". Bryostatins are potent modulators of protein kinase C. (Wender, Paul A., Jeremy L. Baryza, Chad E. Bennett, F. Christopher Bi, Stacey E. Brenner, Michael O. Clarke, Joshua C. Horan, Cindy Kan, Emmanuel Lacôte, Blaise Lippa, Peter G. Nell, and, and Tim M. Turner. The Practical Synthesis of a Novel and Highly Potent Analogue of Bryostatin. *Journal of the American Chemical Society* 2002 124 (46), 13648-13649 DOI: 10.1021/ja027509+)

10 Examples of bryostatin compounds suitable to be combined with the UCART22 of the invention and methods for preparing these compounds are described in WO2001040214A1 or in EP2737904A2, WO1997034598 incorporated here by reference.

15 An example of a dose of bryostatin-1 that may be used in combination with the UCART22 of the present invention is as previously described in Varterasian ML1, Mohammad RM, Shurafa MS, Hulburd K, Pemberton PA, Rodriguez DH, Spadoni V, Eilender DS, Murgo A, Wall N, Dan M, Al-Katib AM. Phase II trial of bryostatin 1 in patients with relapsed low-grade non-Hodgkin's lymphoma and chronic lymphocytic leukemia. *Clin Cancer Res.* 2000 Mar;6(3):825-8.

20 An engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] or a pharmaceutical composition comprising said UCART22 is provided as a medicament.

25 An engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] for use in the treatment of cancer or to attenuate inflammation is another object of the present invention.

An engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] for use in the

treatment of ALL, CLL, relapse refractory aggressive forms of CLL or ALL is another object of the present invention.

An engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] for use in the treatment of a CD19 relapse cancer, preferably a CD19 relapse B-ALL is provided.

In another embodiment, hypoxia resistant, engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] or a pharmaceutical composition comprising said UCART22 is provided as a medicament.

In another embodiment, hypoxia resistant, engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] for use in the treatment of cancer or to attenuate inflammation is another object of the present invention.

In another embodiment hypoxia resistant, engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] for use in the treatment of ALL, CLL, relapse refractory aggressive forms of CLL or ALL is another object of the present invention.

In another embodiment hypoxia resistant, engineered (TRAC and dCK KO or TRAC and CD52 KO) immune T cell expressing a CD22 CAR of the invention (preferably of SEQ ID NO 15) [an UCART22] for use in the treatment of a CD19 relapse cancer, preferably a CD19 relapse B-ALL is provided.

In another embodiment, isolated cell obtained by the different methods of the present invention or cell line derived from said isolated cell can be used as a medicament. In another embodiment, said medicament can be used for treating cancer, particularly for the treatment of B-cell lymphomas and leukemia in a patient in need thereof. In another embodiment, said isolated cell according to the invention or cell line derived from said isolated cell can be used in the manufacture of a medicament for treatment of a cancer in a patient in need thereof.

The present invention encompasses autologous transfer of engineered cells. In that case cells are isolated from one donor, a human donor, engineered and then transferred to the initial donor in need thereof.

5 In this particular embodiment, cells may be engineered for example to be resistant to a drug such as alemtuzumab (campath) and/or pna and optionally to be resistant to hypoxia.

### Therapeutic applications

The term "cancer" refers to a disease characterized by the uncontrolled growth of one or several types of cells.

10 Examples of cancers are described herein and, include but are not limited to liquid tumors or hematological cancer.

A hematological cancer according to the present invention may be selected from lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), 15 and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, preferably a CD22-expressing hematological cancer, more preferably a relapse or refractory CD22-expressing hematological cancer, even more preferably an aggressive form of said CD22-related hematological cancer.

20 In a preferred embodiment, a relapsed or refractory CD22-expressing hematological cancer is relapsed and/or refractory CD22 expressing or positive B-ALL.

Accordingly, a therapeutically effective amount of UCART 22 according to any one of the 25 embodiments described above or a therapeutically effective amount of the pharmaceutical composition as described above is provided for use as a medication for treating a patient suffering a relapsed and/or refractory CD22 expressing or positive B-ALL.

In another embodiment a therapeutically effective amount of UCART 22 according to any one of the embodiments described above or a therapeutically effective amount of the pharmaceutical composition as described above is provided for use as a

medication for treating a patient suffering a CD22 positive hematological cancer selected from leukemia and lymphoma, hairy cell leukemia, any of acute lymphocytic cancer, acute lymphocytic leukemia (ALL), acute myeloid leukemia, chronic lymphocytic leukemia, B-chronic lymphocytic leukemia, chronic myeloid cancer, Hodgkin lymphoma, 5 non-Hodgkin lymphoma, and Burkitt's lymphoma, multiple myeloma.

In another embodiment a therapeutically effective amount of UCART 22 according to any one of the embodiments described above or a therapeutically effective amount of the pharmaceutical composition as described above is provided for use as a medication for treating a patient suffering a CD22 positive cancer selected from alveolar rhabdomyosarcoma, bladder cancer (e.g., bladder carcinoma), bone cancer, brain cancer (e.g., medulloblastoma), breast cancer, cancer of the anus, anal canal, or anorectum, cancer of the eye, cancer of the intrahepatic bile duct, cancer of the joints, cancer of the neck, cancer of the gallbladder, cancer of the pleura, cancer of the nose, cancer of the nasal cavity, cancer of the middle ear, cancer of the oral cavity, cancer of the vulva, chronic lymphocytic leukemia, chronic myeloid cancer, colon cancer, esophageal cancer, cervical cancer, fibrosarcoma, gastrointestinal carcinoid tumor, head and neck cancer (e.g., head and neck squamous cell carcinoma), hypopharynx cancer, 10 kidney cancer, larynx cancer, liver cancer, lung cancer (e.g., non-small cell lung carcinoma), malignant mesothelioma, mastocytoma, melanoma, nasopharynx cancer, ovarian cancer, pancreatic cancer, peritoneum cancer, omentum cancer, mesentery cancer, pharynx cancer, prostate cancer, rectal cancer, renal cancer, skin cancer, small intestine cancer, soft tissue cancer, solid tumors, stomach cancer, testicular cancer, 15 thyroid cancer, ureter cancer.

Other Examples of CD22-mediated cancers are described herein and, include but are not limited to liver cancer, lung cancer (e.g., non-small cell lung carcinoma), ovarian cancer, 20 pancreatic cancer, thyroid cancer, and urothelial cancer.

In a particular embodiment, the object of the present invention is provided for the treatment of aggressive forms of these cancers, defined as growing at least 2 times faster than the general mean of growth of such cancers in the population. 30

In one embodiment the objects of the present invention are used in the treatment of leukemia during the accelerated phase of the treatment.

In a particular embodiment, the object of the present invention is provided for the treatment of Refractory/Relapsed Diffuse Large B-Cell Non-Hodgkin's Lymphoma -  
5 Breast metastasis in lung- Triple cancer consisting of chronic lymphocytic leukemia with bladder and prostate carcinoma.

Preferably, the cancer is a hematological malignancy (e.g., leukemia or lymphoma, including but not limited to Hodgkin lymphoma, non-Hodgkin lymphoma, chronic lymphocytic leukemia, acute lymphocytic cancer, acute myeloid leukemia, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma).

More preferably, the cancer is characterized by the expression of CD22, more preferably, the cancer is characterized by the expression of CD22 by cancerous cells, even more preferably by overexpression of CD22 by cancer cells.

15

In one embodiment said cancer cells are a relapsed refractory CD19 negative cancer cells.

In one embodiment said cancer cells are a relapsed refractory CD22 expressing cancer cells.

20

In a preferred embodiment said cancer cells are a relapsed refractory CD19 negative CD22 positive expressing B-ALL.

B-cell ALL comprises:

25

- Early precursor B (early pre-B) ALL (also called pro-B ALL)
- Common ALL
- Pre-B ALL
- Mature B-cell ALL also called Burkitt leukemia or Non-Hodgkin Lymphoma in Children.

30 The term "disease associated with expression of CD22" as used herein includes, but is not limited to, a disease associated with expression of CD22 or condition linked to the activity of cells which express CD22 including, tumor cells of various cancers such as, e.g., a CD22 expressing B-ALL .

Cellular destruction by lyse is one of the mechanisms whereby the CD22 CAR T cells of the invention acts against CD22-expressing cells, reducing or eliminating tumors, facilitating infiltration of immune cells of the hosts to the tumor site, and enhancing/extending anti-tumor responses.

5 In another aspect, the present invention relies on methods for treating patients in need thereof, said method comprising at least one of the following steps:

- providing an UCART22 of the invention
- Administrating said transformed immune cells to said patient,

10 In one embodiment, said UCART22 cells of the invention can undergo robust *in vivo* T cell expansion and can persist for an extended amount of time in the host.

In another aspect, the present invention provides methods for treating patients in need thereof, said method comprising at least one of the following steps:

- . Conditioning a patient suffering a cancer
- providing an UCART22 of the invention
- Administrating said transformed immune cells to said patient,

Conditioning includes lymphodepletion, or any appropriate conditioning a skilled person, preferably also a Medical Doctor, will recognize as determinant for curing said patient.

15 In a preferred embodiment said method further comprises a step of bone marrow transplantation.

In one embodiment, said UCART22 cells of the invention can undergo robust *in vivo* T cell expansion and can persist for an extended amount of time in the host.

20 Said treatment can be ameliorating, curative or prophylactic. It may be either part of an autologous immunotherapy or part of an allogenic immunotherapy treatment. By autologous, it is meant that cells, cell line or population of cells used for treating patients are originating from said patient or from a Human Leucocyte Antigen (HLA) compatible donor. By allogeneic is meant that the cells or population of cells used for treating patients are not originating from said patient but from a donor.

In one embodiment, survival of said T cells of the invention in the host is controlled using an anti CD20 (rituximab) and/or QBEN10 treatment.

## SUBJECT

Compositions and methods of the present invention may be used to treat a subject who has been characterized as having pathological cells or tissues expressing CD22, or is suspected of having pathological cells or tissues expressing CD22. For example, subjects benefiting from treatment according to the invention include subjects with B-ALL or CLL, refractory BALL, relapse B-ALL.

In a preferred embodiment the patients are children suffering BALL, relapsed BALL, refractory BALL (pediatric indication).

The treatment with the engineered immune cells according to the invention may be in combination with one or more therapies against cancer selected from the group of antibodies therapy, chemotherapy, cytokines therapy, dendritic cell therapy, gene therapy, hormone therapy, laser light therapy and radiation therapy.

Accordingly, the present invention provides a pharmaceutical composition comprising a therapeutically active amount of UCART22 for the treatment of children suffering BALL, relapsed BALL, refractory BALL.

The present invention also provides a pharmaceutical composition comprising a UCART22 and a pharmaceutically acceptable excipient for the treatment of children suffering BALL, relapsed BALL, refractory BALL.

In a preferred embodiment, a pharmaceutical composition comprises the UCART22 of the invention and a compound of the bryostatin family, preferably bryostatin-1 and a pharmaceutically acceptable excipient for the treatment of children suffering BALL, relapsed BALL, refractory BALL.

According to a preferred embodiment of the invention, said treatment can be administrated into patients undergoing an immunosuppressive treatment, (conditioning treatment), more preferably a lymphodepletion. Indeed, the present invention preferably relies on cells or population of cells, which have been made resistant to at least one immunosuppressive agent due to the inactivation of a gene encoding a receptor for such immunosuppressive agent. In this aspect, the immunosuppressive

treatment or lymphodepletion should help the selection and expansion of the T-cells according to the invention within the patient and destruction of CD22 cancerous cells.

The administration of the cells or population of cells according to the present invention may be carried out in any convenient manner, including by aerosol inhalation, injection, ingestion, transfusion, implantation or transplantation. The compositions described herein may be administered to a patient subcutaneously, intradermally, intratumorally, intranodally, intramedullary, intramuscularly, by intravenous or intralymphatic injection, or intraperitoneally. In one embodiment, the cell compositions of the present invention are preferably administered by intravenous injection.

The administration of the cells or population of cells can consist of the administration of  $10^4$ - $10^9$  cells per kg body weight, preferably  $10^5$  to  $10^6$  cells/kg body weight including all integer values of cell numbers within those ranges. The cells or population of cells can be administrated in one or more doses, preferably several successive doses (redosing) to avoid escaping (relapsed cells). In another embodiment, said effective amount of cells are administrated as a single dose or in to doses. In another embodiment, said effective amount of cells are administrated as more than one dose over a period time.

Timing of administration is within the judgment of managing physician and depends on the clinical condition of the patient.

The cells or population of cells may be obtained from any source, such as a blood bank or a donor. While individual needs vary, determination of optimal ranges of effective amounts of a given cell type for a particular disease or conditions within the skill of the art. An effective amount means an amount which provides a therapeutic or prophylactic benefit. The dosage administrated will be dependent upon the age, health and weight of the recipient, kind of concurrent treatment, if any, frequency of treatment and the nature of the effect desired.

The present UCART22 are design to be efficient but for being not to active and limit cytokine storm. In case of overresponding patients, the present invention may be combined with adequate medication for preventing of blocking cytokine storm such as anti IL-6 drugs.

In another embodiment, said effective amount of cells or composition comprising those cells are administrated parenterally. Said administration can be an intravenous administration. Said administration can be directly done by injection within a tumor.

5 In certain embodiments of the present invention, cells are administered to a patient in conjunction with (e.g., before, simultaneously or following) any number of relevant treatment modalities, including but not limited to treatment with agents such as antiviral therapy, cidofovir and interleukin-2, Cytarabine (also known as ARA-C) or natalizumab treatment for MS patients or efalizumab treatment for psoriasis patients or  
10 other treatments for PML patients. In further embodiments, the T cells of the invention may be used in combination with chemotherapy, radiation, immunosuppressive agents, such as cyclosporin, azathioprine, methotrexate, mycophenolate, and FK506, antibodies, or other immunoablative agents such as CAMPATH, alemtuzumab, anti-CD3 antibodies or other antibody therapies, cytoxin, fludarabine, cyclosporin, FK506, rapamycin, mycoplenolic acid, steroids, FR901228, cytokines, and irradiation. These  
15 drugs inhibit either the calcium dependent phosphatase calcineurin (cyclosporine and FK506) or inhibit the p70S6 kinase that is important for growth factor induced signaling (rapamycin) (Henderson, Naya et al. 1991; Liu, Albers et al. 1992; Bierer, Hollander et al. 1993).

20 In a further embodiment, the cell compositions of the present invention are administered to a patient in conjunction with (e.g., before, simultaneously or following) bone marrow transplantation, T cell ablative therapy using either chemotherapy agents such as, fludarabine, external-beam radiation therapy (XRT), cyclophosphamide, or antibodies such as OKT3 or CAMPATH. In another embodiment, the cell compositions  
25 of the present invention are administered following B-cell ablative therapy such as agents that react with CD20, e.g., Rituxan. or QBEN10. For example, in one embodiment, subjects may undergo standard treatment with high dose chemotherapy followed by peripheral blood cell transplantation. In certain embodiments, following the transplant, subjects receive an infusion of the expanded immune cells of the present invention. In  
30 an additional embodiment, expanded cells are administered before or following surgery.

In another embodiment, following the transplant, subjects receive an agent that react with CD20, e.g., Rituxan, or Ritiximab, preferably with an agent that reacts with CD22 and CD20.

#### Other definitions

5 - Amino acid residues in a polypeptide sequence are designated herein according to the one-letter code, in which, for example, Q means Gln or Glutamine residue, R means Arg or Arginine residue and D means Asp or Aspartic acid residue.

10 - Amino acid substitution means the replacement of one amino acid residue with another, for instance the replacement of an Arginine residue with a Glutamine residue in a peptide sequence is an amino acid substitution.

15 - Nucleotides are designated as follows: one-letter code is used for designating the base of a nucleoside: a is adenine, t is thymine, c is cytosine, and g is guanine. For the degenerated nucleotides, r represents g or a (purine nucleotides), k represents g or t, s represents g or c, w represents a or t, m represents a or c, y represents t or c (pyrimidine nucleotides), d represents g, a or t, v represents g, a or c, b represents g, t or c, h represents a, t or c, and n represents g, a, t or c.

20 - "As used herein, "nucleic acid" or "polynucleotides" refers to nucleotides and/or polynucleotides, such as deoxyribonucleic acid (DNA) or ribonucleic acid (RNA), oligonucleotides, fragments generated by the polymerase chain reaction (PCR), and fragments generated by any of ligation, scission, endonuclease action, and exonuclease action. Nucleic acid molecules can be composed of monomers that are naturally-occurring nucleotides (such as DNA and RNA), or analogs of naturally-occurring nucleotides (e.g., enantiomeric forms of naturally-occurring nucleotides), or a combination of both. Modified nucleotides can have alterations in sugar moieties and/or in pyrimidine or purine base moieties. Sugar modifications include, for example, replacement of one or more hydroxyl groups with halogens, alkyl groups, amines, and azido groups, or sugars can be functionalized as ethers or esters. Moreover, the entire sugar moiety can be replaced with sterically and electronically similar structures, such as aza-sugars and carbocyclic sugar analogs. Examples of modifications in a base moiety 25 include alkylated purines and pyrimidines, acylated purines or pyrimidines, or other 30

well-known heterocyclic substitutes. Nucleic acid monomers can be linked by phosphodiester bonds or analogs of such linkages. Nucleic acids can be either single stranded or double stranded.

- By chimeric antigen receptor (CAR) is intended molecules that combine a binding domain against a component present on the target cell, for example an antibody-based specificity for a desired antigen (e.g., tumor antigen) with a T cell receptor-activating intracellular domain to generate a chimeric protein that exhibits a specific anti-target cellular immune activity. Generally, CAR consists of an extracellular single chain antibody (scFvFc) fused to the intracellular signaling domain of the T cell antigen receptor complex zeta chain (scFvFc:ζ) and have the ability, when expressed in T cells, to redirect antigen recognition based on the monoclonal antibody's specificity. One example of CAR used in the present invention is a CAR directing against CD22 antigen and can comprise as non-limiting example the amino acid sequences : SEQ ID NO: 15 to 18 preferably SEQ ID NO.16 or 18, more preferably SEQ ID NO.16;

- The term “endonuclease” refers to any wild-type or variant enzyme capable of catalyzing the hydrolysis (cleavage) of bonds between nucleic acids within a DNA or RNA molecule, preferably a DNA molecule. Endonucleases do not cleave the DNA or RNA molecule irrespective of its sequence, but recognize and cleave the DNA or RNA molecule at specific polynucleotide sequences, further referred to as “target sequences” or “target sites”. Endonucleases can be classified as rare-cutting endonucleases when having typically a polynucleotide recognition site greater than 12 base pairs (bp) in length, more preferably of 14-55 bp. Rare-cutting endonucleases significantly increase HR by inducing DNA double-strand breaks (DSBs) at a defined locus (Perrin, Buckle et al. 1993; Rouet, Smih et al. 1994; Choulika, Perrin et al. 1995; Pingoud and Silva 2007). Rare-cutting endonucleases can for example be a homing endonuclease (Paques and Duchateau 2007), a chimeric Zinc-Finger nuclease (ZFN) resulting from the fusion of engineered zinc-finger domains with the catalytic domain of a restriction enzyme such as FokI (Porteus and Carroll 2005), a Cas9 endonuclease from CRISPR system (Gasiunas, Barrangou et al. 2012; Jinek, Chylinski et al. 2012; Cong, Ran et al. 2013; Mali, Yang et al. 2013) or a chemical endonuclease (Eisenschmidt, Lanio et al. 2005; Arimondo, Thomas et al. 2006). In chemical endonucleases, a chemical or peptidic cleaver is conjugated

either to a polymer of nucleic acids or to another DNA recognizing a specific target sequence, thereby targeting the cleavage activity to a specific sequence. Chemical endonucleases also encompass synthetic nucleases like conjugates of orthophenanthroline, a DNA cleaving molecule, and triplex-forming oligonucleotides (TFOs), known to bind specific DNA sequences (Kalish and Glazer 2005). Such chemical endonucleases are comprised in the term “endonuclease” according to the present invention.

- By a “TALE-nuclease” (TALEN) is intended a fusion protein consisting of a nucleic acid-binding domain typically derived from a Transcription Activator Like Effector (TALE) and one nuclease catalytic domain to cleave a nucleic acid target sequence. The catalytic domain is preferably a nuclease domain and more preferably a domain having endonuclease activity, like for instance I-TevI, CofE7, NucA and Fok-I. In a particular embodiment, the TALE domain can be fused to a meganuclease like for instance I-Crel and I-Onul or functional variant thereof. In a more preferred embodiment, said nuclease is a monomeric TALE-Nuclease. A monomeric TALE-Nuclease is a TALE-Nuclease that does not require dimerization for specific recognition and cleavage, such as the fusions of engineered TAL repeats with the catalytic domain of I-TevI described in WO2012138927. Transcription Activator like Effector (TALE) are proteins from the bacterial species *Xanthomonas* comprise a plurality of repeated sequences, each repeat comprising di-residues in position 12 and 13 (RVD) that are specific to each nucleotide base of the nucleic acid targeted sequence. Binding domains with similar modular base-per-base nucleic acid binding properties (MBBBD) can also be derived from new modular proteins recently discovered by the applicant in a different bacterial species. The new modular proteins have the advantage of displaying more sequence variability than TAL repeats. Preferably, RVDs associated with recognition of the different nucleotides are HD for recognizing C, NG for recognizing T, NI for recognizing A, NN for recognizing G or A, NS for recognizing A, C, G or T, HG for recognizing T, IG for recognizing T, NK for recognizing G, HA for recognizing C, ND for recognizing C, HI for recognizing C, HN for recognizing G, NA for recognizing G, SN for recognizing G or A and YG for recognizing T, TL for recognizing A, VT for recognizing A or G and SW for recognizing A. In another embodiment, critical amino acids 12 and 13 can be mutated

5 towards other amino acid residues in order to modulate their specificity towards nucleotides A, T, C and G and in particular to enhance this specificity. TALE-nuclease have been already described and used to stimulate gene targeting and gene modifications (Boch, Scholze et al. 2009; Moscou and Bogdanove 2009; Christian, Cermak et al. 2010; Li, Huang et al. 2011). Custom-made TAL-nucleases are commercially available under the trade name TALEN<sup>TM</sup> (Collectis, 8 rue de la Croix Jarry, 75013 Paris, France).

10 The rare-cutting endonuclease according to the present invention can also be a Cas9 endonuclease, Zinc finger endonuclease, MegaTAL endonuclease. The genome engineering tool has been developed based on the RNA-guided Cas9 nuclease (Gasiunas, Barrangou et al. 2012; Jinek, Chylinski et al. 2012; Cong, Ran et al. 2013; Mali, Yang et al. 2013) from the type II prokaryotic CRISPR (Clustered Regularly Interspaced Short palindromic Repeats) adaptive immune system (see for review (Sorek, Lawrence et al. 2013)). The CRISPR Associated (Cas) system was first discovered in bacteria and 15 functions as a defense against foreign DNA, either viral or plasmid. CRISPR-mediated genome engineering first proceeds by the selection of target sequence often flanked by a short sequence motif, referred as the proto-spacer adjacent motif (PAM). Following target sequence selection, a specific crRNA, complementary to this target sequence is 20 engineered. Trans-activating crRNA (tracrRNA) required in the CRISPR type II systems paired to the crRNA and bound to the provided Cas9 protein. Cas9 acts as a molecular anchor facilitating the base pairing of tracrRNA with crRNA (Deltcheva, Chylinski et al. 2011). In this ternary complex, the dual tracr RNA:crRNA structure acts as guide RNA that directs the endonuclease Cas9 to the cognate target sequence. Target recognition 25 by the Cas9-tracrRNA:crRNA complex is initiated by scanning the target sequence for homology between the target sequence and the crRNA. In addition to the target sequence-crRNA complementarity, DNA targeting requires the presence of a short motif adjacent to the protospacer (protospacer adjacent motif - PAM). Following pairing between the dual-RNA and the target sequence, Cas9 subsequently introduces a blunt double strand break 3 bases upstream of the PAM motif (Garneau, Dupuis et al. 2010).

30 Rare-cutting endonuclease can be a homing endonuclease, also known under the name of meganuclease. Such homing endonucleases are well-known to the art

(Stoddard 2005). Homing endonucleases recognize a DNA target sequence and generate a single- or double-strand break. Homing endonucleases are highly specific, recognizing DNA target sites ranging from 12 to 45 base pairs (bp) in length, usually ranging from 14 to 40 bp in length. The homing endonuclease according to the invention may for example correspond to a LAGLIDADG endonuclease, to a HNH endonuclease, or to a GIY-YIG endonuclease. Preferred homing endonuclease according to the present invention can be an *I-CreI* variant.

- By "delivery vector" or "delivery vectors" is intended any delivery vector which can be used in the present invention to put into cell contact (i.e "contacting") or deliver inside cells or subcellular compartments (i.e "introducing") agents/chemicals and molecules (proteins or nucleic acids) needed in the present invention. It includes, but is not limited to liposomal delivery vectors, viral delivery vectors, drug delivery vectors, chemical carriers, polymeric carriers, lipoplexes, polyplexes, dendrimers, microbubbles (ultrasound contrast agents), nanoparticles, emulsions or other appropriate transfer vectors. These delivery vectors allow delivery of molecules, chemicals, macromolecules (genes, proteins), or other vectors such as plasmids, peptides developed by Diatos. In these cases, delivery vectors are molecule carriers. By "delivery vector" or "delivery vectors" is also intended delivery methods to perform transfection.

- The terms "vector" or "vectors" refer to a nucleic acid molecule capable of transporting another nucleic acid to which it has been linked. A "vector" in the present invention includes, but is not limited to, a viral vector, a plasmid, a RNA vector or a linear or circular DNA or RNA molecule which may consists of a chromosomal, non-chromosomal, semi-synthetic or synthetic nucleic acids. Preferred vectors are those capable of autonomous replication (episomal vector) and/or expression of nucleic acids to which they are linked (expression vectors). Large numbers of suitable vectors are known to those of skill in the art and commercially available.

Viral vectors include retrovirus, adenovirus, parvovirus (e. g. adeno-associated viruses, in particular aav6), coronavirus, negative strand RNA viruses such as orthomyxovirus (e. g., influenza virus), rhabdovirus (e. g., rabies and vesicular stomatitis virus), paramyxovirus (e. g. measles and Sendai), positive strand RNA viruses such as picornavirus and alphavirus, and double-stranded DNA viruses including adenovirus,

herpesvirus (e. g., Herpes Simplex virus types 1 and 2, Epstein-Barr virus, cytomegalovirus), and poxvirus (e. g., vaccinia, fowlpox and canarypox). Other viruses include Norwalk virus, togavirus, flavivirus, reoviruses, papovavirus, hepadnavirus, and hepatitis virus, for example. Examples of retroviruses include: avian leukosis-sarcoma, 5 mammalian C-type, B-type viruses, D type viruses, HTLV-BLV group, lentivirus, spumavirus (Coffin, J. M., Retroviridae: The viruses and their replication, In Fundamental Virology, Third Edition, B. N. Fields, et al., Eds., Lippincott-Raven Publishers, Philadelphia, 1996).

- By "lentiviral vector" is meant HIV-Based lentiviral vectors that are very promising for gene delivery because of their relatively large packaging capacity, reduced immunogenicity and their ability to stably transduce with high efficiency a large range of different cell types. Lentiviral vectors are usually generated following transient transfection of three (packaging, envelope and transfer) or more plasmids into producer cells. Like HIV, lentiviral vectors enter the target cell through the interaction of viral surface glycoproteins with receptors on the cell surface. On entry, the viral RNA undergoes reverse transcription, which is mediated by the viral reverse transcriptase complex. The product of reverse transcription is a double-stranded linear viral DNA, which is the substrate for viral integration in the DNA of infected cells. By "integrative lentiviral vectors (or LV)", is meant such vectors as nonlimiting example, that are able to integrate the genome of a target cell. At the opposite by "non-integrative lentiviral vectors (or NILV)" is meant efficient gene delivery vectors that do not integrate the genome of a target cell through the action of the virus integrase.

- Delivery vectors and vectors can be associated or combined with any cellular permeabilization techniques such as sonoporation or electroporation or derivatives of these techniques.

- By cell or cells is intended any eukaryotic living cells, primary cells and cell lines derived from these organisms for *in vitro* cultures.

- By "primary cell" or "primary cells" are intended cells taken directly from living tissue (i.e. biopsy material) and established for growth *in vitro*, that have undergone very few population doublings and are therefore more representative of the main

functional components and characteristics of tissues from which they are derived from, in comparison to continuous tumorigenic or artificially immortalized cell lines.

As non-limiting examples cell lines can be selected from the group consisting of CHO-K1 cells; HEK293 cells; Caco2 cells; U2-OS cells; NIH 3T3 cells; NSO cells; SP2 cells; CHO-S cells; DG44 cells; K-562 cells, U-937 cells; MRC5 cells; IMR90 cells; Jurkat cells; HepG2 cells; HeLa cells; HT-1080 cells; HCT-116 cells; Hu-h7 cells; Huvec cells; Molt 4 cells.

All these cell lines can be modified by the method of the present invention to provide cell line models to produce, express, quantify, detect, study a gene or a protein of interest; these models can also be used to screen biologically active molecules of interest in research and production and various fields such as chemical, biofuels, therapeutics and agronomy as non-limiting examples.

- by "mutation" is intended the substitution, deletion, insertion of up to one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, twenty, twenty five, thirty, forty, fifty, or more nucleotides/amino acids in a polynucleotide (cDNA, gene) or a polypeptide sequence. The mutation can affect the coding sequence of a gene or its regulatory sequence. It may also affect the structure of the genomic sequence or the structure/stability of the encoded mRNA.

- by "variant(s)", it is intended a repeat variant, a variant, a DNA binding variant, a TALE-nuclease variant, a polypeptide variant obtained by mutation or replacement of at least one residue in the amino acid sequence of the parent molecule.

- by "functional variant" is intended a catalytically active mutant of a protein or a protein domain; such mutant may have the same activity compared to its parent protein or protein domain or additional properties, or higher or lower activity.

—"identity" refers to sequence identity between two nucleic acid molecules or polypeptides. Identity can be determined by comparing a position in each sequence which may be aligned for purposes of comparison. When a position in the compared sequence is occupied by the same base, then the molecules are identical at that position. A degree of similarity or identity between nucleic acid or amino acid sequences is a function of the number of identical or matching nucleotides at positions shared by the nucleic acid sequences. Various alignment algorithms and/or programs may be used

to calculate the identity between two sequences, including FASTA, or BLAST which are available as a part of the GCG sequence analysis package (University of Wisconsin, Madison, Wis.), and can be used with, e.g., default setting. For example, polypeptides having at least 70%, 85%, 90%, 95%, 98% or 99% identity to specific polypeptides described herein and preferably exhibiting substantially the same functions, as well as polynucleotide encoding such polypeptides, are contemplated. Unless otherwise indicated a similarity score will be based on use of BLOSUM62. When BLASTP is used, the percent similarity is based on the BLASTP positives score and the percent sequence identity is based on the BLASTP identities score. BLASTP "Identities" shows the number and fraction of total residues in the high scoring sequence pairs which are identical; and BLASTP "Positives" shows the number and fraction of residues for which the alignment scores have positive values and which are similar to each other. Amino acid sequences having these degrees of identity or similarity or any intermediate degree of identity of similarity to the amino acid sequences disclosed herein are contemplated and encompassed by this disclosure. The polynucleotide sequences of similar polypeptides are deduced using the genetic code and may be obtained by conventional means, in particular by reverse translating its amino acid sequence using the genetic code.

- "signal-transducing domain" or "co-stimulatory ligand" refers to a molecule on an antigen presenting cell that specifically binds a cognate co-stimulatory molecule on a T-cell, thereby providing a signal which, in addition to the primary signal provided by, for instance, binding of a TCR/CD3 complex with an MHC molecule loaded with peptide, mediates a T cell response, including, but not limited to, proliferation activation, differentiation and the like. A co-stimulatory ligand can include but is not limited to CD7, B7-1 (CD80), B7-2 (CD86), PD-L1, PD-L2, 4-1BBL, OX40L, inducible costimulatory ligand (ICOS-L), intercellular adhesion molecule (ICAM, CD30L, CD40, CD70, CD83, HLA-G, MICA, M1CB, HVEM, lymphotxin beta receptor, 3/TR6, ILT3, ILT4, an agonist or antibody that binds Toll ligand receptor and a ligand that specifically binds with B7-H3. CD28 is excluded from this list. A co-stimulatory ligand also encompasses, *inter alia*, an antibody that specifically binds with a co-stimulatory molecule present on a T cell, such as but not limited to, CD27, , 4-IBB, OX40, CD30, CD40, PD-1, ICOS, lymphocyte function-

associated antigen-1 (LFA-1), CD2, CD7, LTGHT, NKG2C, B7-H3, a ligand that specifically binds with CD83.

5 A “co-stimulatory molecule” refers to the cognate binding partner on a T cell that specifically binds with a co-stimulatory ligand, thereby mediating a co-stimulatory response by the cell, such as, but not limited to proliferation. Co-stimulatory molecules include, but are not limited to an MHC class I molecule, BTLA and Toll ligand receptor.

A “co-stimulatory signal” as used herein refers to a signal, which in combination with primary signal, such as TCR/CD3 ligation, leads to T cell proliferation and/or upregulation or downregulation of key molecules.

10 The term “extracellular ligand-binding domain” as used herein is defined as an oligo- or polypeptide that is capable of binding a ligand. Preferably, the domain will be capable of interacting with a cell surface molecule. For example, the extracellular ligand-binding domain may be chosen to recognize a ligand that acts as a cell surface marker on target cells associated with a particular disease state. Thus examples of cell surface markers that may act as ligands include those associated with viral, bacterial and parasitic 15 infections, autoimmune disease and cancer cells.

20 The term "subject" or "patient" as used herein includes all members of the animal kingdom including non-human primates and humans, preferably human. In one embodiment patients are patients with aggressive, or refractory or relapsing ALL, or, aggressive, refractory, relapsing CLL.

A mammal is any warm-blooded vertebrate of the class Mammalia, preferably a human.

25 "Suicide domain or switches," or safety on-and-off switches" means a domain usually a cell surface domain recognized by a molecule, protein, chemical, antibody for immunoselecting expressing cells and eventually controlling their functioning and survival.

30 The above written description of the invention provides a manner and process of making and using it such that any person skilled in this art is enabled to make and use the same, this enablement being provided in particular for the subject matter of the appended claims, which make up a part of the original description.

Where a numerical limit or range is stated herein, the endpoints are included. Also, all values and subranges within a numerical limit or range are specifically included as if explicitly written out.

The above description is presented to enable a person skilled in the art to make and use the invention, and is provided in the context of a particular application and its requirements. Various modifications to the preferred embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention. Thus, this invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

## GENERAL METHOD

### Screening and selection of CAR

- *Primary T-cell cultures*

T cells were purified from Buffy coat samples provided by EFS (Etablissement Français du Sang, Paris, France) using Ficoll gradient density medium. The PBMC layer was recovered. T cells were activated in X-Vivo<sup>TM</sup>-15 medium (Lonza) supplemented with 20ng/mL Human IL-2, 5% Human, and Dynabeads Human T activator CD3/CD28 at a bead:cell ratio 1:1 (Life Technologies).

- *CAR mRNA transfection*

Transfections of *CAR mRNAs* encoding each CAR constructs were done at Day 4 or Day 11 after T-cell purification and activation. Cells were immediately diluted in X-Vivo<sup>TM</sup>-15 media and incubated at 37°C with 5% CO<sub>2</sub>. IL-2 was added 2h after electroporation at 20ng/mL.

- *T-cell transduction*

Vectors coding a CD22 CAR are introduced into T cells as previously described.

CAR detection at the surface of T-cells is performed using a recombinant protein consisting on the extracellular domain of the human CD22 protein (whole protein, distal portion of CD22 or proximal portion of CD22) fused together with a murine IgG1 Fc fragment. Binding of this protein to the CAR molecule is detected with a PE-conjugated

secondary antibody (Jackson Immunoresearch) targeting the mouse Fc portion of the protein, and analyzed by flow cytometry.

#### Inactivation of specific gene(s) in primary T cells

Inactivation of specific gene(s) in primary T cells may be performed before preferably after CD22 CAR introduction into cells using endonucleases such as TAL endonuclease, optionally Crispr Cas 9 endonucleases, designed accordingly. At least one gene is inactivated, one, two or three genes may be inactivated in one step or in several successive step. ; In a preferred embodiment two genes are inactivated, preferably TCRalpha gene and a gene which deletion confers resistance to a drug selected from purine nucleotide analogues, alemtuzumab, platines (cisplatin or carboplatin), anti-topoisomerase I (Irinotecan), anti-topoisomerase II (Etoposide), Methotrexate (folic acid analogs), preferably purine nucleotide analogues, alemtuzumab.

In general, heterodimeric nuclease, in particular TALE-Nuclease targeting two long sequences (called half targets) separated by a spacer within a target gene is designed and produced.

Each TALE-nuclease construct may be cloned in an appropriate mammalian expression vector. mRNA encoding TALE-nuclease cleaving a targeted genomic sequence may be synthesized from plasmid carrying the coding sequence downstream a promoter. Purified T cells preactivated with anti-CD3/CD28 coated beads are used and transfected with each of the 2 mRNAs encoding both half TALE-nucleases. Cells may be reactivated with soluble anti-CD28 to measure cell proliferation for various times and the activation marker CD25 detected to assess the activation state of the cells.

- *Degranulation assay (CD107a mobilization)*

Cells were incubated in 96-well plates, together with an equal amount of cells expressing various levels of the targeted protein (CD22). Co-cultures were maintained for 6 hours at 37°C with 5% CO<sub>2</sub>. CD107a staining was done during cell stimulation, by the addition of a fluorescent anti-CD107a antibody at the beginning of the co-culture, together with an anti-CD49d, anti-CD28, and 1x Monensin solution, as a control. After the 6h incubation period, cells were stained with a fixable viability dye and fluorochrome-conjugated anti-CD8 and analyzed by flow cytometry. The degranulation

activity was determined as the % of CD8+/CD107a+ cells, and by determining the mean fluorescence intensity signal (MFI) for CD107a staining among CD8+ cells. Degranulation assays were carried out 24h after mRNA transfection.

- *IFN gamma release assay*

5 24h after mRNA transfection, CD22 CAR expressing T-cells were incubated together with cell lines expressing various levels of the targeted protein for 24 hours at 37°C. The supernatants were recovered and IFN gamma detection in the cell culture supernatants was done by ELISA assay.

- *Cytotoxicity assay*

10 Cells were incubated together with target cells (expressing different levels of CD22) or (negative control) cells. Target and control cells were labelled with fluorescent intracellular dyes (CFSE or Cell Trace Violet) before co-culturing them with CAR+ T-cells. The co-cultures were incubated for 4 hours at 37°C. After this incubation period, cells were labelled with a fixable viability dye and analyzed by flow cytometry. Viability of 15 each cellular population (target cells or negative control cells) was determined and the % of specific cell lysis was calculated. Cytotoxicity assays were carried out 48h after mRNA transfection.

- *Anti-tumor mouse model*

20 Immuno deficient mice are implanted with tumor cells (CD22 BALL from patients) or with targeted protein expressing -Luciferase cells into the flank. Subsequently, cells were implanted into mouse brains. Serial transplantation into further generations of mice continues the maintenance of in vivo xenograft cell lines. Optionally, mice received 25 an anti-cancer treatment before/or together with injection with CAR+ T-cells (alemtuzumab and/or flu). Mice are then iv injected (either 2 or 7 days after injection of the tumor cell line) with different doses of CAR+ T-cells to be tested, or with T-cells that were not expressing CD22CAR. Bioluminescent signals are determined at the day of T-cell injection (D0), at D7, 14, 21, 28 and 40 after T-cell injection in order to follow tumoral progression in the different animals.

30 Phase I dose-escalation study to evaluate the safety, expansion and persistence of allogeneic CD22 CART (UCART22) in patients with relapsed or refractory or MRD+ CD22+ B-cell acute lymphoblastic leukemia (B-ALL)

## BACKGROUND AND RATIONALE

With the current multi-drug chemotherapy regimens, long term survival is seen in >80% of childhood acute lymphoblastic leukemia (ALL) and in approximately 40% of adult ALL.(1) Further intensification of chemotherapy has not proved to be effective.(2) There has been significant advancement in our understanding of the biology of ALL in the last few years which provides an opportunity for 'targeted therapy'.(3, 4).

Relapse/refractory ALL remains a challenging disease. Post-relapse therapies will lead to a second CR (CR2) in 30-40% of patients with a 5-year OS of only around 10%. In the largest report of relapsed adult ALL patients to date, Fielding and colleagues analyzed the outcomes of relapsed adult ALL patients who were treated on the MRC UKALLXII/ECOG E2993 trial.(5) Of the 1508 evaluable patients, 1372 (91%) achieved CR1 of whom 609 (44% of the CR1 patients) relapsed at a median of 11 months. The 5-year OS was only 7% for the relapsed patients. The median OS for the relapsed patients was 5.5 months. Tavernier and colleagues reported outcomes of 421 ALL patients who experienced first relapse treated on the French LALA-94 trial.(6) A CR2 was achieved in 44% patients with a median DFS of 5.2 months and median OS of 6.3 months. Oriol and colleagues reported the outcomes of 263 ALL patients in first relapse treated on 4 consecutive PETHEMA trials.(7) CR2 was achieved in 45% of patients, a rate similar to the French LALA trials. The median OS was after relapse was 4.5 months with a 5-year OS of 10%.

CD22 expression occurs in >90% of patients with ALL, and is a valid therapeutic target. Cellular therapies such as chimeric antigen receptor (CAR) T cell therapies are increasingly being used to treat patients with hematologic malignancies.(8-16) In patients with relapsed acute lymphoblastic leukemia (ALL), a very high complete response rate (80-90%) have been reported with autologous CD19-CART cells.(12) Similarly, response rate of 40-50% is seen in patients with relapsed chronic lymphocytic leukemia (CLL) undergoing autologous CD19 CART therapies.(9)

The present study evaluates allogeneic CART cells directed to CD22 in patients with relapsed and/or refractory CD22 B-ALL.

## OBJECTIVES

### Primary Objectives

To evaluate the safety and tolerability of allogeneic CD22 CART and to determine the maximum tolerated dose (MTD)

### Secondary Objectives

To determine the efficacy of allogeneic CD22 CART  
To determine the incidence of GVHD

#### Exploratory Objectives

5 To determine the expansion, phenotype, trafficking and persistence of infused CART cells

#### INCLUSION CRITERIA

1. Relapsed or refractory CD22-positive ALL (For expansion phase: patients with MRD+ disease are allowed)
- 10 2. Patients aged  $\geq 2$  years
3. ECOG performance status  $\leq 2$
4. Normal organ function including bilirubin  $\leq 2$  mg/dl, ALT/AST  $< 3 \times$  ULN, and creatinine  $\leq 2$  mg/dl
- 15 5. Left Ventricle Ejection Fraction (LVEF)  $\geq 40\%$

#### EXCLUSION CRITERIA

1. Patient is pregnant or breastfeeding
2. Patients with uncontrolled active infections
- 20 3. Isolated extramedullary relapse (i.e. testicular, CNS)
4. Known active CNS leukemia. Note: Patients with history of CNS disease that has been effectively treated will be eligible provided that they have been in CNS remission  $>4$  weeks before enrollment
5. Active hepatitis B or active hepatitis C
- 25 6. HIV infection
7. Active GVHD requiring systemic steroid therapy. Steroid therapy for physiologic replacement is acceptable.
8. Received a DLI within 4 weeks of CD22 CART infusion
9. Allo-SCT within 60 days of CD22 CART infusion

30

#### DESCRIPTION OF STUDY

This is Phase I study. There are 2 phases to this trial. Dose escalation, and Dose expansion.

Patients receive CD22 allogeneic CART after receiving lymphodepletion chemotherapy.

35 Dose-escalation: Four dose levels are studied in a standard 3x3 design. A total of 9-18 patients are be enrolled.

Dose Level	UCART22 cells/kg
-1	$1 \times 10^4$
1 (Starting dose)	$1 \times 10^5$
2	$1 \times 10^6$
3	$5 \times 10^6$

Once the R2PD level is identified, dose-expansion starts.

A total of 20 patients are then enrolled (10 R/R ALL; 10 MRD+ post-SCT).

Total sample size: 29-38 patients

Number of Patients with DLT at a Dose Level	Decision
0 of 3	Escalate and evaluate in 3 subsequent patients.
1 of 3	Enroll 3 additional subjects at this dose level.
$\geq 2$ of 3	The MTD has been exceeded. Dose escalation will stop and this level will be declared the maximum administered dose. Evaluate 3 additional patients at the prior dose level if only three were treated at that dose previously.
1 of 6	Escalate dose and evaluate in 3 subsequent patients.
$\leq 1$ out of 6 at the Highest Dose Below the Maximum Administered Dose	This is the MTD.
$\geq 2$ of 6	The MTD has been exceeded. Dose escalation will stop and this level will be declared the maximum administered dose. Evaluate 3 additional patients at the prior dose level if only three were treated at that dose previously.

5

The second study compares allogeneic CART cells directed to CD22 to allogeneic CART cells directed to CD22 and CD19 (2 forms) in patients with CD19+CD22+ B-ALL.

## OBJECTIVES

### Primary Objectives

To evaluate the safety and tolerability of allogeneic CD19+CD22 CART and to determine the maximum tolerated dose (MTD)

#### Secondary Objectives

5            To determine the efficacy of allogeneic CD22 CART  
              To determine the incidence of GVHD

#### Exploratory Objectives

10           To determine the expansion, phenotype, trafficking and persistence of infused CART cells

#### INCLUSION CRITERIA

1. Relapsed or refractory CD22-positive ALL (For expansion phase: patients with MRD+ disease are allowed)
2. Patients aged  $\geq 2$  years
3. ECOG performance status  $\leq 2$
4. Normal organ function including bilirubin  $\leq 2$  mg/dl, ALT/AST  $< 3 \times$  ULN, and creatinine  $\leq 2$  mg/dl
5. Left Ventricle Ejection Fraction (LVEF)  $\geq 40\%$

20

#### EXCLUSION CRITERIA

1. Patient is pregnant or breastfeeding
2. Patients with uncontrolled active infections
3. Isolated extramedullary relapse (i.e. testicular, CNS)
- 25           4. Known active CNS leukemia. Note: Patients with history of CNS disease that has been effectively treated will be eligible provided that they have been in CNS remission  $>4$  weeks before enrollment
5. Active hepatitis B or active hepatitis C
6. HIV infection
- 30           7. Active GVHD requiring systemic steroid therapy. Steroid therapy for physiologic replacement is acceptable.
8. Received a DLI within 4 weeks of CD22 CART infusion
9. Allo-SCT within 60 days of CD22 CART infusion

35

#### DESCRIPTION OF STUDY

This is Phase I study. There are 2 phases to this trial. Dose escalation, and Dose expansion.

Patients receive CD22 allogeneic CART after receiving lymphodepletion chemotherapy.

5 Dose-escalation: Four dose levels are studied in a standard 3x3 design. A total of 9-18 patients are be enrolled.

Dose Level	UCART22 cells/kg
-1	$1 \times 10^4$
1 (Starting dose)	$1 \times 10^5$
2	$1 \times 10^6$
3	$5 \times 10^6$

Once the R2PD level is identified, dose-expansion starts.

A total of 20 patients are then enrolled (10 R/R ALL; 10 MRD+ post-SCT).

Total sample size: 29-38 patients

Number of Patients with DLT at a Dose Level	Decision
0 of 3	Escalate and evaluate in 3 subsequent patients.
1 of 3	Enroll 3 additional subjects at this dose level.
>/=2 of 3	The MTD has been exceeded. Dose escalation will stop and this level will be declared the maximum administered dose. Evaluate 3 additional patients at the prior dose level if only three were treated at that dose previously.
1 of 6	Escalate dose and evaluate in 3 subsequent patients.
</=1 out of 6 at the Highest Dose Below the Maximum Administered Dose	This is the MTD.
>/=2 of 6	The MTD has been exceeded. Dose escalation will stop and this level will be declared the maximum administered dose. Evaluate 3 additional patients at the prior dose level if only three were treated at that dose previously.

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## EXAMPLES

Example 1: Proliferation of TCR alpha inactivated cells expressing a CD22-CAR.

10 Heterodimeric TALE-nuclease targeting two 17-bp long sequences (called half targets) separated by an 15-bp spacer within T-cell receptor alpha constant chain region (TRAC) gene were designed and produced. Each half target is recognized by repeats of the half TALE-nucleases listed in Table 6.

15 Table 6: TAL-nucleases targeting TCRalpha gene

Target	Target sequence	Repeat sequence	Half TALE-nuclease
TRAC_T01	TTGTCCCACAGATATCC Agaaccctgaccctg	Repeat TRAC_T01-L	TRAC_T01-L TALEN (SEQ ID NO: 16)
	CCGTGTACCAGCTGAGA (SEQ ID NO: 18)	Repeat TRAC_T01-R	TRAC_T01-R TALEN (SEQ ID NO: 17)

20 Each TALE-nuclease construct was subcloned using restriction enzyme digestion in a mammalian expression vector under the control of the T7 promoter. mRNA encoding TALE-nuclease cleaving TRAC genomic sequence were synthesized from plasmid carrying the coding sequence downstream from the T7 promoter.

Purified T cells preactivated during 72 hours with anti-CD3/CD28 coated beads were transfected with each of the 2 mRNAs encoding both half TRAC\_T01 TALE-nucleases. 48 hours post-transfection, different groups of T cells from the same donor were respectively transduced with a vector encoding one of the CD22 CAR of the

invention. 2 days post-transduction, CD3<sub>NEG</sub> cells were purified using anti-CD3 magnetic beads and 5 days post-transduction cells were reactivated with soluble anti-CD28 (5 µg/ml).

Cell proliferation was followed for up to 30 days after reactivation by counting 5 cell 2 times per week. The proliferation in TCR alpha inactivated cells expressing the CD22 CARs, was comparable to that of non inactivated cells and increased especially when reactivated with anti-CD28.

#### Multiple transfection of TALEN mRNA

mRNAs encoding the TRAC TALENs (Left and right) and mRNAs encoding TALEN pairs specific 10 for the B2M gene were transfected in activated T cells, and subsequently transduced with exogenous polynucleotides encoding a CAR specific for CD22 or a CAR specific for CD19 or both.

Double KO TRAC and B2M or CD56 gene expressed undetectable level of TCR and MHC I or 15 TCR and CD56. After purification, cells were transduced again.

#### Example 2: CD22 CAR-T

Development of engineered CAR T-cells targeting CD22, for the treatment of refractory, relapsing or aggressive ALL or CLL.

20

- **CD22 CARs: (Figure 2)**
- Construct as m971 and m971 variants with decreased affinity for CD22 and high selectivity

25

CD22 CARs were designed and prepared using different scfv. The m971 scfv is derived from 971 antibody (Haso W<sup>1</sup>, Lee DW, Shah NN, Stetler-Stevenson M, Yuan CM, Pastan IH, Dimitrov DS, Morgan RA, FitzGerald DJ, Barrett DM, Wayne AS, Mackall CL, Orentas RJ. Anti-CD22-chimeric antigen receptors targeting B-cell precursor acute lymphoblastic leukemia. *Blood*. 2013 Feb 14;121(7):1165-74. doi: 10.1182/blood-2012-06-438002. Epub 2012 Dec 14)

30

A CARs architecture (figure 2) was constructed with the 41BB costimulatory domain, the CD3ζ activation domain, the CD8α transmembrane domain and a hinge, CD8α hinge

(SEQ-ID N°15). The construction comprising a Fc<sub>Y</sub>RIII<sub>α</sub>- hinge correspond to (SEQ-ID N°14).

Constructs were inserted into a vector for stable expression and screening of designed CARs.

5 CD22 CARs were m971-V3 CAR (SEQ ID NO.22); and SEQ ID N°24.

Sequences may be also optimized for CD22 binding and the treatment of ALL and CLL, preferably their refractory relapsing and aggressive forms.

- **CAR expression**

10 CD22 CARs were introduced into primary KO TCR T cells 5 days after activation by anti-CD3CD28 coated beads and IL-2. CAR expression was assessed by flow cytometry. All CAR were expressed at the cell surface. Activity towards CD22+ transformed cell lines and refractory or relapsed CD22+ B ALL from patients.

15 To test the functionality of the anti-CD22 CARs, B Cell expressing CD22 (ALL lines REH, SEM, NALM6-GL, KOPN8, Daudi, Raji, and on K562 were used (see Haso et al., 2013, 2013; Blood: 121 (7) : 1165 – 1174 for experimental details). refractory or relapsed CD22+ B ALL were obtained from patients.

As expected all cells expressing CD22 were positively stained and targeted by the CD22 CAR from m971 of the invention, as with the CD22 CAR (scfv2 from HA22).

20 **Degranulation assay**

To validate the CD22 CAR constructs a degranulation assay was performed on target cells with T cells expressing the CD22 CAR of the invention. The CART degranulation was evaluated by flow cytometry. The read-out is the CD107a expression at the T cell plasma membrane after 5 hours incubation with target cells. The results 25 showed that degranulation was more important from the CARm971- (scfv-1) than for CD22 CAR T cells against the distal part of the CD22 (SEQ ID 20) scfv-2 (Figure 5).

- **Cytotoxicity assay**

A cytotoxicity assay was performed on these same target cells with T cells expressing CD22 CARs of the invention. CD22 CARs, showed a strong specific lysis of CD22 cells of

UCART 22 of the invention as compared to cells expressing a scfv against the distal part of CD22 (scfv2) (figure 6).

### **Interferon gamma assay**

Interferon gamma production of UCART22 (scfv-V1 against the proximal domain of CD22) as 5 compared to that of non transduced (NT) or of T cells transduced with a CAR targeting the distal part of CD22(scfv-V2) cells in the presence of CD22-positive NALM-16 cells as compared to CD22 negative SUP-T1 cells (Figure 7).

### **Mice survival**

10 Mice survival was improved in the presence UCART22 (scfv-V1 against the proximal domain of CD22) or CART22 (no TRAC inactivation) as compared to control cells (Figure 8).

### **Resistance to hypoxia and/or drugs**

15 Engineered cells UCART22 of the invention were not significantly affected (survival and CTL activity) in the presence of alemtuzumab (50 microgramme /mL), or PNA (flu) as compared to non engineered cells sensitive cells which died 48 hours following addition of the drug in the cell culture, or following culture condition under hypoxia (less than 5%, preferably less than 1% O<sub>2</sub>).

20 Tests performed under low O<sub>2</sub> condition (<5% or <1%) generated similar results and confirmed that UCART22 with increase HIF-1a expression can survive, express CD22 CAR and be active under hypoxia.

25 Similar results (survival, CTL activity) were obtained in mice treated with Campath (50 microgramme /mL) confirming the resistance of UCART22 to drugs. The possibility for the UCART22 cells of the invention to reach cancer cells nested in tissues or to reach cancer cells making clusters in vivo is suggested, as the amount of cancer cells “recovering” or “escaping” the treatment with UCART22 was much less (about 15% decrease) than in mice treated with UCART22 non resistant to O<sub>2</sub>. It seems therefore that a local hypoxia created by liquid tumors may prevent immune cells to fight them.

Experiments carried out to determine whether UCART22 cells could be eliminated if and when desired (Figure 3 and 4). In mice, Rituximab induced a significant decrease in UCART as suggested by an increased fluorescence intensity of tumor cells in mice treated with rituximab and UCART as compared to cells alone.

5

The clinical first data obtained show that UCAR T cells significantly reduce relapse and refractory ALL in vivo and in vitro, with no or very mild (grade 1) GVHD and mild to no uncontrolled cytokine storm .

10

Such treatment is to be less “toxic” than autologous CD22 CAR T and can be controlled in patients using rituximab and/or QBEN10.

Cells persists in human long enough to be active (over a month) and can be depleted using QBEN10.

15

### Examples of CD22 CAR polypeptide sequences prepared

Framed sequences correspond to preferred VH and VL sequences. VH and VL may be swapped (modification in hot spot) to improve CAR efficiency as described above

20

- v1-m972 (Fc $\gamma$ RIII $\alpha$ -CD8 $\alpha$ TM-41BB.IC-CD3 $\zeta$ .IC) (Control not part of the invention)  
MALPV TALLPL ALLLHAARP--  
EVQLVQSGGGVVRPGGSLRLPCAASGFTFDDYGMSWVRQAPGKGLEWVSGINWNGGSTGYADS  
VKGRFTISRDNAKNSLYLQMNSLRAEDTALYHCARGGDDAFDIWGQGTMVTVSS —  
GGGGSGGGGGSGGGGS—

25

RIVMTQSPGTL SVSPGETATLSCRASQFSNMLAWYQQKSGQPPRLLIYGVSTRAAGVPARFSGSG  
SGTEFTLTISNLQSEDFAVYYCQQYGDWPRYTFGQGTVKVERK --  
GLAVSTISSLFPPGYQIYIWAPLAGTCVLLSLVITLYCKRGRKKLLYIFKQPFMRPVQTTQEDGCSC  
RFPEEEEGGCELRVKFSRSADAPAYQQGQNQLYNELNLGRREYDVLKRRGRDPEMGGKPRRKN  
PQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQALPPR

30

- V3-m972 (CD8 $\alpha$ -CD8 $\alpha$ TM-41BB.IC-CD3 $\zeta$ .IC) (control not part of the invention)  
MALPV TALLPL ALLLHAARP--  
EVQLVQSGGGVVRPGGSLRLPCAASGFTFDDYGMSWVRQAPGKGLEWVSGINWNGGSTGYADS  
VKGRFTISRDNAKNSLYLQMNSLRAEDTALYHCARGGDDAFDIWGQGTMVTVSS—  
GGGGSGGGGGSGGGGS—

35

RIVMTQSPGTL SVSPGETATLSCRASQFSNMLAWYQQKSGQPPRLLIYGVSTRAAGVPARFSGSG

SGTEFTLTISNLQSEDFAVYYCQQYGDWPRYTFGQGTKVERK—  
TTTPAPRPPTPAPTIASQPLSLRPEACRPAAGGAHVTRGLDFACDIYIWAPLAGTCVLLSLVITLYC  
KRGRKKLLYIFKQPFMRPVQTTQEEDGCSRFPEEEQGCELRVKFSRSADAPAYQQGQNQLYNEL  
NLGRREEYDVLKRRGRDPEMGGKPRRKNPQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDG  
5 LYQGLSTATKDTYDALHMQALPPR

- v1-m971 (Fc $\gamma$ RIII $\alpha$ -CD8 $\alpha$ TM-41BB.IC-CD3 $\zeta$ .IC)

MALPV TALLPL ALLLHAARP--

QVQLQQSGPGLVKPSQTLSLTCAISGDSVSSNSAAWNWIRQSPSRGLEWLGRYYRSKWYNDYAV  
SVKS RITINPDTSKNQFSLQLNSVT PEDA TAVYYCAREV TGDLED AFDI WQGQ GTMVT VSS —

10 GGGGSGGGGGGGGS—

DIQMTQSPSSLSASVGDRV TICRASQTIWSYLNWYQQRPGKAPNLLIYAASSLQSGVPSRFSGRGS  
GTDFTLTSSLQAEDFATYYCQQSY SIPQTFGQGT KLEIK —

GLAVSTI SFFPPGYQIYIWAPLAGTCVLLSLVITLYC KRG RKKLLYIFKQPFMRPVQTTQEEDG CSC  
RFPEEEQGCEL RVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLKRRGRDPEMGGKPRRK N

15 PQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQALPPR

- v3-m971 (CD8 $\alpha$ -CD8 $\alpha$ TM-41BB.IC-CD3 $\zeta$ .IC)

MALPV TALLPL ALLLHAARP--

QVQLQQSGPGLVKPSQTLSLTCAISGDSVSSNSAAWNWIRQSPSRGLEWLGRYYRSKWYNDYAV  
SVKS RITINPDTSKNQFSLQLNSVT PEDA TAVYYCAREV TGDLED AFDI WQGQ GTMVT VSS —

20 GGGGSGGGGGGGGS—

DIQMTQSPSSLSASVGDRV TICRASQTIWSYLNWYQQRPGKAPNLLIYAASSLQSGVPSRFSGRGS  
GTDFTLTSSLQAEDFATYYCQQSY SIPQTFGQGT KLEIK —

TTTPAPRPPTPAPTIASQPLSLRPEACRPAAGGAHVTRGLDFACDIYIWAPLAGTCVLLSLVITLYC  
KRGRKKLLYIFKQPFMRPVQTTQEEDGCSRFPEEEQGCELRVKFSRSADAPAYQQGQNQLYNEL

25 NLGRREEYDVLKRRGRDPEMGGKPRRKNPQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDG  
LYQGLSTATKDTYDALHMQALPP

## RESULTS

The CAR construct selected for preparing in UCART22 comprises the m971 anti-human CD22 scFv (described in Haso et al., 2013), a CD8 $\alpha$  hinge (optional) and transmembrane domain, and a cytoplasmic tail composed of 4-1BB co-stimulatory domain and CD3 $\zeta$  signaling domain (Figure 3).

5 Another CAR construct comprises successively, a sequence the m971 anti-human CD22 scFv, two binding domains for rituximab (CD20), a CD8 $\alpha$  hinge and transmembrane domain, and a cytoplasmic tail composed of 4-1BB co-stimulatory domain and CD3 $\zeta$  signaling domain (Figure 3).

An alternative CAR construct comprised successively a binding domain for rituximab (CD20), a binding domain for Q-BEN10 (CD34), the m971 anti-human CD22 scFv, two binding domains for 10 rituximab (CD20), a CD8 $\alpha$  hinge and transmembrane domain, and a cytoplasmic tail composed of 4-1BB co-stimulatory domain and CD3 $\zeta$  signaling domain (Figure 3).

In UCART22, a recombinant third generation self-inactivating (SIN) lentiviral vector (rLV) is used to generate T-cells expressing the anti-CD22 CAR and the RQR8 depletion mechanism under the control of the human EF1 $\alpha$  promoter (Figure 4). Recombinant lentiviral vectors derived from HIV are 15 genetically stable and have not yet shown evidence of pathological consequences ascribed to the vector (Chang and Sadelain, 2007; Wang et al., 2009). In addition, the conditions for transduction of T-cells with rLV are known and are compatible with the preservation of the functional properties of T-cells.

In UCART22, AAV6 vector may be used after genetic editing of a gene such as the TRAC gene (gene 20 encoding the alpha subunit or the TCR) or any gene disclosed in PCT/EP2017/076798 (figure 9).

Variants of anti-CD22 CAR construct of the invention comprising an additional CD19 scfv (before or 25 after the CD22 scfv) were also prepared as well as a multichain CD22 CAR, a multichain CD22, CD19 CAR (figure 2) were also constructed and inserted into lentiviral vector Adeno-associated virus 6 (AAV6) vector allowing the CD22 CAR constructs or CD19 CAR constructs described below to be inserted into the TRAC gene or into the CD25 gene, or into the beta 2 microglobulin gene were made (the CAR sequence was flanked in 5' and in 3' of sequences allowing homologous recombination into the TRAC gene, into the CD25 gene or into the beta 2 microglobulin gene after specific cut of said gene using a specific TAL-protein-Fok-1 (TALEN).

A UCART22 was made comprising in addition a TGFbeta receptor KO gene, an IL-10 receptor KO gene, 30 an AHR KO gene, a PD1 KO gene, a LAG-3 KO gene, a TIM-3 KO gene, or combination thereof.

An example of each UCART22 comprising in addition either a TGFbeta receptor KO gene, or an IL-10 receptor KO gene, or an aryl hydrocarbon receptor (AHR) KO gene, or a PD1 KO gene, or a LAG-3 KO gene, or a TIM-3 KO gene, was made.

To test the effect of depleting CD19+ CD22+ cancer cells, the anti-CD19 construct previously described in “Molecular remission of infant B-ALL after infusion of universal TALEN gene-edited CAR T cells. Waseem Qasim, et al., 2017. Science Translational Medicine 25 Jan 2017), and further comprising a suicide gene distinct from those carried by CD22 CAR (as described in

5 WO2016120216A1), was also prepared. In the present study, the cytolytic activity of

- 1) a combination of UCART19 + UCART 22 (two single chain CARs), as compared to individual cells alone (all at 5x106 cells),
- 2) TCR-negative cells expressing a bispecific anti-CD22-ant-CD19 CAR, (a bispecific single chain CAR), as compared to individual cells alone (all at 5x106 cells),
- 10 3) , or a multichain CAR comprising both CD22 and CD19 scfvs -or CD19 CD22scfvs,

Was measured as compared to individual cells alone (all at 5x106 cells).

#### **Expression of RQR8, R2CD22CAR or QR3CD22CAR to confer sensibility to Rituximab /Rituximab and QBEN10**

The lentiviral vector cassette that drives the expression of CD22CAR has been designed to co-express RQR8 (through a 2A peptide linker). RQR8 is a depletion ligand that can be potentially activated in case of unmanageable adverse events related to the administration of UCART22. RQR8 is a 136 amino acid artificial cell surface protein combining antibody-binding epitopes from human CD34, recognized by the QBEnd-10 antibody, and human CD20 (Philip et al., 2014). The CD20 epitopes present within the construct are recognized by rituximab, thus enabling deletion of RQR8-expressing cells through complement-mediated cell killing (CDC) and antibody-dependent cell-mediated cytotoxicity (ADCC) in the presence of Rituximab/and or QBEN10.

In other experiments, constructs corresponding to an anti-CD22 CAR comprising 2 epitopes recognized by rituximab (R) (R2 CD22 CAR: two epitopes recognized by rituximab, inserted just after the scfv and just before the hinge, or instead of the hinge to shorten the extracellular domain as compared to the whole construction with hinge) or a “QR3” QR3 CD22 CAR (Q: epitope recognized by QBEN 10, Q-R -in N terminal before the VH-linker-VL RR hinge TM -41BB- CD3 zeta), were prepared and tested against cells expressing various level of CD22.

#### **TRAC gene knock-out to limit alloreactivity of UCART22**

A potential limitation of allogeneic adoptive immunotherapy approaches is that recognition of MHC disparities between donor and recipient through the donor cell’s TCR $\alpha\beta$  complex may lead to donor T-cell activation/proliferation and the development of Graft-versus-Host Disease (GvHD). TCR $\alpha\beta$  is composed of  $\alpha$  and  $\beta$  subunits, with the TCR $\alpha$  encoded by a single gene and TCR $\beta$  by two homologous genes.

UCART22 cells are genetically modified to specifically disrupt the T-cell receptor alpha constant (TRAC) gene. The inactivation of the TRAC gene prevents the cell surface expression of the TCR $\alpha\beta$  complex, eliminating TCR-mediated recognition of histocompatibility antigens that can lead to GvHD. At the end of UCART22 manufacturing process, the remaining TCR $\alpha\beta$ + cells are depleted ensuring a residual level of  $\leq 3.0\%$  of TCR $\alpha\beta$ + cells in the final product, as per release criteria.

**CD52 gene knock-out to confer resistance to alemtuzumab**

UCART22 has been engineered to be a mix of CD52<sup>-</sup> and CD52<sup>+</sup> cells allowing the potential use of alemtuzumab in the lymphodepletion regimen before UCART22 administration. Alemtuzumab is a monoclonal antibody that binds to human CD52. The CD52<sup>-</sup> fraction of UCART22 is thus resistant to alemtuzumab.

TALEN<sup>®</sup> technology is used to disrupt both the TRAC and CD52 genes. In the UCART22 production process, the TRAC and CD52 TALEN<sup>®</sup> are introduced into the cells as messenger Ribonucleic Acid (mRNA) using an electroporation system. This transient expression permits TALEN<sup>®</sup> to perform efficient targeted gene knock-out before being degraded by the cells. This approach prevents potential risks associated with long-term expression of nucleases in cells injected into patients.

**B2M gene knock-out to limit alloreactivity of UCART22**

The TALEN<sup>®</sup> technology is used to disrupt both the TRAC and B2M genes. In the UCART22 production process, the TRAC and B2M TALEN<sup>®</sup> are introduced into the cells as messenger Ribonucleic Acid (mRNA) using an electroporation system. This transient expression permits TALEN<sup>®</sup> to perform efficient targeted gene knock-out before being degraded by the cells.

## EXAMPLES

Sources of T-cells used in non-clinical studies (pharmacology and toxicology)

A description of the cell products utilized in the non-clinical studies is summarized in Table .

Table C Engineered T-cells used in in vitro and in vivo preclinical studies.

Cells	Description	Process	Comments
NTD T-cells	Non transduced T-cells	- Non transduced - Non electroporated	Unmodified T-cells
NTD DKO T-cells	Non transduced double KO T-cells	- Non transduced - TRAC and CD52 TALEN® mRNA electroporation - Purification of TCRαβ-cells	Non transduced TCRαβ-_CD52- T-cells
NTD DKO T-cells	Non transduced double KO T-cells	- Non transduced - TRAC and B2M TALEN® mRNA electroporation - Purification of TCRαβ-cells	Non transduced TCRαβ-_MHCI- T-cells
UCART22 cells	Transduced double KO T-cells	- LV-RQR8-2A-CD22CAR transduction - TRAC and CD52 TALEN® mRNA electroporation - Purification of TCRαβ- cells	TCRαβ-_CD52- transduced with the rLV encoding the CD22CAR and RQR8 and purified for TCRαβ-deficient cells
UCART22 cells	Transduced double KO T-cells	- CD22CAR transduction - TRAC and b2M TALEN® mRNA electroporation - Purification of TCRαβ- cells	TCRαβ-_MHCI- transduced with the AAV6 encoding the CD22CAR (R2) or AAV6 encoding CD22 CD19CAR and purified for TCRαβ-deficient cells
UCART22 /19 cells	Transduced double KO T-cells	- CD22CD19CAR transduction - TRAC and b2M TALEN® mRNA electroporation - Purification of TCRαβ- cells	TCRαβ-_MHCI- transduced with the AAV6 encoding the CD22CD19CAR and RQR8 and purified for TCRαβ-deficient cells

5 DKO: double KO, KO: knock-out, rLV: recombinant lentiviral vector

MHCI major histocompatibility classI

B2m beta2 microglobulin

### Summary

10 UCART22 activation is driven by contact between the anti-CD22 Chimeric Antigen Receptor (CD22CAR) and the CD22 antigen leading to the destruction of CD22+ B-ALL cells through T-cell mediated cytotoxicity and potentially pro-inflammatory cytokine production.

Proof of concept studies performed during the development of other UCART products (UCART19 and UCART123) demonstrated that UCART cells (TCR $\alpha\beta$ -deficient CAR T-cells) are as active as non gene-edited CAR T-cells (TCR $\alpha\beta$ -positive CAR T-cells) in vitro and in vivo in tumor xenograft models in NSG mice (Poirot et al., 2015). This was verified for TCR $\alpha\beta$ -deficient CD22 CAR T-cells and for TCR $\alpha\beta$ -deficient, MHC I deficient CD22 CAR T-cells as compared to TCR $\alpha\beta$ -positive CD22 CAR T-cells.

5 In vitro pharmacology studies performed during UCART22 non-clinical development are summarized in Table . Studies have demonstrated:

- The anti-tumor activity of UCART22 through CD22 antigen-dependent cytotoxicity and cytokine secretion assays. Activity assays were performed against B-ALL cell lines and 10 primary B-ALL samples.
- The efficient TALEN® mediated inactivation of the TRAC and CD52 genes.
- The efficient TALEN® mediated inactivation of the TRAC and beta2microglobulin genes.
- That CD52- T-cells are resistant to alemtuzumab.
- The efficient elimination of RQR8+ cells or R2 CD22CAR+ cells using rituximab.

Table D List of in vitro pharmacology studies.

Study	Method	Cells	GLP	Results
<b>Primary Pharmacology</b>				
Cytotoxicity assay	Flow cytometry	UCART22	No	Cytotoxicity assays using CD22+ cells (B-ALL cell lines or B-ALL primary samples) showed CD22 specific cell killing by UCART22 cells.
		GMP UCART22	Yes	Cytotoxicity assay against a CD22+ tumor cell line will be performed on all GMP batches.
Cytokine secretion assay	ELISA / flow cytometry	UCART22	No	UCART22 cells specifically secrete IFN $\gamma$ in presence of CD22+ tumor cells (B-ALL cell lines or B-ALL primary samples).
		GMP UCART22	Yes	Cytokine secretion assay against a CD22+ tumor cell line will be performed on all GMP batches.
<b>SECONDARY PHARMACOLOGY</b>				
Molecular inactivation of the TRAC and CD52 genes	High throughput sequencing of the TRAC and CD52 loci	T-cells transfected with mRNA encoding TRAC and CD52 TALEN® (GMP grade mRNA)	No	High throughput sequencing of the TRAC and CD52 loci in TALEN® treated T-cells showed high levels of site specific modifications at the TRAC and CD52 loci.
Functional inactivation of the TCR $\alpha\beta$	Flow cytometry analysis	UCART22	No	No upregulation of CD25 and CD69 activation markers in UCART22 following PHA-mediated TCR stimulation.
Resistance to CD8+ cells	Cytolytic assays	B2M +TRAC TALEN® treated T-cells	No	T-cells that contain beta2M gene and TRAC inactivation are not eliminated in the presence of CD8+T cells.
Resistance to alemtuzumab of CD52- cells	CDC assays	CD52 TALEN® treated T-cells	No	T-cells that contain a CD52 gene inactivation are not eliminated in the presence of both alemtuzumab and complement in CDC assays.
Sensitivity of UCART22 to rituximab	CDC assay	UCART22 (development batches)	No	UCART22 cells are eliminated in the presence of both rituximab and complement in CDC assay.

CDC = complement-dependent cytotoxicity, PHA = Phytohaemagglutinin.

In vivo pharmacology studies (summarized in Table ) have demonstrated:

- the anti-tumor activity of UCART22 in vivo against tumor xenografts in immunodeficient mice using a B-ALL cell line. The in vivo activity of UCART22 manufactured under GMP conditions confirmed against a B-ALL cell line.
- the improved anti-tumor activity of UCART22/19 in vivo against tumor xenografts in immunodeficient mice using a B-ALL cell line. The in vivo activity of UCART22/19 and 19/22 manufactured under GMP conditions against a B-ALL cell line.
- the ability of rituximab to eliminate RQR8+ cells in an immunocompetent mouse model.

Table E List of in vivo studies.

Study	Cells	Animal model	Tumor model	GLP study	Results
PRIMARY PHARMACOLOGY					
Anti-tumor activity of UCART22	UCART22	Tumor xenograft model in NSG mice	B-ALL cell line (Daudi)	No	In vivo studies performed to demonstrate the anti-tumor activity of UCART22 against a B-ALL cell line. Read-out: - tumor burden (by in vivo bioluminescent imaging) - survival of the mice
				GLP-like	A confirmatory study is being performed with GMP UCART22 to demonstrate activity in vivo.
SECONDARY PHARMACOLOGY					
Sensitivity of RQR8+ cells to rituximab	mouse splenocytes transduced with a retrovirus encoding the RQR8-2A-CD19 CAR construct	C57BL/6 x Balb/c (F1) mice		No	POC study demonstrating efficient rituximab-induced depletion of RQR8+ cells in blood, spleen, bone marrow and lymph nodes. Study published in Philip et al., 2014.

To demonstrate the activity of UCART22 cells, CAR driven cytotoxicity and cytokine secretion assays were performed against tumor cell lines and primary B-ALL cells.

## 5 UCART22 activity evaluated by cytotoxicity assays

Cytotoxic activity against B-ALL cell lines

The potential cytotoxicity of UCART22 was evaluated against several tumor cell lines derived from child or adult B-ALL patients (Table F). The results show that MHH-CALL-4, MUTZ-5, SEMK2, PALL-2, LAX2, BALL-1, NALM-6 and RS4;11 are all CD22+ cell lines expressing different levels of CD22. Two

10 Acute Myeloid Leukemia (AML) cell lines (OCI-AML2 and MOLM13), that do not express CD22, were used as negative controls.

Table F Characteristics of the cell lines.

Cell line	Provider	Reference	Type of disease	CD22 expression
BALL-1	DSMZ	ACC 742	B-ALL (complex karyotype)	+
LAX2	M. Muschen		B-ALL (Ph-positive)	+
MHH-CALL-4	DSMZ	ACC 337	B-ALL (Ph-like)	+
MUTZ-5	DSMZ	ACC 490	B-ALL (Ph-like)	+
NALM-6	ATCC	CRL-3273	B-ALL (t(5;12))	+
PALL-2	JCRB	JCRB1345	B-ALL (Ph-positive)	+
RS4;11	ATCC	CRL-1873	B-ALL (t(4;11) and hyperdiploid)	+
SEMK2	DSMZ	ACC 546	B-ALL (t(4;11))	+
MOLM13	DSMZ	ACC 554	AML	-
OCI-AML2	DSMZ	ACC 99	AML	-

The specific cytotoxicity of UCART22 against CD22+ cells is evaluated by measuring the viability of CD22+ target cells after co-culture with UCART22 cells. Non-transduced (CAR-) TRAC and CD52

5 double KO T-cells are used as a control to calculate the percentage of specific cell lysis of target CD22+ B-ALL cells by UCART22. **Error! Reference source not found.** show the cytotoxic activity of UCART22 cells against a panel of CD22+ B-ALL tumor cell lines. UCART22 shows specific cell lysis activity against all cell lines expressing CD22, even at the lowest levels.

#### 10 Cytotoxic activity against primary B-ALL samples

The cytotoxic activity of UCART22 was confirmed against several primary B-ALL samples. The characteristics of the primary samples are presented in Table G. Only patient samples with greater than 50% blasts were used for the co-incubation studies, which accounted for 14 of the 19 samples.

Table G ALL primary samples evaluated in preclinical studies. ND: non determined

ID	Name	Age/Sex	Cytogenetic abnormalities	Mutations	Clinical Status	% Blasts	% CD22+ Blasts
Pt1	PB6265310	24/M	CRLF2+ AND PH+	JAK2R683G, EZH2	Diagnosis	84	ND
Pt2	PB6296870	69/F	Ph-like ALL (CRLF2+)	TP53	Diagnosis	17	92.3
Pt3	PB3882028	29/M	Ph-like ALL (CRLF2+)	No mutations	Relapse	32	58.7
Pt4	PB6232236	21/M	Ph-like (IGH-CRLF2)	JAK2R683S	Relapse	65	94.7
Pt5	PB6304576	68/M	NOT CRLF2+, NOT Ph+	TP53, IDH2	Diagnosis	69	25.7
Pt6	PB6352880	81/M	Ph+ ALL	No mutations	Diagnosis	48	86.5
Pt7	PB6351838	56/F	Ph+ ALL	No mutations	Diagnosis	68	90.2
Pt9	PB6268010	21/M	NOT CRLF2+, NOT Ph+, trisomy 4	No mutations	Diagnosis	60	92.0
Pt10	BM6301348	69/F	Ph-like ALL (CRLF2+)	NRAS, EZH2	Relapse	93	84.3
Pt11a	PB6301394-1	55/F	Ph-like ALL (CRLF2+)	No mutations	Diagnosis	75	89.7
Pt11b	BM6301394-2	55/F	Ph-like ALL (CRLF2+)	No mutations	Diagnosis	91	98.1
Pt12	PB6300308	22/M	Ph+ ALL	No mutations	Diagnosis	79	47.2
Pt13	PB6124238	33/M	t(4;11)	TP53	Relapse	59	80.2
Pt14	PB6309102	54/F	Ph+ ALL	No mutations	Diagnosis	23	83.8
Pt15	PB6269878	68/M	hypodiploid complex cyto	No mutations	Diagnosis	67	67
Pt16	PB6229772	70/M	Complex	TP53	Relapse	51	51
Pt17	BM3748646	39/M	Ph-like	NOT DONE	Diagnosis	90	90
Pt18	BM2820966	65/F	Ph-like (IGH-CRLF2)	IKZF1 deletion	Diagnosis	92	92
Pt19	BM4198594	21/M	Ph-like (IGH-CRLF2+BCR-ABL1)	CRLF2_F232C, ITPKB_P167R, ITPKB_S92SG, PTPN11	Relapse	82.5	82.5

The CD22 and CD19 expression level was also evaluated in all primary B-ALL samples except Pt1. 11 had CD22 surface expression above CD22- controls and 4 B-ALL patient samples showed CD22 surface expression in the range found in B-ALL cell lines (>1000 CD22 molecules/cell). Highly expressing CD22 (> 60 %) also expressed CD19 except for two relapse samples).

Using the same approach as for the cell lines, it the CTL activity against that 8 B-ALL patient samples (greater than 10% specific cell lysis) was confirmed.

#### **Cytokine secretion assay against B-ALL cell lines and primary B-ALL samples**

5 The release of interferon-gamma (IFN $\gamma$ ) and other cytokines by UCART22 cells co-incubated with several cells line or B-ALL patient samples was assessed using the BioLegend Legend PLEX 13-cytokine assay. IFN $\gamma$  was found to have the highest concentration of all detected cytokines (IL-2, IL-4, IL-5, IL-6, IL-9, IL-10, IL-13, IL-17A, IL-17F, IL-21, IL-22 and tumor necrosis factor alpha (TNF- $\alpha$ )) secreted into the media after a 25 hour co-incubation between B-ALL cells and either UCART22 or

10 control T-cells (NTD DKO).

High level of IFN $\gamma$  secretion was observed when UCART22 is co-incubated with both B-ALL cell lines and primary B-ALL samples.

#### **In vitro secondary studies**

#### **TALEN®-induced inactivation of the TRAC, B2M and CD52 genes**

15 The ability to use UCART22 in an allogeneic setting depends on the capacity to prevent the cell surface expression of the TCR $\alpha\beta$ , MHC Cl, eliminating TCR-mediated recognition of histocompatibility antigens that can lead to GvHD and attack by host CD8+ cells. To effectively eliminate TCR $\alpha\beta$  and MHC Cl from the cell surface, TALEN®-mediated gene-editing has been used to inactivate the TRAC and the beta 2 microglobulin gene (B2M), gene. In addition, another TALEN® was used during the

20 manufacturing process of UCART22 to inactivate the CD52 gene allowing the use of alemtuzumab in the lympho-depleting conditioning regimen. In particular settings, the TALEN® was used during the manufacturing process of UCART22 to inactivate the beta 2 microglobulin gene (B2M), to alter major histocompatibility class I (MHC Class I) molecules expression and to prevent rejection by hosts T cells.

#### **Molecular analysis of TRAC, CD52, B2M genes disruption**

25 To demonstrate targeted modifications of the TRAC and CD52 genes at a molecular level, genomic deoxyribonucleic acid (DNA) was isolated from T-cells electroporated with GMP grade TRAC and CD52 TALEN® mRNA or TRAC and B2M TALEN® mRNA and purified for TCR $\alpha\beta$ - cells MHCCI-. The regions around the TRAC, B2M and CD52 TALEN® cleavage sites were amplified by polymerase chain reaction (PCR) and analyzed by Next Generation Sequencing (NGS, Illumina). In control samples, the

30 same analysis was performed with cells removed before electroporation of TALEN® mRNA (at Day 6). This analysis indicates that while control cells at Day 6 did not display any modifications at the TRAC and CD52 loci, a high frequency of modifications were detected in the TALEN®-treated T-cells (Table ).

Table H Percentage of Non-Homologous End Joining (NHEJ) upon TALEN® cleavage at the TRAC and CD52 and B2M loci.

Percentages are determined by NGS in TALEN®-treated T-cells from 3 different batches. Control cells were sampled before TALEN® mRNA electroporation for all batches.

5

Table H

	TRAC		CD52		B2M	
	mean	SD	mean	SD	Mean	SD
Control	0,09	0,08	0,09	0,07	0,09	0,06
TALEN	84,63	5,65	83,26	4,91	89,0	3,88

Further analysis of the sequences indicates that TALEN® induced modifications are located in a small region surrounding the target site with 93-97% of these modifications being deletions. These 10 deletions are generally small, with on average 97% smaller than 150 bp and 81% smaller than 50 bp.

**Functional assay demonstrating TRAC gene disruption in UCART22**

To demonstrate the functional inactivation of TCR $\alpha\beta$ , UCART22 cells were assayed for their ability to express activation markers such as CD25 and CD69 following Phytohaemagglutinin (PHA)-mediated TCR stimulation. UCART22, performed with all the GMP raw materials, T-cells were recovered either

5 before (TRAC) or after (UCART22) depletion of TCR $\alpha\beta$ + cells. Cells were reactivated with 0.5  $\mu$ g/mL PHA during 24h. Expression of activation markers (CD25 and CD69) was measured by flow cytometry. While control TRAC cells (65.2% TCR $\alpha\beta$ -) upregulate CD25 and CD69, no upregulation was observed on UCART22 cells (98.9% TCR $\alpha\beta$ -) confirming the absence of the TCR $\alpha\beta$  receptor in UCART22.

**Resistance to alemtuzumab of CD52- UCART22 cells**

10 The ability to use alemtuzumab, an anti-CD52 monoclonal antibody, in the lymphodepletion regimen depends on the effective elimination of the CD52 glycoprotein from the cell surface of UCART22 cells to prevent their elimination by alemtuzumab. UCART22 are thus engineered, using CD52 TALEN®, to be a mix of CD52+ and CD52- cells. Flow cytometry analysis performed with development batches of UCART22 at the end of manufacturing process indicate that on average 72% of the T-cells (CD45+ /

15 CD4+ or CD8+ cells) are CD52- (range 62.3-76.5%, N=6).

20 To demonstrate that CD52- cells are resistant to alemtuzumab, a complement-dependent cytotoxicity (CDC) assay was performed. Human T-cells containing a TALEN®-mediated CD52 gene inactivation were treated with 50  $\mu$ g/mL of a rat anti-CD52 antibody from which the therapeutic antibody alemtuzumab is derived or rat immunoglobulin G (IgG) as control with or without rabbit complement for 2 hours at 37°C, then analysed by flow cytometry for viability and CD52 expression.

The results show that cells that do not contain a CD52 gene inactivation are specifically eliminated through complement-dependent cytotoxicity in the presence of alemtuzumab.

**Resistance to host CD8+ T cells**

25 MHC Class I deficient UCART22 cells were resistant to CD8+ T-cell-mediated destruction. Although interferon- $\gamma$  (IFN- $\gamma$ ) treatment significantly induced  $\beta$ 2-microglobulin expression, promoting CD8+ T cell-mediated killing of control UCART22.

**Demonstration of effective depletion of UCART22 following treatment with rituximab**

30 UCART22 are allogeneic T-cells and thus should be eliminated upon recovery of the patient's immune system. In addition, UCART22 are engineered to co-express the CD22CAR and RQR8, a short membrane protein that provides two epitopes that bind rituximab (RTX), a therapeutic monoclonal antibody specific for human CD20. RQR8 provides therefore the possibility of depleting UCART22 through the administration of rituximab.

35 The ability to eliminate UCART22 cells through complement-dependent cytotoxicity (CDC) following treatment with RTX was examined. Frozen UCART22 (from 5 different development batches) were thawed and co-cultured with Raji CD22+ cells at a 1:0.25 ratio for 3 days. After this reactivation period, the CDC assay was performed (cells were incubated with RTX (100 $\mu$ g/ml) for 2 hours in the presence or absence of baby rabbit complement (BRC)). The results demonstrate that ~85% of CAR+ cells are efficiently eliminated in vitro in the presence of both RTX and complement.

Another mechanism of action for RTX, by which depletion of RQR8+ cells can be achieved, is Antibody-Dependent Cell-mediated Cytotoxicity (ADCC) (Seidel et al., 2013). In this case, effector cells of the immune system (mainly Natural Killer -NK- cells) can actively lyse target cells whose membrane-surface antigens have been bound by a specific antibody.

5 Complementary experiments have been published by Martin Pule at UCL (Philip et al., 2014) demonstrating effective in vitro mediated elimination of RQR8+ T-cells by CDC and ADCC (primary human T-cells transduced with a bicistronic retroviral vector (SFG.RQR8.IRES.eGFP) encoding RQR8 and GFP and selected with Miltenyi QBEnd10 beads). Time course and RTX dose titration demonstrate that CDC is highly effective at RTX concentrations of 25 µg/mL and above, with killing 10 occurring within 30 minutes. Similarly, ADCC mediated sensitivity has been demonstrated for RQR8+ T-cells.

### **In vivo studies**

Rationale for selection of animal species/model

15 Because of the human specificity of UCART22, studies in standard immunocompetent animal models are not applicable due to the rapid targeting and elimination of human UCART22 cells by xenogeneic immune reactions.

Thus, two approaches may be envisaged for in vivo modelling of UCART22 activity: syngeneic animal models and human tumor xenograft models in immunodeficient animals.

20 A syngeneic animal model approach would involve the re-creation/re-development of a species specific-version of UCART22 for a model organism, followed by assessment of the functional properties of this species-specific UCART22 surrogate product when engrafted in a syngeneic host. This approach is not considered relevant due to the fact that the properties of individual CARs vary considerably, and because species-specific differences in immune function, physiology, and genetics significantly compromise extrapolation of activity of UCART22 in humans.

25 The immunodeficient murine xenograft model was chosen as it allows the engraftment of both UCART22 and human tumor CD22+ cells (B-ALL cell lines or primary samples). This animal model has been extensively used for the assessment of in vivo activity of CAR T-cell therapies. While these models have the same limitations as the above immunocompetent models with respect to on-target/off-tumor cytotoxicity and off-target cytotoxicity, and completely eliminate any role of MHC 30 mismatch, they have proven to be extremely useful for assessing in vivo anti-tumor efficacy of CAR T-cells. They have emerged as the de-facto standard for assessment of in vivo activity of CAR T-cell products (see for example in Carpenito et al., 2009; Gade et al., 2005; Gill et al., 2014; Hudecek et al., 2010; Kenderian et al., 2015; Mardiros et al., 2013; Zhou et al., 2013 among many published articles). They have proven capable of discriminating the relative anti-tumor activity of different CARs, 35 highlighting their capacity to capture and semi-quantitatively read out useful human in vivo T-cell functions (see for example Milone et al., 2009). Thus, human CD22+ tumor cells have been engrafted into immunodeficient mice (NSG mice) followed by administration of UCART22, with serial assessment of the tumor burden and survival time as an index of anti-tumor activity.

### Selected tumor models

With respect to the tumor xenografts, UCART22 activity in vivo has been evaluated against Daudi cells, a CD22+ B-ALL cell line (CCL-213, ATCC). The cell line has been modified to express the firefly luciferase (and GFP) by transduction with a lentiviral vector (amsbio LVP438-PBS) in order to follow 5 the tumor burden by in vivo imaging (Daudi-Luc-GFP cells).

### Selected mouse strains

The mouse strains used in the in vivo non-clinical studies were:

- 1/ Highly immunodeficient NSG mice (NOD.Cg-Prkdcscid Il2rgtm1Wjl/SzJ; The Jackson Laboratory strain #5557) lacking mature T cells, B cells and functional NK cells to demonstrate the anti-tumor 10 activity.
- 2/ An immunocompetent mouse model (C57BL/6 x Balb/c (F1) mice) to demonstrate the efficacy of the RQR8 depletion or R2 CD22CAR mechanism.

### Methods of Analysis

The activity of UCART22 in vivo was evaluated using:

- 15 - bioluminescence measurement of treated mice in respect to the control group (for the xenograft model with cell lines expressing the luciferase),
- clinical signs,
- overall survival of the mice.

### Route of Administration

20 The route of administration of UCART22 in animals is the intravenous injection (single non-split dose). In human, UCART 19 and UCART 22 were also injected intravenously (non-split dose), once twice or three or four times, alone or one after the other one according to the following succession 19. 22 19 22 19 or 22 19 22 19 or 19/22 19/22.

### Demonstration of anti-tumor activity in vivo of UCART22

25 UCART22 activity was demonstrated in immunodeficient mice engrafted with Daudi-Luc-GFP human tumor cells with several development batches of UCART22. An example of a study is shown Figure 8. In addition, a confirmatory study is ongoing to evaluate the in vivo activity of a GMP batch of UCART22.

30 Briefly, NSG mice were intravenously injected with 0.5x10<sup>6</sup> Daudi-Luc-GFP cells at Day -7 and treated at Day 0 with UCART22 (intravenous injection, 2 doses: 3x10<sup>6</sup> and 10x10<sup>6</sup> UCART22 cells / mouse, 5 mice / group) or left untreated (vehicle injection). Non-transduced T-cells double KO for TRAC and CD52 (NTD DKO) were injected as a control. The UCART22 doses administered were determined according to the doses of CAR+ T-cells used in the literature to demonstrate anti-tumor activity in vivo of other CD22CAR T-cells (Haso et al., 2013). UCART22 treatment resulted in the elimination of 35 the tumor cells, as shown by in vivo imaging, and extended survival, with all the treated mice alive at the end of study (80 days post-UCART22 treatment). Those results demonstrated the anti-tumor activity of UCART22.

**CD52- cells are resistant to alemtuzumab in vivo and CD52- CAR+ T-cells show activity in vivo in presence of alemtuzumab**

Studies performed during the development of UCART19, another UCART product containing the same TRAC/CD52 double knock-out, demonstrated that CD52- T-cells are resistant to alemtuzumab in vivo (Poirot et al., 2015).

In addition, the activity of UCART19 cells in presence of alemtuzumab was demonstrated in a tumor xenograft model in NSG mice. All mice receiving tumor cells but no UCART19 cells showed tumor progression leading to their sacrifice by 13 days post-injection. In 5 out of 7 mice receiving tumor and UCART19 cells, the tumor was completely controlled at day 13 and in the remaining two mice, partial

10 responses were observed. In contrast, alemtuzumab treatment was observed to only delay progression of the tumor without UCART19 cell infusion (6/6 mice). In mice treated with alemtuzumab combined with UCART19 cells, the tumor cells were eliminated from the bone marrow, as assessed by luminometry or flow cytometry of cell suspensions obtained from bone marrow isolated at 13 days post-injection.

15 In conclusion, the mice that received alemtuzumab therapy 2 days before infusion of UCART19 cells, demonstrate anti-tumor efficacy of the UCART19 cells in the presence of alemtuzumab in vivo. In addition, spleen engraftment data at Day 13 show that CD52- T-cells are resistant to alemtuzumab in vivo.

**Demonstration of effective rituximab-induced depletion of RQR8+ cells in vivo**

20 The susceptibility of RQR8+ UCART22 to RTX depletion has been previously shown in vitro. Moreover, Martin Pule's group has shown that RTX was able to eliminate RQR8+ cells in an immunocompetent mouse model using a re-engineered RTX to a mouse IgG2a, the functional equivalent of human IgG1 (mRtx-IgG2a) (Philip et al., 2014). This antibody has been adapted for use in murine systems by transfer of the binding portions of RTX to a murine Fc allowing binding to murine Fc receptors with 25 an affinity approximating that with which RTX binds to human Fc receptors. The study was performed using an immunocompetent haploidentical adoptive transfer model with RQR8 transduced C57BL/6 splenocytes transferred to non-lethally irradiated C57BL/6 x Balb/c cross (F1) recipients. This model allows good engraftment levels in all lymphoid tissue sustained by allogeneic stimulation, but also preserves endogenous lymphocytes.

30 At Day 1, 1.5x10<sup>6</sup> RQR8+ donor splenocytes from C57BL/6 mice (splenocytes transduced using a retrovirus encoding a RQR8-2A-GD2CAR construct and purified using Miltenyi CD34 beads) were intravenously injected into F1 mice (C57BL/6 x Balb/c), 4 hours after a 5Gy X-ray irradiation pre-conditioning. On Day 7, the engraftment of donor cells has been confirmed by flow cytometry in the 35 peripheral blood. Mice were treated three times with murinized RTX (ritux-mIgG2a 150µg, intravenously injected by tail vein, at Day 7, Day 10 and Day 12) or PBS (untreated). Each cohort had 5 mice. Animals were sacrificed at Day 14 for flow cytometry analysis of the spleen, the bone marrow, the blood and the lymph nodes. In the RTX-treated mice, 50, 60 and 70% depletion of RQR8+ cells were observed in spleen, bone-marrow and blood respectively within 6 hours post ritux-mIgG2a therapy of the mice.

The same study was also performed with the anti-CD19 CAR used in the UCART19 product. UCART19 is also an allogeneic engineered CAR T-cells product containing the same RQR8 construct as UCART22.

## 5 REDOSING

This study assessed anti-tumor activity of single or multiple injections of UCART22. A B-ALL tumor cell line expressing CD22 (Daudi expressing high level of CD22). Cells were transduced with a lentiviral vector in order to express the GFP and the firefly luciferase.

10 Tumor cells (0.5x10<sup>6</sup> Daudi-Luc-GFP) have been intravenously injected on Day -7 to NSG mice (NOD.Cg-Prkdcscid Il2rgtm1Wjl/SzJ, strain 005557, The Jackson Laboratory) via the tail vein. At Day 0, mice were randomized according to the bioluminescence signal measured at Day -1 and body weight into 11 groups of 6 mice.

15 1, 2 or 3 treatments of UCART22 (at 1 or 3 million of CAR+ cells / mouse) were administered. UCART22 was intravenously injected to mice on Day 0 +/- Day 10 +/- Day 20.

20 Anti-tumor activity of UCART22 was evaluated by the tumor burden followed by bioluminescence imaging on Day -1, Day 7, Day 14, Day 21, Day 28 and Day 35, observation of the clinical signs and survival of the mice.

Daudi model, treatment at 1 x 10<sup>6</sup> UCART22 cells/ mouse

25 Mice treated 2 or 3 times with 1 x 10<sup>6</sup> UCART22 show a better control of the tumor progression and longer survival compared to mice treated once with 1 x 10<sup>6</sup> UCART22 (80% survival at day 60 for 3 doses over 0% for one dose).

In one experiment UCART19 was intravenously injected to mice on Day 30. In these mice still alive, the level of cancer cells was below detection at day 90.

## SUMMARIES

The activity of UCART22 was demonstrated in vitro and in vivo against B-ALL cell lines and in vitro against primary B-ALL samples.

30 UCART22 are allogeneic T-cells and thus should be eliminated upon recovery of patients' immune system. In addition, UCART22 are engineered to co-express RQR8, a short membrane protein that provides two epitopes that bind to the monoclonal antibody rituximab. RQR8 provides therefore a means to deplete RQR8+ UCART22 by administration of rituximab in the event of a non-manageable UCART22-related toxicity such as Cytokine Release Syndrome (CRS) or GvHD or prior to allo-HSCT.

35 The effectiveness of rituximab to eliminate RQR8+ cells in vitro was demonstrated using CDC and ADCC assays. Furthermore, the efficiency of the rituximab-induced depletion of RQR8+ cells was demonstrated in vivo in blood, spleen, bone marrow and lymph nodes using an immune-competent mouse model and a murinized version of the rituximab.

40 Similar results were obtained using R2 or QR3 anti-CD22 CAR expressed in TCR-deficient MHC CI - deficient T cells.

The resistance to alemtuzumab of CD52- cells was demonstrated in vitro and in vivo allowing the potential use of alemtuzumab in the lymphodepleting regimen.

Lastly, resistance to CD8+ T-cell-mediated destruction was observed using R2 - anti-CD22 CAR expressed in TCR-deficient MHC Cl -deficient T cells.

Additional studies performed to evaluate various risks are summarized in

5 Table and Table and detailed in sections below.

**Table I List of in vitro toxicology studies performed.**

Study	Test item	Method	GLP/ GMP study	Results
TALEN® persistence	T-cells transfected with mRNA encoding TRAC and CD52 or B2M TALEN® (GMP mRNA)	Western blot	No	Experiments examining the persistence of TALEN® proteins within primary human T-cells have shown that high levels of TALEN® proteins are detected only within the first 24h post electroporation.
Off-target cleavage induced by TALEN®	T-cells transfected with B2M, TRAC CD52 TALEN® alone or combined	Guide Sequencing	No	GUIDE sequencing was performed to identify potential off-target sites by an unbiased genome wide analysis.
	UCART22	High throughput sequencing	No	High throughput sequencing of TRAC and CD52 TALEN®-treated human T-cells confirmed an extremely low frequency (2.1 - 3.9 x 10-3) of modifications at three of the putative off-target sites identified by the GUIDE-seq method.
	UCART22		GMP	The level of modifications at the three confirmed off-target sites will be evaluated on all the GMP batches.
Genetic stability	UCART22	Karyotype/ FISH analysis	No	Karyotyping and FISH analysis have been performed on development batches of UCART22 to evaluate the frequency of translocations.
	UCART22		GMP	Karyotyping will be performed in GMP on all the GMP batches as a release criterion. FISH analysis will be performed if translocations are detected by karyotyping.
	UCART22	IL-2 independent proliferation assay	No	No IL-2 independent proliferation after 18 days in culture was observed in development batches of UCART22 evaluated.
	UCART22		GMP	The IL2-independent proliferation release test aiming to detect any clonal advantage triggered by genes modifications will be performed on all the GMP batches as a release criterion.
	UCART22	qPCR	GMP	Vector copy number will be measured in all the GMP batches.
Tissue cross-reactivity	Fusion peptide scFv-	Immuno-histo-	GLP	In the human tissue panel, specific, plasma membrane scFv-CD22(971)-CD8-mFc binding

γ assay	CD22(m971)-CD8-mFc: m971scFv-CD8 hinge-mouse IgG1 Fc fragment	chemical analysis against a panel of human tissues		was observed in lymphoid follicle compartments of lymphoid organs and within lymphoid mucosal aggregates/infiltrates of several other tissues. Based on morphology and distribution, the targeted cells were generally consistent with B lymphocytes. There was no significant unexpected off-target binding of scFv-CD22(971)-CD8-mFc in human tissues.
Retrogenix		Cell microarray technology	No	The binding specificity of the scFv-CD22(m971)-CD8-mFc fusion protein is under evaluation using the Retrogenix platform.

Table J List of in vivo toxicology studies.

Study	Test item	Animal model	GLP study	Results
Potential GvHD	UCART22 and Previous UCART products (UCART19 and UCART123) or unmodified T-cells (NTD) in control	NSG mice irradiated at 2 Gy, 1 day before T-cells injection	GLP-like	All mice injected with TCRαβ-positive unmodified T-cells showed treatment-related changes considered probably suggestive of GvHD (weight loss and histopathological changes) with dose-relationship in severity and time of onset. But, UCART products did not elicit any sign of GvHD in the selected model and during a follow-up period of up to 80 days.

5 The potential risk of GvHD, was assessed in immunodeficient mice during the development of previous UCART products. This animal model allows the efficient engraftment of human T-cells and has been previously shown to consistently develop xenogeneic GvHD following injection of human PBMCs or T-cells (Ali et al., 2012; Schroeder and DiPersio, 2011).

#### Off target activity of the CD22 CAR

10 The CD22 specificity of the CD22CAR was evaluated through a GLP-compliant tissue cross-reactivity study showing no significant unexpected off-target binding of the scFv component of the CD22CAR with human tissues and a Retrogenix screen is ongoing. Moreover, published clinical data on patient treated with m971 derived CAR T-cells showed no off-target toxicity (Fry et al., 2017).

As CD22 is expressed on normal B-cells, a risk of B-cell aplasia, resulting from on-target/off-tumor activity of UCART22, is anticipated as long as UCART22 will persist.

#### **GVHD of the UCART 22 CAR**

An essential safety feature of UCART22 product is whether the potential of the UCART22 to mediate a GvH reaction has been abrogated by disruption of the TRAC gene and purification of TCR $\alpha\beta$ - cells. This risk was assessed during the development of previous UCART products (UCART19 and UCART123) in in vivo preclinical studies. GvHD signs were observed in all NSG mice injected with unmodified T-cells with more severe findings at the highest dose, but no treatment related changes were observed in mice injected with UCART. In clinic, so far, among the fourteen patients treated with UCART19, four of them developed a skin GvHD which was mild to moderate (3 Grade 1 and 1 Grade 2 (Qasim et al., 2017) and data presented at ASH meeting 2017 by R. Benjamin et W. Qasim) and manageable without systemic treatment.

#### **CRS**

Other potential safety risks associated with administration of immunotherapy products and with underlying treated disease have been identified: infusion related reaction, cytokine release syndrome (CRS), tumor lysis syndrome, infections and neurotoxicity. CRS is a frequent adverse event in immunotherapy and especially in CAR T-cells trials. In autologous anti-CD19 CAR T-cells clinical trials, the intensity of the cytokine release observed was a result of a combination of several parameters such as the dose of CAR T-cells injected, the signaling domains of the CARs (4-1BB/CD28), the level of proliferation of the CAR T-cells and the tumor burden of the patient at the day of administration. These risks are evaluated in vivo in a model closed to that recently published (Taraseviciute, A., Kean, L., & Jensen, M. C. (2016). Creation of the First Non-Human Primate Model That Faithfully Recapitulates Chimeric Antigen Receptor (CAR) T Cell-Mediated Cytokine Release Syndrome (CRS) and Neurologic Toxicity Following B Cell-Directed CAR-T Cell Therapy. *Blood*, 128(22), 651. Accessed March 28, 2018. Retrieved from <http://www.bloodjournal.org/content/128/22/651>).

#### **Starting dose recommendation for FIH studies**

The standard methods for clinical dose determination are not transposable for CAR T-cell-based immunotherapy, due to the limited relevance of animal model(s), the biodynamic nature of the product and the immune-adoptive mechanism of action.

Therefore, the choice of the starting clinical dose has been mainly based on (i) previous experience gained with CAR T-cells administered in humans (literature on autologous CAR T-cells); (ii) the compassionate cases and patients treated in the ongoing clinical studies with UCART19 at University College London (UCL) and King's College London (KCL) (refer to (Qasim et al., 2017) and the presentations by R. Benjamin and W. Qasim at the ASH meeting 2017) and (iii) the doses currently investigated or approved in other B-ALL autologous CAR studies. The approach is described in the clinical section.

The first results of clinical studies show a huge debulking of tumoral mass in both assays, (>80%) in patients treated with UCART22. Further, the data are demonstrating

that even short but efficient treatment (from two doses) can interrupt and free from malignant B cell, (73% remission at 150 days) especially after redosing and/or use of UCART22 and 19.

**CLAIMS**

1. An engineered human T Cell Receptor Knock Out (TCR KO) cell endowed with a Chimeric Antigen Receptor (CAR) specific for CD22 (UCART 22), a safety switch, preferably expressed at the cell surface, said anti-CD22 CAR (CD22 CAR) comprising:

5        i) at least one extracellular domain comprising :  
          - a hinge domain from CD8alpha,  
          - an antigen binding domain specific for CD22, optionally a leader sequence,  
ii) a transmembrane domain from CD8alpha, and  
iii) an intracellular signaling domain said CD22 CAR having a polypeptide sequence with  
10      at least 80% identity with SEQ ID N°15,

said safety switch comprising :

- a RQR8 temporarily linked to the CD22 CAR by a peptide 2A, or
- at least two rituximab mAb-specific epitopes, preferably located between the VH and the Hinge domain, or 3 rituximab mAb-specific epitopes or 3 rituximab mAb-specific epitopes and a QBEN-10 mAb-specific epitopes linked to the CD22 CAR.

15      2. The UCART 22 of claim 1 wherein a polynucleotide sequence having at least 80% identity with SEQ ID N°11 is inserted into the genome, and further comprising an inactivated TRAC gene with an insertion, a deletion or a mutation within SEQ ID N°18, with

20      undetectable level of T Cell Receptor (TCR) at the cell surface as measured by flow cytometry, and undetectable level of off site events as measured by guide sequence technique.

25      3. The UCART22 according to claim 2 wherein said anti-CD22 CAR is inserted preferably into the TRAC gene, preferably with SEQ ID N°18.

4. The UCART22 according to any one of claim 1 to 2 comprising another inactivated gene selected from dCK gene, B2M gene, CD52 gene, preferably CD52 gene.

5. The UCART22 according to any one of claim 1 to 4 wherein and at least one additional gene is inactivated, said gene is selected from a gene encoding aryl hydrocarbon receptor

(AHR), Transforming growth factor beta receptor) (TGF beta receptor), Interleukin 10 receptor (IL-10 R), Program cell death protein 1, a combination thereof.

6. The UCART22 according to any one of claim 1 to 5 comprising an additional scfv specific for any one of the following tumor-associated surface antigens selected from CD19, CD20,

5 CD30, a major histocompatibility complex (MHC) molecule, an Immunoglobulin (Ig), CD3, CD5, CD34, CD79, preferably CD79b, CD138, B7-1 (CD80), BCMA (CD269, TNFRSF 17), FLT-3, or PAX5, preferably CD19.

7. The UCART22 according to any one of claim 1 to 6 wherein said CD22CAR further

10 comprises an antigen binding domain specific for CD19 or wherein said UCART 22 further comprises a CD19CAR, preferably a CD19 CAR having at least 80% identity with SEQ ID N°25 or a SEQ ID N°26.

8. The UCART22 according to any one of claim 1 to 7 wherein the anti-CD22 CAR is a single-chain CAR or a multi-chain CAR.

15

9. The UCART22 according to any one of claim 6 or 7 wherein the anti-CD19 CAR is a single-chain CAR or a multi-chain CAR.

10. A population of UCART cells comprising the UCART 22 according to any one of claim 1 to

20 9.

11. The population of UCART cells according to claim 10 comprising a UCART 19, preferably a UCART19 expressing an anti-CD19 CAR comprising a sequence of SEQ ID N°25 or SEQ ID N°26 at the cell surface.

12. A kit comprising a UCART 22 and a UCART19 for a successive (at least once) or a

25 concomitant or a successive (at least once) and then concomitant administration in a patient in need thereof.

13. The kit of claim 12 wherein the UCART 19 is used first at least once, twice, three, four or several times, and then the UCART 22, alone or with the UCART19.

14. The kit of claim 12 or 13 wherein the UCART 22 is used first at least once, twice, three, four or several times, and then the UCART 19, alone or with the UCART22.
15. The kit according to any one of claim 12 to 14 further comprising a lymphodepleting treatment, administered before the UCART.
- 5 16. The kit according to any one of claim 12 to 15 wherein lymphodepletion is achieved using fludarabine and cyclophosphamide, preferably fludarabine 25 mg/m<sup>2</sup> i.v. × 5 doses on days -6 to -2 and cyclophosphamide 60 mg/kg i.v. for 1 dose on day -5.
- 10 17. The kit according to any one of claim 12 to 16 comprising at least one other UCART cell directed against a cancer antigen selected from CD79a, CD79b, CD20, CD30, CD52, CD40, CD80, CD86, CD74, VEGF.
18. A pharmaceutical composition comprising the UCART 22 according to any one of claim 1 to 9 or a population of cells comprising said UCART 22 according claim 10 or 11 and a pharmaceutically acceptable excipient.
19. The pharmaceutical composition of claim 18 further comprising a Bryostatin, preferably Bryostatin-1.
- 15 20. The pharmaceutical composition of claim 18 or 19 or the kit according to any one of claim 12 to 17 for its use as a medication for preventing or treating a patient suffering a CD22+-mediated cancer or a CD22+-mediated inflammatory disease.
21. The pharmaceutical composition of according to any one of claim 18 or 19 or the kit according to any one of claim 12 to 17 for its use as a medication for preventing or treating a patient suffering a CD19+-mediated cancer or a CD19+-mediated inflammatory disease.
- 20 22. The pharmaceutical composition of according to any one of claim 18 or 19 or the kit according to any one of claim 12 to 17 for its use as a medication for preventing or treating a patient suffering a CD19+CD22+-mediated cancer or a CD19+CD22+-mediated inflammatory disease.
- 25 23. The pharmaceutical composition of according to any one of claim 18 or 19 or the kit according to any one of claim 12 to 17 for its use according any one of claim 20 or 22, wherein treating a patient comprises a step of administering the pharmaceutical

composition at least twice (re dosing) to avoid a relapse /refractory development of the cancer.

24. The pharmaceutical composition of according to any one of claim 18 or 19 or the kit  
5 according to any one of claim 12 to 17 for its use according any one of claim 20 or 22, for the treatment of a CD22-mediated hematological cancer selected from lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, preferably a CD22 expressing  
10 hematological cancer selected from (lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, more preferably a relapse refractory CD22-expressing hematological cancer, even more preferably an aggressive form of said CD22-related  
15 hematological cancer.

25. The pharmaceutical composition of according to any one of claim 18 or 19 or the kit according to any one of claim 12 to 17 for its use according any one of claim 21 or 22 for the treatment of a CD19-mediated hematological cancer selected from lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, preferably a CD19 expressing  
20 hematological cancer selected from (lymphoma, Hodgkin lymphoma, non Hodgkin lymphoma, leukemia, multiple myeloma, B-chronic lymphocytic leukemia, hairy cell leukemia, acute lymphocytic leukemia (ALL), and Burkitt's lymphoma, acute lymphocytic cancer, acute myeloid leukemia, more preferably a relapse refractory CD19-expressing hematological cancer, even more preferably an aggressive form of said CD19-related  
25 hematological cancer.

30 26. The pharmaceutical composition of according to any one of claim 18 or 19 or the kit according to any one of claim 12 to 17 for its use according any one of claim 20 to 23 for the treatment of a relapse or refractory expressing B ALL, preferably as a pediatric indication.

27. The pharmaceutical composition of according to any one of claim 18 or 19 or the kit according to any one of claim 12 to 17 for its use according any one of claim 20 to 26, wherein treating a patient comprises administering at least one monoclonal antibody (mAb),

5 preferably QBEN 10 and or Rituximab, in a patient, at a dose allowing contacting said UCART22 with at least one specific mAb.

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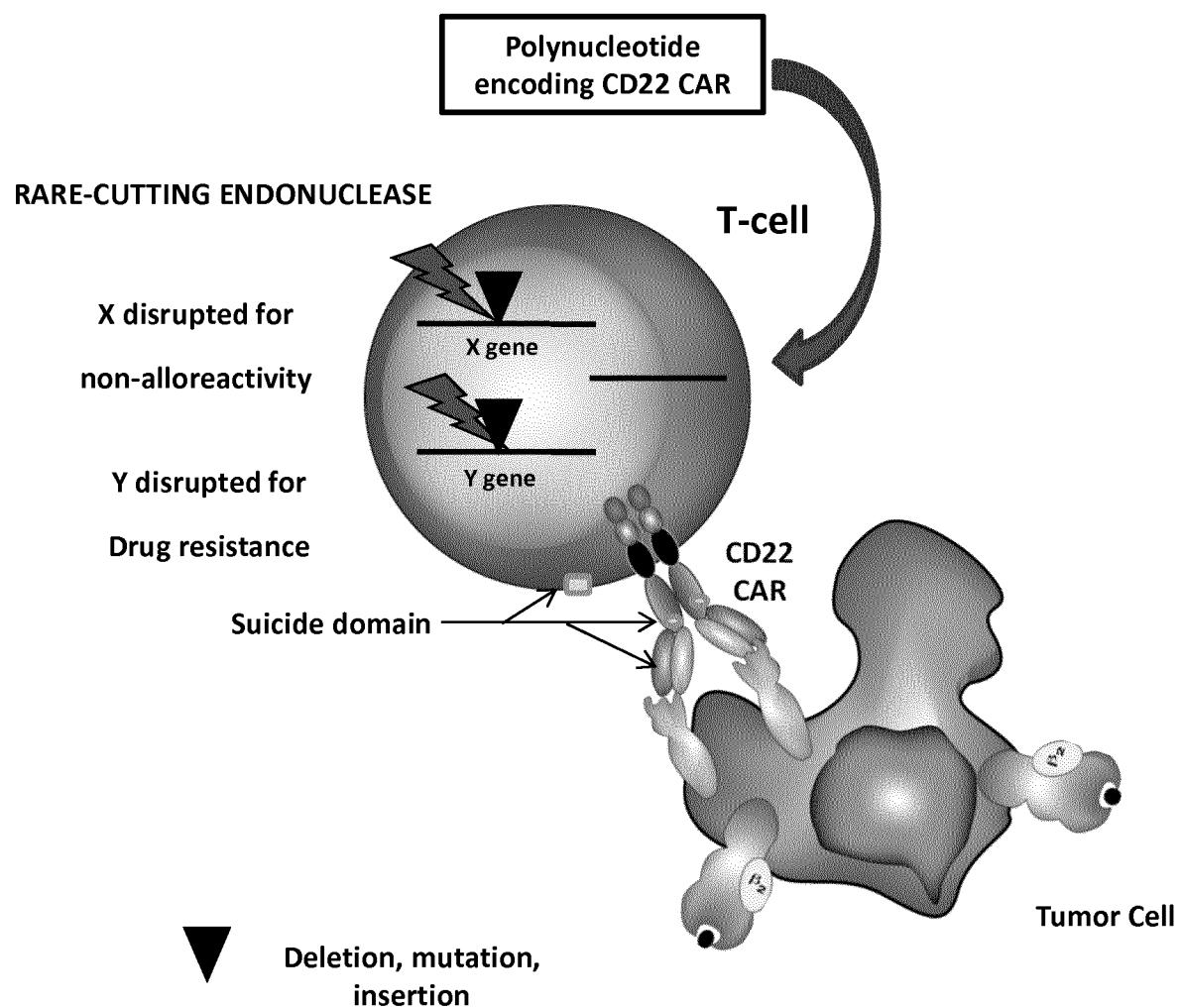
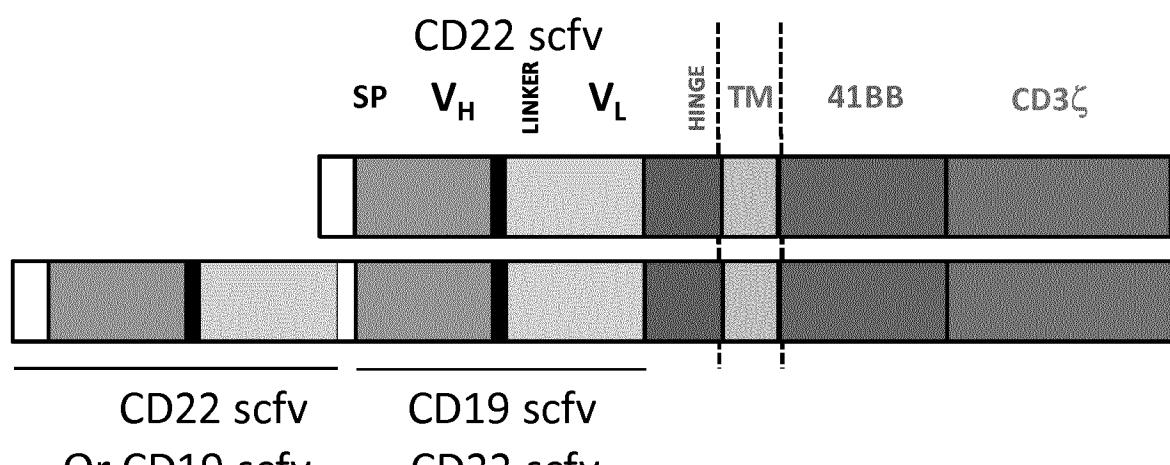


Figure 1

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## Single chain anti-CD22 and/or CD19 CAR



## Multi-chain anti-CD22 or -22/19 CAR

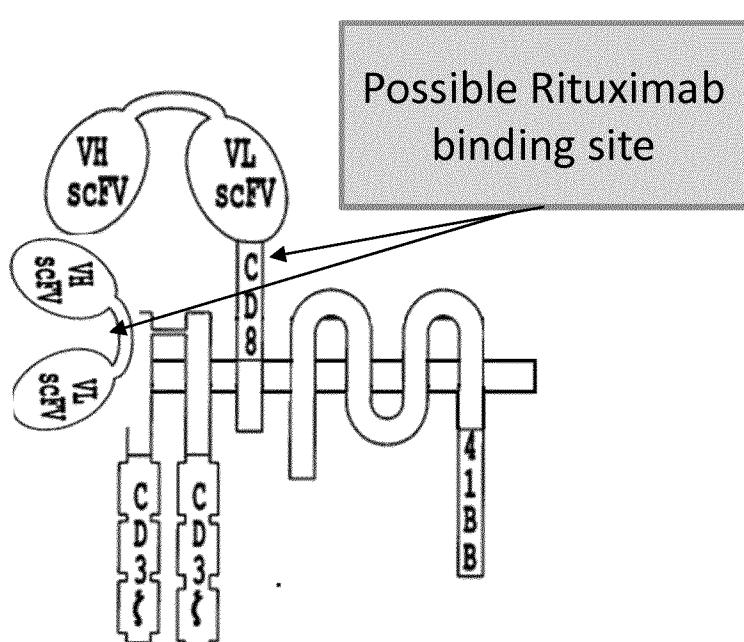


Figure 2

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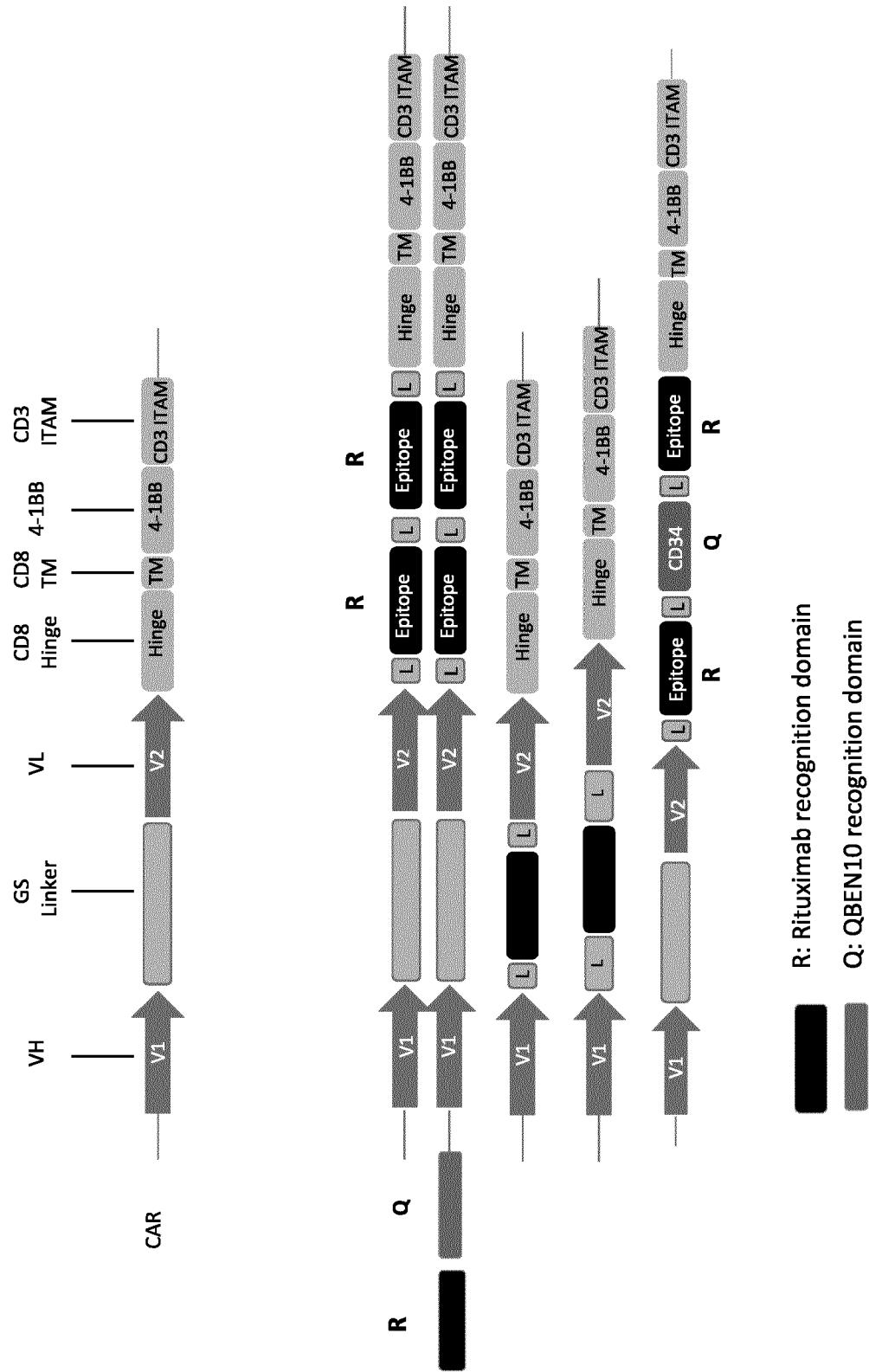


Figure 3

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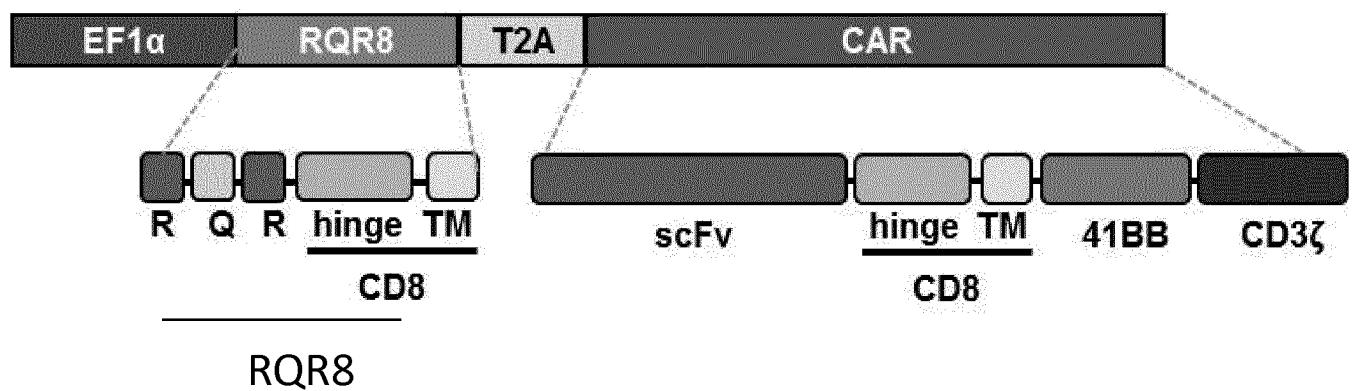


Figure 4

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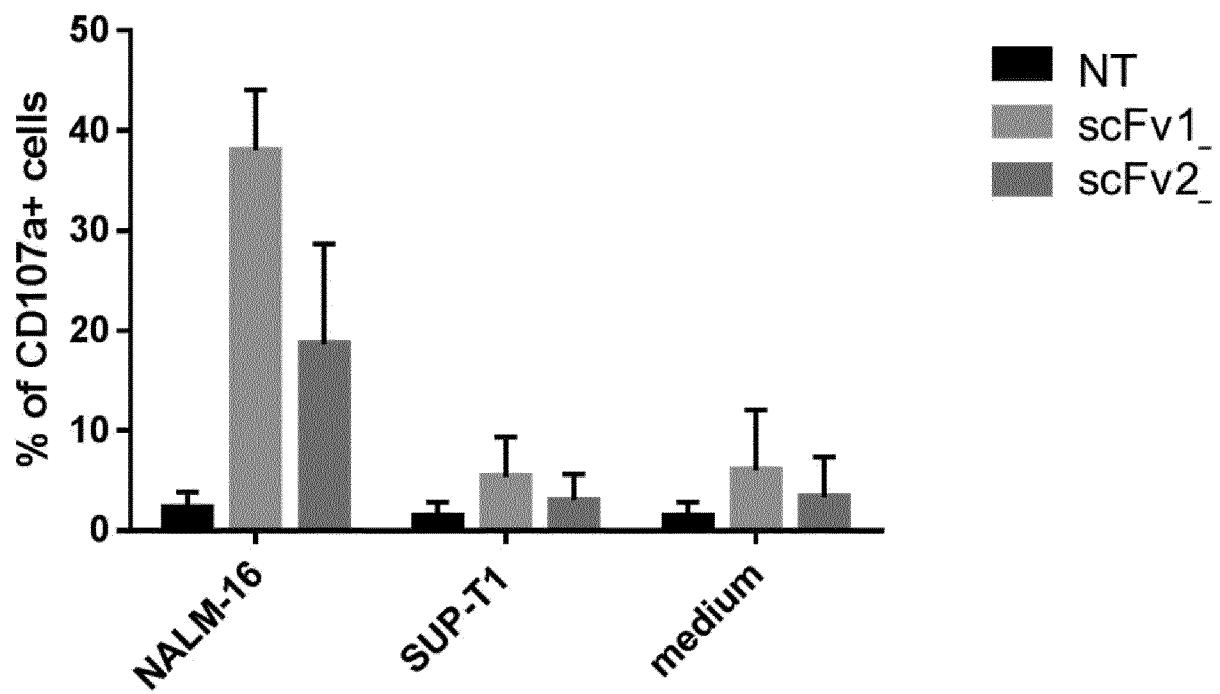


Figure 5

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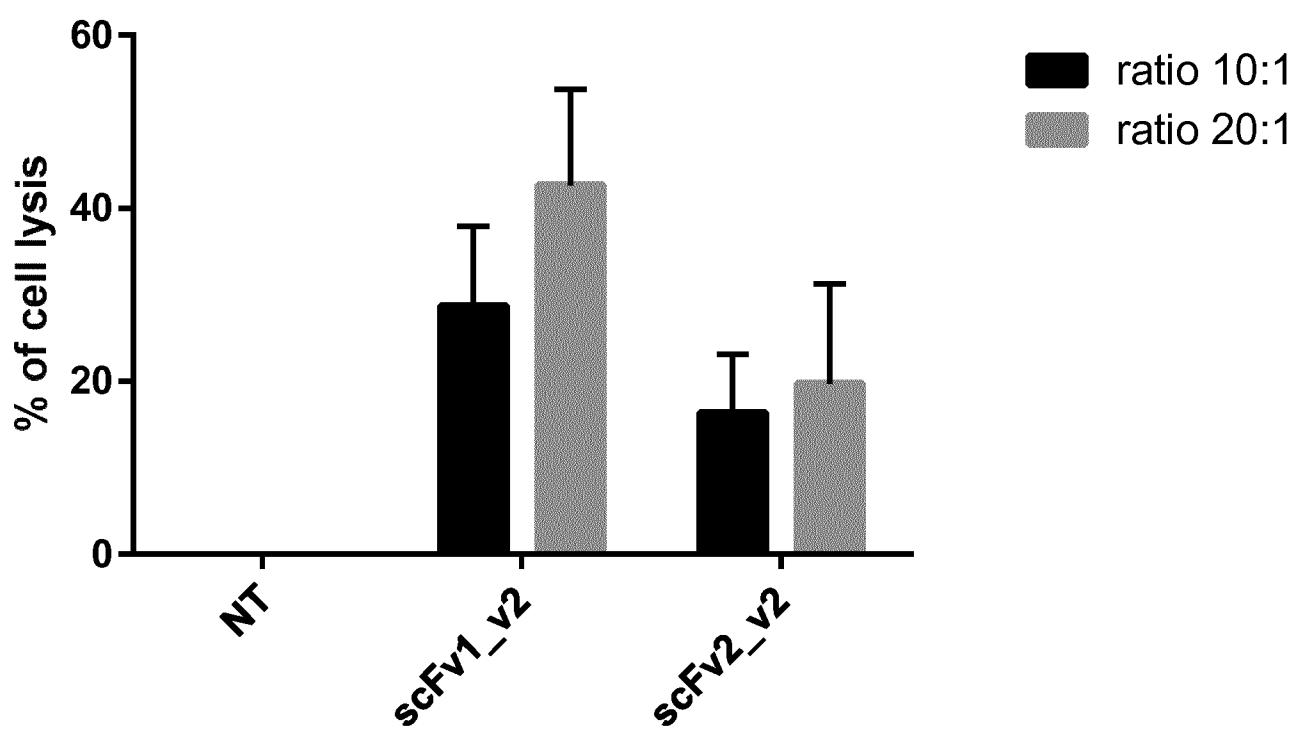


Figure 6

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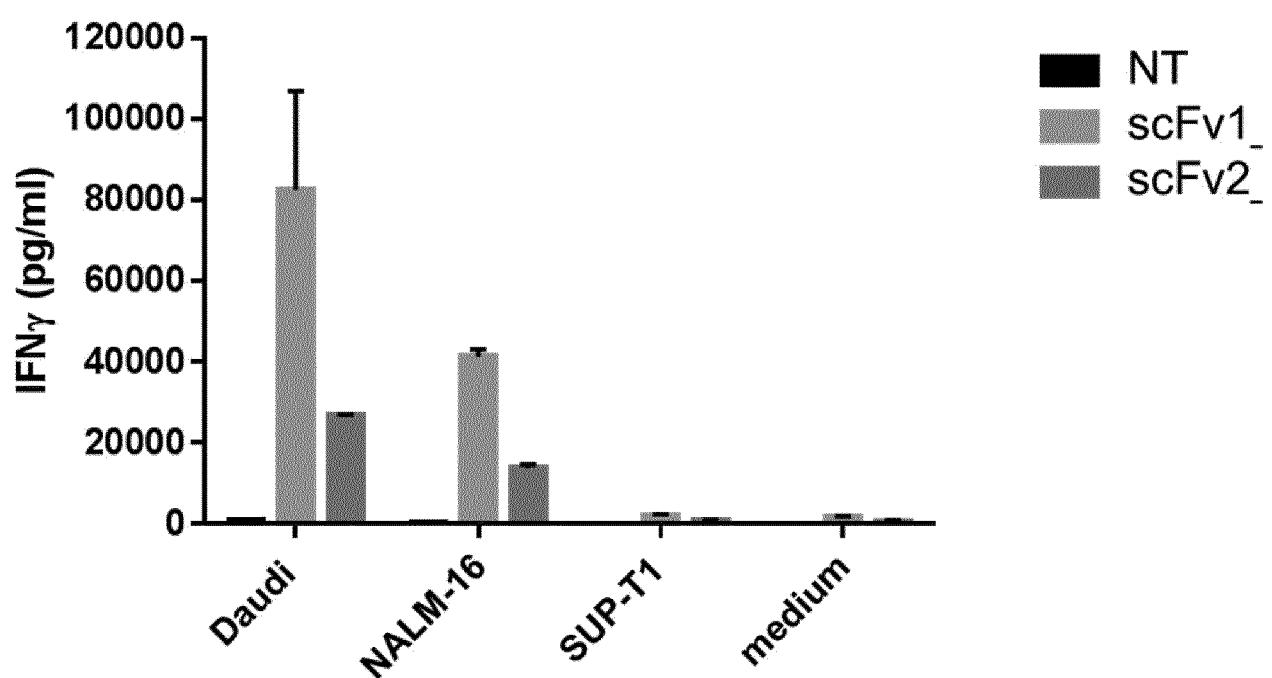


Figure 7

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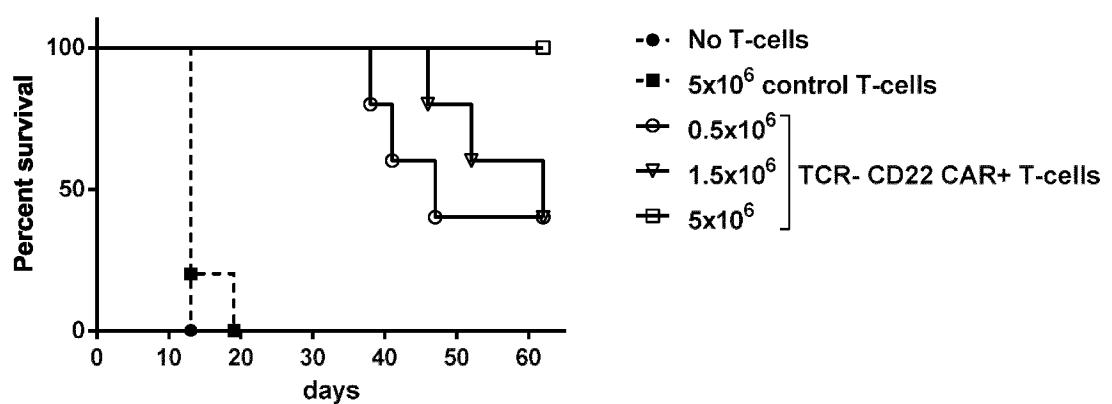
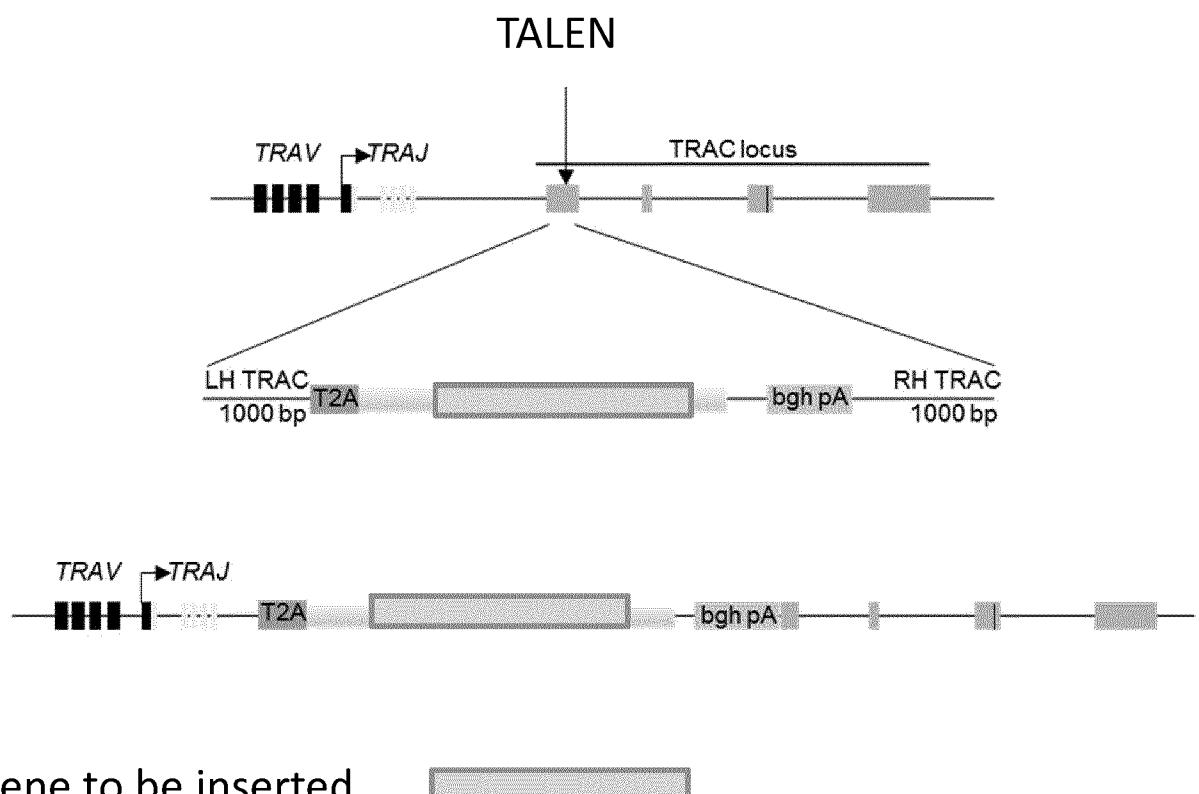


Figure 8

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**Figure 9**

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2018/058367

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>	<b>INV.</b>	<b>A61K39/00</b>	<b>A61K35/17</b>	<b>C07K16/28</b>	<b>C12N5/0783</b>	<b>C07K19/00</b>
		<b>C07K14/47</b>				

**ADD.**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**A61K C12N C07K**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**EPO-Internal, WPI Data, BIOSIS, CHEM ABS Data, EMBASE**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<b>X,P</b>	<p>JULIA WELLS ET AL: "Pre-Clinical Activity of Allogeneic Anti-CD22 CAR-T Cells for the Treatment of B-Cell Acute Lymphoblastic Leukemia", BLOOD, AMERICAN SOCIETY OF HEMATOLOGY, US , vol. 130 suppl. 1 7 December 2017 (2017-12-07), page 808, XP009505340, ISSN: 0006-4971</p> <p>Retrieved from the Internet: URL:<a href="http://www.bloodjournal.org/content/130/Suppl_1/808?utm_source=TrendMD&amp;utm_medium=cpc&amp;utm_campaign=Blood_TrendMD_0">http://www.bloodjournal.org/content/130/Suppl_1/808?utm_source=TrendMD&amp;utm_medium=cpc&amp;utm_campaign=Blood_TrendMD_0</a> the whole document</p> <p style="text-align: center;">-/-</p>	1-3,8, 10,18, 23,24



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

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- "O" document referring to an oral disclosure, use, exhibition or other means
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

Date of mailing of the international search report

29 June 2018

16/07/2018

Name and mailing address of the ISA/  
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Authorized officer

Armandola, Elena

## INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/058367

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X, P	<p>GOUBLE A., SCHIFFER-MNNIOUI C., THOMAS S., GAUTRON A-S. ET AL.: "UCART22:allogenic adoptive immunotherapy of leukemia by targeting CD22 with CAR T-cells", CANCER RES., vol. 77, no. 13, 3763, 1 July 2017 (2017-07-01), XP002781056, DOI: 10.1158/1538-7445.AM2017-3763</p> <p>the whole document</p> <p>-----</p>	1-3, 8, 10, 18, 23, 24
A	<p>WO 2016/120216 A1 (CELLLECTIS [FR]; RINAT NEUROSCIENCE CORP [US])</p> <p>4 August 2016 (2016-08-04)</p> <p>-----</p>	1-27
A	<p>W. HASO ET AL: "Anti-CD22-chimeric antigen receptors targeting B cell precursor acute lymphoblastic leukemia", BLOOD, 14 December 2012 (2012-12-14), XP055048750, ISSN: 0006-4971, DOI: 10.1182/blood-2012-06-438002</p> <p>the whole document</p> <p>-----</p>	1-27
A	<p>CN 105 968 210 A (SHENZHEN IPM BIOPHARM CO LTD) 28 September 2016 (2016-09-28)</p> <p>-----</p>	1-27
A	<p>LONG ADRIENNE H ET AL: "Lessons learned from a highly-active CD22-specific chimeric antigen receptor", ONCOIMMUNOLOGY, LANDES BIOSCIENCE, US, vol. 2, no. 4, 1 April 2013 (2013-04-01), pages e23621/1-3, XP009173972, ISSN: 2162-4011, DOI: 10.4161/ONCI.23621</p> <p>-----</p>	1-27
A	<p>WO 2015/092024 A2 (CELLLECTIS [FR])</p> <p>25 June 2015 (2015-06-25)</p> <p>-----</p> <p>-/-</p>	1-27

## INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/058367

## C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JUSTIN EYQUEM ET AL: "Targeting a CAR to the TRAC locus with CRISPR/Cas9 enhances tumour rejection", NATURE, vol. 543, no. 7643, 22 February 2017 (2017-02-22), pages 113-117, XP55397283, GB ISSN: 0028-0836, DOI: 10.1038/nature21405 -----	1-27
A	Brian Philip ET AL: "86. A Highly Compact Epitope-Based Marker Suicide Gene for Safer and Easier Adoptive T-Cell Gene Therapy", Gene & Cell Therapy, 1 May 2012 (2012-05-01), pages S35-s36, XP055476201, Retrieved from the Internet: URL: <a href="https://www.cell.com/molecular-therapy-family/molecular-therapy/pdf/S1525-0016(16)35890-7.pdf">https://www.cell.com/molecular-therapy-family/molecular-therapy/pdf/S1525-0016(16)35890-7.pdf</a> [retrieved on 2018-05-17] -----	1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/058367

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