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(54) **Title:** THE CORE DOMAIN OF ANNEXINS AND USES THEREOF IN ANTIGEN DELIVERY AND VACCINATION

(57) **Abstract:** The present disclosure provides immunogenic compositions, such as vaccines, including DNA vaccines, and uses thereof, e.g., which include an annexin core domain to mediate efficient antigen delivery and antigen presentation in order to induce an antigen-specific immune response and/or to treat or prevent infectious diseases and/or cancer.

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The core domain of annexins and uses thereof in antigen delivery and vaccination

The present disclosure provides immunogenic compositions, such as vaccines, including DNA vaccines, and uses thereof, e.g., which include an annexin core domain for mediating efficient antigen delivery and antigen presentation in order to induce an antigen-specific immune response, and/or to treat or prevent infectious diseases and/or cancer.

Background of the invention

Central to the initiation of an adaptive immune response are professional antigen presenting cells (APC), which display antigen-derived peptides bound to MHC class I and class II complexes on their cell surface (Verboogen, Dingjan et al. 2016). While cytosolic proteins are degraded by the proteasome and loaded onto MHC class I complexes recognized by CD8+ T cells, engulfment of exogenous proteins (e.g. from phagocytosed bacteria or apoptotic cells) leads to endosomal/lysosomal degradation and presentation on MHC class II complexes presented to CD4+ T cells. In addition, APC such as dendritic cells (DC) are able to shuttle peptides derived from engulfed proteins also into the MHC class I pathway to be presented to CD8+ T cells, a process termed cross-presentation (Segura and Amigorena 2015). Amongst different cells types described to fulfill APC-like functions, DC are regarded as the most efficient (Kambayashi and Laufer 2014). Following APC:T cell interactions, T-cell receptors (TCR) engagement leads to initial T cell activation (priming), characterized, *e.g.*, by secretion of cytokines like Interleukin (IL)-2 and Interferon-γ (Grakoui, Bromley et al. 1999). Activated T cells will proceed to divide and differentiate into different types of effector T cells, which can be classified in two major lineages, CD4+ T helper cells (Th) and CD8+ cytotoxic T cells. Cytotoxic T cells directly induce apoptosis in target cells, while Th cells direct immune responses by production of cytokines and have been classified into Th1, Th2 and Th17 major subsets (Lutz 2016). Summarizing their effector functions, Th1 cells are necessary to activate cellular immunity while Th2 cells induce humoral immune responses. Th17 cells are thought to be involved in immunity against extracellular pathogens like fungi. Regarding anti-tumor immune responses, the induction of efficient CD8+ T cell response has been regarded as critical for tumor rejection, and many tumor vaccination regimes fail to induce CD8+ T cell

anti-tumor responses (Buhrman and Slansky 2013). Thus, efficient antigen presentation by APCs plays a pivotal role for induction of adaptive immunity.

Annexins comprise a family of calcium- and phospholipid-binding proteins. Over 20 members have been found in all eukaryotic kingdoms as well as plants and animals with the exception of fungi. Annexins have molecular weights ranging between 30 and 40 kDa (only annexin VI is 66 kDa) and possess striking structural features. Annexins' aminoterminal domains are diverse in sequence and length (ranging from 11 to 196) on each annexin member. In contrast the carboxyterminal regions consisting of four (eight only for annexin VI) a-helical domains composed of about 70 amino acid residues are well conserved among annexins. The calcium- and phospholipid-binding sites are located in the carboxyterminal domains. The Ca^{2+} binding similarities of all the annexins is due to their common primary structure, a unique N-terminal domain (the “tail”) and the conserved C-terminal domain (the “core”). With the exception of annexin VI, the conserved C-terminal domain is always composed of 4 repeats (annexin VI having 8) of -70 amino acids containing an increased homology region called the "endonexin fold". In addition to the C terminal core the annexins contain a significantly more variable N terminal head. It is this domain which endows each annexin with unique functions in a diverse range of cellular processes including; endo- and exocytosis, cytoskeletal regulation and membrane conductance and organisation. Given their involvement in such a variety of processes it is not surprising that the annexins have also been implicated in a range of disease pathologies. Although there is no singular disease state directly attributed to a dysregulation in annexin function, several pathological conditions are suggested to be modified by the annexins. Fatimathas and Moss (Fatimathas and Moss 2010) discuss the growing evidence for the role of the annexins in the progression of cancer, diabetes and the autoimmune disorder anti-phospholipid syndrome.

In all annexins, lipid binding is mediated by the C-terminal core domain highly conserved among all annexin family members (Gerke and Moss 2002, Moss and Morgan 2004). In contrast, annexin N-termini vary in sequence. Peptides corresponding to the AnxA1 N-terminus were shown to bind to members of the N-formyl peptide receptor (FPR) family, resulting in a reduction of neutrophil transmigration in several models of acute and chronic inflammation (Walther, Riehemann et al. 2000, Strausbaugh and Rosen 2001, Ernst, Lange et al. 2004, Perretti and Dalli 2009). Downstream signaling induced by binding of AnxA1 N-terminal peptides to FPR family members causes activation of ERK, but not of p38 or JNK

(Hayhoe, Kamal et al. 2006, Pupjalis, Goetsch et al. 2011). The presence of multiple annexin family members in all higher eukaryotes suggests a fundamental role for annexins in cell biology. Mice deficient in individual annexin family members, however, have no severe phenotype, suggesting that several annexins have (partly) overlapping functions (Gerke and Moss 2002, Farber, De Rose et al. 2003). In fact, functional redundancy of annexins was proven in the context of membrane trafficking, inhibition of PLA_2 activity and blood coagulation (Gerke and Moss 2002).

US 2002-052358 describes a method of treating a subject with arthritis or an arthritic disease or preventing arthritis or arthritic disease in a subject, comprising administering to the subject a therapeutically effective amount of an agent that attenuates annexin function. Also provided are various methods of screening for agents.

WO 01/10199 describes a knockout transgenic mouse containing a nonfunctional allele of the tumor suppressing gene, annexin VII. This mouse is used as a screening model for potential therapeutic agents useful in the treatment of tumors resulting from an annexin tumor suppressor disease.

JP 2014-095643 describes screening of a compound effective in treatment of inflammatory disease, based on an inhibition of binding between annexin A2 and ADAM17.

WO 2014/126127 describes a method for screening an active ingredient for the treatment of severe enanthema, skin erythema, body surface erosion, blister and excoriation as formyl peptide receptor 1-induced necroptosis-related diseases. The active ingredient to be screened is said to be a substance capable of inhibiting necroptosis that is induced by the binding of formyl peptide receptor 1 to annexin A1.

WO 02/17857 discloses methods for inhibiting angiogenesis in endothelial cells and selectively inducing apoptosis in endothelial cells via compounds which binds annexin II are provided. These compounds and methods for using these compounds are regarded as useful in the treatment of diseases or disorders characterized by unwanted angiogenesis. Also provided are pharmaceutical compositions containing a compound which binds annexin II and a pharmaceutically acceptable vehicle and methods for identifying such compounds.

WO 2005/027965 discloses anti-annexin antibodies and their uses as well as uses of theirs ligands, the annexins. Such annexins and anti-annexin antibodies are useful for detecting apoptosis and for the production of pharmaceutical compositions for the diagnosis and/or treatment of cancer, autoimmune diseases, cardiovascular and/or vascular diseases.

US 2014/0322214 discloses includes compositions and methods for binding Dectin-1 on immune cells with anti-Dectin-1-specific antibodies or fragment thereof capable of activating the immune cells as well as methods for treating or preventing an influenza infection in a subject in need thereof comprising administering to the subject a therapeutically effective amount of a composition comprising an anti-dectin-1 antibody fused to an influenza antigen. The thesis of Connie Hesse, CLEC7A/Dectin-1 attenuates the immune response against dying and dead cells, Friedrich-Alexander-University Erlangen-Nürnberg, 2011, discusses the role of C-type lectins CLEC4L/DC-SIGN, CLEC9A/DNGR1, and CLEC7A/dectin-1 in the recognition as well as the uptake of apoptotic and necrotic cells and/or their effects on the immunogenicity of dying and dead cells.

The low-density lipoprotein receptor-related protein-1 (LRP-1) is a membrane receptor displaying both scavenging and signaling functions. The wide variety of extracellular ligands and of cytoplasmic scaffolding and signaling proteins interacting with LRP-1 gives it a major role not only in physiological processes, such as embryogenesis and development, but also in critical pathological situations, including cancer and neurological disorders (Emonard, Theret et al. 2014). Cell surface annexin VI may function as an acidic pH binding site or receptor and may also function as a co-receptor with LRP-1 at neutral pH in the context of alpha 2-macroglobulin recognition (Ling, Chen et al. 2004).

Arur and colleagues (Arur, Uche et al. 2003) as well as Tzelepis et al. (Tzelepis, Verway et al. 2015) describe a role for annexin A1 in the process of phagocytosis of apoptotic cells, which is regarded as immunologically silent and not leading to a T cell response. In the same publication, Tzelepis and colleagues further described a role for endogenous annexin A1 in the process of cross presentation. This publication describes annexin A1 as a mediator that acts in the cytosol of dendritic cells. Therefore, this publication does not enable the use of the annexin core domain as exogenous mediator to engage antigen presentation and cross presentation.

Andersen and colleagues (Andersen, Xia et al. 2016) describe the binding of annexin A2 to Toll –like receptor (TLR) 2. By triggering TLR2, annexin A2 can act as a vaccine adjuvant, enhancing TLR-mediated DC activation and processes like upregulation of co-stimulatory surface molecules and antigen cross-presentation. This publication is silent about antigen delivery into DC.

Tzelepis et al. (in: Tzelepis et al. Annexin1 regulates DC efferocytosis and cross-presentation during Mycobacterium tuberculosis infection. J Clin Invest. 2015 Feb;125(2):752-68. Epub 2014 Dec 22) disclose that during Mycobacterium tuberculosis (Mtb) infection, the engulfment ligand annexin1 is an important mediator in DC cross-presentation that increases efferocytosis in DCs and intrinsically enhances the capacity of the DC antigen-presenting machinery. Annexin1-deficient mice were highly susceptible to Mtb infection and showed an impaired Mtb antigen-specific CD8+ T cell response.

Finally, Weyd and colleagues (Weyd, Abeler-Dorner et al. 2013, Linke, Abeler-Dorner et al. 2015) disclose that in mice, Annexin A1, Annexin A5, Annexin A13 and the annexin core domain prevented the development of inflammatory DC and suppressed the cellular immune response against the model antigen ovalbumin (OVA) expressed in apoptotic cells.

Reagents which react specifically or preferentially with DC and mediate antigen presentation have great potential as targeting agents to induce potent immune responses to tumor or infectious disease antigens. These cell-specific targeting agents could also be engineered to deliver toxins to eliminate potent antigen presenting cells (e.g., DC) in bone marrow and organ transplantations or other autoimmune disorders. Accordingly, such DC-specific binding agents possess great therapeutic and diagnostic value.

It is therefore an object of the present invention to provide such new reagents and to employ these reagents in the development of new and effective therapies. Other objects and aspects of the present invention will become apparent to the person of skill upon reading the following description of the invention.

The invention pertains to an isolated annexin core domain, the annexin core domain being defined to comprise an amino acid sequence of an annexin core domain shown within the sequence selected from the group of SEQ ID Nos. 1 to 3 and 6 to 8, or to comprise an amino

acid sequence that is at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, most preferably 99% identical to an annexin core domain amino acid sequence as comprised within a sequence selected from the group of SEQ ID Nos. 1 to 3 and 6 to 8. The definitions of the core domains is provided herein below in the example section. In particular preferred is an annexin core domain consisting of an amino acid sequence of a core domain as shown in an amino acid sequence selected from the group of SEQ ID Nos. 1 to 3 and 6 to 8; or consisting of an amino acid sequence that is at least 50%, 60%, 70%, 80%, 85%, 90%, 95%, 98%, most preferably 99% identical to an amino acid sequence of a core domain as shown in an amino acid sequence selected from the group of SEQ ID Nos. 1 to 3 and 6 to 8.

The present invention also provides a protein conjugate or fusion protein comprising (i) at least one annexin core domain as described herein, and (ii) at least one antigenic peptide that can be presented by MHC (preferably HLA). The antigenic peptide can be derived from a tumor or infectious agent, pathogen or endogenous protein. The present invention also provides respective vaccines comprising fusions and/or conjugates and other therapeutic compositions.

In certain embodiments the protein conjugate or fusion protein of the invention comprises a covalent linkage between the annexin core domain and the at least one antigenic peptide that can be presented by MHC. Also encompassed are conjugates or fusion protein of the invention where the covalent linkage includes a linker molecule or peptide. Selection of suitable linker molecules is well established in the pertinent art. In some embodiments of the invention the linker comprises an amino acid sequence of the linker as shown in figure 10 (SEQ ID NO: 15), or a sequence having at least 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% sequence identity to the linker sequence shown in figure 10B (SEQ ID NO: 15).

In some aspects and embodiments the present invention the fusion protein is encoded by the nucleic acid shown in SEQ ID NO: 13, or a by a nucleic acid variant thereof having at least 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% sequence identity to SEQ ID NO: 13. Preferably the fusion protein of the invention comprises the amino acid sequence of SEQ ID NO: 14, or of a variant thereof having at least 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% sequence identity to SEQ ID NO: 14.

The term "fusion protein" as used herein relates to an artificial proteinaceous construct and means a protein comprising at least two different amino acid sequences which are defined by their origin and/or by special functions. In this aspect the fusion protein of the invention comprises the annexin core domain amino acid sequence fused to second amino acid sequence of another protein which is not annexin, and which is antigenic in the sense that said second protein or fragments thereof, are presented on a cell via the MHC complex. Moreover, the term fusion protein according to the present invention does further include such fusion proteins which also contain non-protein molecules such as nucleic acids, sugars, or markers for radioactive or fluorescent labelling.

It was surprisingly found that the constructs according to the present invention have an immune stimulating (enhancing) effect. Thus, the compositions of the invention containing the annexin core domain complex and/or fusion can be used in a variety of DC-targeted therapies, for example, to enhance antigen presentation and/or induce T cell responses, such as cytotoxic T cell (CTL) responses, against a variety of target cells or pathogens, or to treat antigen presenting cell (APC)-mediated diseases. The invention surprisingly found that combining an antigenic molecule, such as an antigenic peptide, with an annexin core domain as described herein, significantly enhances the immune modulatory effects of said antigenic sequence. Without being bound to a particular theory, coupling an annexin core domain to an antigenic molecule enhances anigen processing and MHC-presentation of antigen presenting cells such as dendritic cells. Therefore the invention broadly enables a products and methods for enhancing the antigen presentation of antigenic molecules via MHC, preferably human MHC (HLA).

As used herein, the term “antigen” refers to a substance capable of eliciting an immune response, e.g., a T-cell-mediated immune response by the presentation of the antigen on Major Histocompatibility Antigen (MHC) cellular proteins and causing an antigen-specific T-cells response. In the case of a regulatory T-cell (Treg) response to the antigen is a decrease or amelioration of the immune response by other effector cells, e.g., helper T-cells (Th) and/or cytotoxic T-cells (Tc). The skilled immunologist will recognize that when discussing antigens that are processed for presentation to T-cells, the term "antigen" refers to those portions of the antigen (e.g., a peptide fragment) that is a T-cell epitope presented by MHC to the T-cell receptor. When the expression “antigen” is modified by self- or auto-, this refers to self or auto antigens that are commonly present in MHC molecules but that also trigger a T-cell

response. When used in the context of a B cell mediated immune response in the form of an antibody that is specific for an "antigen", the portion of the antigen that binds to the complementarity determining regions of the variable domains of the antibody (light and heavy) the bound portion may be a linear or three-dimensional epitope. In certain cases, the antigens delivered by the vaccine or fusion protein or protein conjugate of the present invention are internalized and processed by antigen presenting cells prior to presentation, e.g., by cleavage of one or more portions of the antibody or fusion protein.

As used herein, the term "antigenic peptide" refers to that portion of a polypeptide antigen that is specifically recognized by either B-cells and/or T-cells. B-cells respond to foreign antigenic determinants via antibody production, whereas T-lymphocytes mediate cellular immunity. Thus, antigenic peptides in a T-cell response are those parts of an antigen that are recognized by antigen- specific T-cell receptors in the context of MHC.

As used herein, the term "epitope" refers to any protein determinant capable of specific binding to an immunoglobulin or of being presented by a Major Histocompatibility Complex (MHC) protein (e.g., Class I or Class II) to a T-cell receptor. Epitopic determinants are generally short peptides 5-30 amino acids long that fit within the groove of the MHC molecule that presents certain amino acid side groups toward the T-cell receptor and has certain other residues in the groove, e.g., due to specific charge characteristics of the groove, the peptide side groups and the T-cell receptor. Generally, an antibody specifically binds to an antigen when the dissociation constant is 1 mM, 100 nM or even 10 nM.

As used herein the term "Antigen Presenting Cells" (APC) are cells that are capable of activating T- cells, and include, but are not limited to, certain macrophages, B cells and dendritic cells. "Dendritic cells" (DCs) refer to any member of a diverse population of morphologically similar cell types found in lymphoid or non-lymphoid tissues. These cells are characterized by their distinctive morphology, high levels of surface MHC-class II expression (Steinman, et al., Ann. Rev. Immunol. 9:271 (1991); incorporated herein by reference for its description of such cells). These cells can be isolated from a number of tissue sources, and conveniently, from peripheral blood or differentiated from murine bone marrow, as described herein. Dendritic cell binding proteins refer to any protein for which receptors are expressed on a dendritic cell. Examples include GM-CSF, IL-1, TNF, IL-4, CD40L, CTLA4, CD28, and FLT-3 ligand. An antigenic peptide comprises a peptide sequence that is capable to be

presented by HLA molecules (MHC class I and/or MHC class II) and induces a T cell response, such as cytotoxic T cell (CTL) response. Usually, these peptides are between 8 and 30, preferably between 8 and 24 amino acids long, MHC class I peptides are usually between 8 and 10 long, and MHC class II peptides are usually between 21 and 25 amino acids long. Methods to identify ("screen") for these antigenic peptides are known as well and can involve both in vivo or in vitro and in silico methods.

Methods to prepare respective conjugates (i.e. comprising non-covalent or covalent bonds introduced between different components, i.e. the annexin and the peptide) of the annexin core domain and the antigenic peptide as well as to prepare respective fusion proteins (i.e. expression of one protein after recombinant cloning of the components) are well known in the art.

In the context of the present invention, the term "annexin core domain" shall be understood as indicating/representing the minimal fragment of the polypeptide for annexin (or homologs thereof), which is necessary and sufficient to mediate antigen presentation (see also below). Some preferred proteinaceous annexin core domains are defined herein above. This ability (biological function) may be tested in a number of art known methods as described herein, and, e.g. in the examples, below. This ability may further be tested in a number of art known methods as described in the respective literature. For examples of annexin core domains, see also Figure 7, below. Also, the term shall particularly comprise the vertebrate, in particular mammalian (in particular human) annexin gene and/or protein and/or mRNA and/or the core fragment (core domain) as described herein. The term also covers the annexin core domain in different preparations, such as in the cellular context, a cell recombinantly expressing said core domain, purified from the cell, and fractions, in particular biologically active factions, thereof.

Protein aggregates are known to enhance immune responses. The mechanism by which protein aggregates mediate such potent antibody responses is not fully understood. However, it is believed that the potency is due, at least in part, to the ability of the multivalent protein to extensively cross link the cell surface receptors such as immunoglobulins of B cells and activate the B cells. Therefore it is in context of the invention one embodiment to aggregate the protein conjugate or fusion protein of the invention to further enhance immune responses. This may be achieved by using multimeric antigenic peptides where the antigenic molecule is

multimerized directly or via a linker sequence to form a poly-antigenic peptide with a repeating antigenic sequence for fusion with the annexin core domain in accordance with the invention. Alternatively the fusion protein of the invention may further comprise a moiety that induces aggregation of the protein conjugate or fusion protein, such as a protein multimerization domain or dimerization domain, which is covalently attached to the fusion protein. One particularly favorable example of such a protein multimerization domain is a coiled-coil domain, such as an isoleucine zipper domain that promotes trimerization of multiple polypeptides having such a domain. A further favorable example of a modification for protein multimerization is the use of conjugated biotin or a biotinylation sequence in conjunction with the protein streptavidin. Another option in context of the invention provides compositions of the fusion protein of the invention in combination with the agent for protein aggregation.

Fusion proteins can also be made at the nucleic acid coding level by placing, in-line and in the correct coding frame, the two or more sequences of the portions of the proteins or peptides, i.e. of the annexin core domain and the respective antigenic peptide or antigen. Fusion proteins are synthesized by methods known to those of skill in the art including, e.g., solid phase protein synthesis, and by molecular techniques that permit the manipulation of DNA in vitro, including polymerase chain reaction (PCR) and oligonucleotide-directed mutagenesis.

In the context of the present invention, the terms “C-type lectin receptor”, “Dectin-1”, “DC-SIGN”, and “LRP-1” shall be understood as indicating/representing the minimal fragment of the receptor(s), which is necessary and sufficient to bind to a core domain of the annexin as described and tested in the examples, and in, for example, Hesse as mentioned above for lectin-Fc fusion proteins. This ability may further be tested in a number of art known methods as described in the respective literature. Also, the term shall comprise the mammalian (in particular mouse) homolog of the human receptor gene and/or protein and/or mRNA and/or the fragment (binding part, fragment or domain) as described herein. The term also covers the receptor(s) and/or the minimal fragment of the receptor(s) in different preparations, such as in the cellular context, a cell (recombinantly) expressing said receptor(s) and/or the minimal fragment of the receptor(s), purified from the cell, and fractions thereof.

With Dectin-1 and DC-SIGN as members of the family of C-type lectin receptors and LRP-1, novel DC-surface receptors could be identified that with high affinity bind to the core domain

of all annexins as studied. This is an indication that Dectin-1, DC-SIGN and LRP-1 are responsible for the annexin–mediated effects on the immune response and induction of antigen presentation.

The effect of the annexins on DC via specific receptors is a novel molecular mechanism of antigen presentation, resulting in a multitude of novel possibilities both for the therapy of cancers and tumors, as well as for infectious diseases in mammals, such as mice and humans.

WO 2009/049892 describes a first polypeptide (A) comprising a recruiting polypeptide (a) comprising at least an annexin core domain or a functional variant thereof, a bait polypeptide (b) and a luminophore. The composition according to the invention can be used to measure protein-protein interactions within and/or between entire multiprotein complexes. Described is the use of the method according to the invention for the identification of a test compound in a library of test compounds which modulates a medically relevant protein-protein interaction, without that any concrete disease context is disclosed. WO 2009/049892 is silent about any interaction(s) of annexin with Dectin-1, DC-SIGN and/or LRP-1, and also non-enabling for the screening of therapeutically relevant compounds and/or compositions.

WO 2005/027965 describes that annexin I and other annexins are related to specific receptors, which could be stimulated or blocked by either binding of one of the annexins or fragments thereof or an antibody against this receptor. Thus, annexins and/or functional fragments thereof and/or fusion proteins comprising an annexin or functional fragments thereof are discussed to be of use to modulate the immune system. WO 2005/027965 is silent about the use of the annexin core domain itself to mediate antigen presentation, and thus is also non-enabling for the screening of therapeutically relevant compounds and/or compositions.

Exposure of bone marrow-derived DC (BMDC) to a fusion protein comprising the annexin core domain and the model antigen ovalbumin (OVA) *in vitro* resulted in profound antigen presentation of OVA-derived peptides in surface MHC class I molecules (Fig. 1) as well as in strongly amplified specific T cell stimulation of both, CD8+ and CD4+ T cells (Figs. 2 and 3). These results suggest that the annexin core domain has a previously unappreciated role in antigen presentation and antigen cross-presentation. Manipulating anx-core-domain mediated antigen presentation may, therefore, prove useful when designing vaccination strategies and, accordingly, beneficial for patients with cancer (vaccination with tumor antigens) or

infectious diseases. Of note, this mechanism, in which the annexin core domain mediates antigen delivery and antigen presentation when administered exogenously to DC and linked to an antigen is inherently different from described endogenous, cytosolic functions of annexin A1 (Tzelepis, Verway et al. 2015). This mechanism is also different from described vaccine adjuvant function of annexin A2 binding to Toll-like receptor 2 (Andersen, Xia et al. 2016), because the annexin core domain as described here does not mediate DC stimulation via TLRs but mediates antigen delivery and antigen (cross-) presentation.

Preferred is a protein conjugate or fusion protein according to the present invention, wherein said antigenic peptide is derived from a protein selected from the group consisting of βhCG, gp100 or Pmel17, HER2/neu, WT1, mesothelin, CEA, gp100, MART1, TRP-2, NY-BR-1, NY-CO-58, MN (gp250), idiotype, Tyrosinase, Telomerase, SSX2, MUC-1, MART1, melan-A, NY-ESO-1, MAGE-1, MAGE-3, MAGE-A3, and high molecular weight-melanoma associated antigen (HMW-MAA).

Other antigenic peptides for use with the present invention include cancer peptides selected from tumor-associated antigens, e.g., autologous cancer antigens obtained from a patient. Non-limiting examples of cancer antigens include antigens from leukemias and lymphomas; neurological tumors such as astrocytomas or glioblastomas; melanoma; breast cancer; lung cancer; head and neck cancer; gastrointestinal tumors; gastric cancer; colon cancer; liver cancer; pancreatic cancer; genitourinary tumors such cervix; uterus; ovarian cancer; vaginal cancer; testicular cancer; prostate cancer or penile cancer; bone tumors; vascular tumors; or cancers of the lip; nasopharynx; pharynx and oral cavity; esophagus; rectum; gall bladder; biliary tree; larynx; lung and bronchus; bladder; kidney; brain and other parts of the nervous system; thyroid; Hodgkin's disease; non-Hodgkin's lymphoma; multiple myeloma and leukemia. In a specific aspect the composition further comprises antigenic peptides selected from tumor associated antigens are selected from CEA; prostate specific antigen (PSA); HER-2/neu; BAGE; GAGE; MAGE 1-4; 6 and 12; MUC (Mucin) (e.g.; MUC-1, MUC-2, etc.); GM2 and GD2 gangliosides; ras; myc; tyrosinase; MART (melanoma antigen); MARCO-MART; cyclin Bl; cyclin D; Pmel 17(gpl00); GnT-V intron V sequence (N-acetylglucoaminyltransferase V intron V sequence); Prostate Ca psm; prostate serum antigen (PSA); PRAME (melanoma antigen); β-catenin; MUM-l-B (melanoma ubiquitous mutated gene product); GAGE (melanoma antigen) 1; BAGE (melanoma antigen) 2-10; C-ERB2

(Her2/neu); EBNA (Epstein-Barr Virus nuclear antigen) 1-6; gp75; human papilloma virus (HPV) E6 and E7; p53; lung resistance protein (LRP); Bcl-2; and Ki-67.

Further antigenic peptides or antigens for use in context with the present invention are selected from viral antigens. The term "viral antigen" includes any substance that elicits an immune response against a virus. Examples include Retro viridae, in particular HIV-I and HIV-LP; Picornaviridae, in particular polio virus and hepatitis A virus; enterovirus, in particular human coxsackie virus, rhinovirus, echovirus; Calciviridae, in particular strains that cause gastroenteritis; Togaviridae, in particular equine encephalitis virus and rubella virus; Flaviridae, in particular dengue virus, encephalitis virus and yellow fever virus; Coronaviridae, in particular coronavirus; Rhabdoviridae, in particular vesicular stomatitis virus and rabies virus; Filoviridae, in particular Ebola virus or and Marburg virus; Paramyxoviridae, in particular parainfluenza virus, mumps virus, measles virus and respiratory syncytical virus; Orthomyxoviridae, in particular influenza virus; Bungaviridae, in particular Hantaan virus, bunga virus, phlebovirus and Nairo virus; Arena viridae, in particular hemorrhagic fever virus; Reoviridae, in particular reovirus, orbivirus and rotavirus; Birnaviridae; Hepadnaviridae, in particular Hepatitis B virus; Parvovirida, in particular parvovirus; Papovaviridae, in particular papilloma virus, simian virus- 40 (SV40) and polyoma virus; Adenoviridae; Herpesviridae, in particular herpes simplex virus (HSV) 1 and 2, varicella zoster virus, cytomegalovirus (CMV), herpes virus; Poxyiridae, in particular variola virus, vaccinia virus and pox virus; and Irido viridae, in particular African swine fever virus; Hepatitis C, and HPV L6, HPV L7, fragments and derivatives thereof.

Further antigenic peptides or antigens for use in context with the present invention are selected from bacterial antigens. As used herein, the term "bacterial antigen" includes any substance that elicits an immune response against a bacterium. Examples include Helicobacter species, in particular Helicobacter pyloris; Borelia species, in particular Borelia burgdorferi; Legionella species, in particular Legionella pneumophilia; Mycobacteria species, in particular M. tuberculosis, M. avium, M. intracellulare, M. kansasii, M. gordonae; Staphylococcus species, in particular Staphylococcus aureus; Neisseria species, in particular N. gonorrhoeae, N. meningitidis; Listeria species, in particular Listeria monocytogenes; Streptococcus species, in particular S. pyogenes, S. agalactiae; S. faecalis; S. bovis, S. pneumoniae; anaerobic Streptococcus species; pathogenic Campylobacter species; Enterococcus species; Haemophilus species, in particular Haemophilus influenzae; Bacillus species, in particular Bacillus anthracis; Corynebacterium species, in particular

Corynebacterium diphtheriae; Erysipelothrix species, in particular Erysipelothrix rhusiopathiae; Clostridium species, in particular C. perfringens, C. tetani; Enterobacter species, in particular Enterobacter aerogenes, Klebsiella species, in particular Klebsiella pneumoniae, Pasturella species, in particular Pasturella multocida, Bacteroides species; Fusobacterium species, in particular Fusobacterium nucleatum; Streptobacillus species, in particular Streptobacillus moniliformis; Treponema species, in particular Treponema pertenue; Leptospira; pathogenic Escherichia species; and Actinomyces species, in particular Actinomyces israelii.

Preferred is furthermore a protein conjugate or fusion protein according to the present invention, wherein said conjugate or said fusion protein is further conjugated/fused to a co-stimulatory molecule or an immunogenic fragment thereof or a costimulatory second peptide sequence.

Another aspect of the present invention then relates to a nucleic acid encoding for the fusion protein or protein conjugate according to the present invention. Preferably, the coding sequence codes for an antigen derived from a protein selected from the group consisting of βhCG, gp100 or Pmel17, HER2/neu, WT1, mesothelin, CEA, gp100, MART1, TRP-2, NY-BR-1, NY-CO-58, MN (gp250), idiotype, Tyrosinase, Telomerase, SSX2, MUC-1, MART1, melan-A, NY-ESO-1, MAGE-1, MAGE-3, MAGE-A3, and high molecular weight-melanoma associated antigen (HMW-MAA). More preferably, said coding sequence is fused to at least one (additional) DC-stimulatory nucleic acid sequence. It is also possible to use fusions of multiple antigenic peptides, for example multiple sequences found in one tumor disease, or patient specific antigens found in an individual tumor.

Another aspect of the present invention then relates to a recombinant expression vector expressing the nucleic acid according to the invention.

The invention also relates to an isolated annexin core domain comprising an amino acid sequence of the core domain as shown in the sequences selected from SEQ ID Nos. 1 to 3 and 6 to 8. The domain ranges are provided herein in the example section. Preferred are domains consisting of said sequences, or essentially consist of said sequences (e.g. having 5 to 10 amino acid extensions that do not interfere with the function of the domain). The annexin core domain according to the present invention that can further be used in the method according to

the present invention can be derived from any of the known annexins or functional fragments (i.e. able to bind to the receptors as described herein) thereof, and is preferably selected from the group of the human or murine annexin 1, 5, and 13 core domain, preferably according to a sequence comprised in the sequence according to SEQ ID NO: 1 to 3 and 6 to 8, or according to a sequence of a core comprised in the sequence according to SEQ ID NO: 1,2,3,6,7, or 8, or functional fragments thereof, more preferably according to the boxed sequences as shown in Figure 8.

The term "contact" in the present invention means any interaction between the potentially binding substance(s)/ antigens with the annexin core domain, whereby any of the two components can be independently of each other in a liquid phase, for example in solution, or in suspension or can be bound to a solid phase, for example, in the form of an essentially planar surface or in the form of particles, pearls or the like.

Another aspect of the present invention relates to a method for manufacturing a pharmaceutical composition for treating or preventing infectious diseases or cancer, comprising the step of admixing the protein conjugate or fusion protein according to the present invention, or the nucleic acid according to the present invention, or the expression vector according to the present invention, with a suitable agent or carrier.

Thus, the compounds of the invention can be admixed with suitable auxiliary substances and/or additives. Such substances comprise pharmacological acceptable substances, which increase the stability, solubility, biocompatibility, or biological half-life of the interacting compound or comprise substances or materials, which have to be included for certain routs of application like, for example, intravenous solution, sprays, band-aids or pills.

Carriers, excipients and strategies to formulate a pharmaceutical composition, for example to be administered systemically or topically, by any conventional route, in particular enterally, e.g. orally, e.g. in the form of tablets or capsules, parenterally, e.g. in the form of injectable solutions or suspensions, topically, e.g. in the form of lotions, gels, ointments or creams, or in nasal or a suppository form are well known to the person of skill and described in the respective literature.

Another aspect of the present invention thus is a pharmaceutical composition comprising the protein conjugate or fusion protein according to the present invention, or the nucleic acid according to the present invention, or the expression vector according to the present invention. Preferably, the pharmaceutical composition is a vaccine.

Administration of an agent, e.g., the complex or fusion, can be accomplished by any method which allows the agent to reach the target cells. These methods include, e.g., injection, deposition, implantation, suppositories, oral ingestion, inhalation, topical administration, or any other method of administration where access to the target cells by the agent is obtained. Injections can be, e.g., intravenous, intradermal, subcutaneous, intramuscular or intraperitoneal. Implantation includes inserting implantable drug delivery systems, e.g., microspheres, coated microparticles, hydrogels, polymeric reservoirs, cholesterol matrices, polymeric systems, e.g., matrix erosion and/or diffusion systems and non-polymeric systems, e.g., compressed, fused or partially fused pellets. Suppositories include glycerin suppositories. Oral ingestion doses can be enterically coated. Inhalation includes administering the agent with an aerosol in an inhalator, either alone or attached to a carrier that can be absorbed. The agent can be suspended in liquid, e.g., in dissolved or colloidal form. The liquid can be a solvent, partial solvent or non-solvent. In many cases, water or an organic liquid can be used.

In certain embodiments, the compound (activator or inhibitor) is administered to the subject by administering a recombinant nucleic acid, such as, for example, an annexin core domain or antigen RNA. Preferably, the recombinant nucleic acid is a gene therapy vector.

Another aspect of the present invention relates to a method or use as described herein, wherein the pharmaceutical composition further comprises additional pharmaceutically active ingredients for treating or preventing autoimmune diseases, chronic inflammatory diseases, allergies or cancer, i.e. chemotherapeutics.

Another aspect of the present invention relates to an isolated annexin core domain; a complex or fusion of an annexin core domain with at least one antigen; an activating antibody, optionally coupled to at least one antigen or allergenic compound; or a pharmaceutical composition according to the present invention for use in the prevention and/or therapy of diseases as described herein (see, e.g., below). Preferred is the complex or fusion for use

according to the present invention, wherein said complex or fusion is soluble or bound to a carrier, such as a liposome or latex bead.

Another aspect of the present invention then relates to a method for treating or preventing infectious diseases or cancer in a patient, comprising administering to said patient an effective amount of an isolated annexin core domain; a complex or fusion of an annexin core domain with at least one antigen or allergenic compound; an activating antibody, optionally coupled to at least one antigen or allergenic compound; or a pharmaceutical composition obtained by the method according to the present invention.

In general, the attending physician will base a treatment on the compound as identified, and optionally also on other individual patient data (clinical data, family history, DNA, etc.), and a treatment can also be performed based on the combination of these factors. This method of the present invention for example involves integrating individual diagnostic immunological data with patient clinical information and general healthcare statistics to enable, for example, the application of personalized medicine to the patient. Significant information about drug effectiveness, drug interactions, and other patient status conditions can be used, too.

Preferred is a therapeutic method according to the present invention, wherein said mammal to be treated is a mouse, rat or human.

Preferably, an active agent of the invention (preferably the annexin core domain or the protein conjugate or fusion protein of the invention) is administered in form of a pharmaceutical composition comprising an activating agent as described above, such as an antibody, nucleotide or an activating binding compound for the annexin core domain/receptor binding. Preferably, said patient is a human being. Treating is meant to include, e.g., preventing, treating, reducing the symptoms of, or curing the disease or condition, i.e. immunological diseases such as immunodeficiency, infectious diseases or cancer.

In general, the attending physician will base a treatment on the compound as identified, and optionally also on other individual patient data (clinical data, family history, DNA, etc.), and a treatment can also be performed based on the combination of these factors. This method of the present invention for example involves integrating individual diagnostic cancer data with

patient clinical information and general healthcare statistics to enable, for example, the application of personalized medicine to the patient. Significant information about drug effectiveness, drug interactions, and other patient status conditions can be used, too.

Preferred is a therapeutic method according to the present invention, wherein said mammal to be treated is a mouse, rat or human.

More preferably, the cancer to be treated is a solid tumor, such as, for example, selected from breast, bone, ovarian, liver, kidney, and lung cancer.

Preferably, an active agent is administered in form of a pharmaceutical composition, such as a protein conjugate or fusion protein of the invention, said patient is a human being. Treating is meant to include, e.g., preventing, treating, reducing the symptoms of, or curing the disease or condition, i.e. cancer. Treatment generally involves the administration of a therapeutically effective amount of the protein conjugate or fusion protein of the invention to the subject in need of the treatment.

In another aspect the invention provides a method for the vaccination of a subject comprising the administration of the protein conjugate or fusion protein of the invention to the subject in need of vaccination. The protein conjugate or fusion protein of the invention is preferably in the form of a vaccine composition and comprises additionally at least one carrier and/or excipient and/or vaccine adjuvant.

The herein disclosed pharmaceutical and in particular vaccine compositions preferably further comprise one or more immune stimulatory compounds such as adjuvants. An "adjuvant" is an agent that enhances the production of an immune response in a non-specific manner. Common adjuvants include suspensions of minerals (alum, aluminum hydroxide, aluminum phosphate) onto which the fusion protein of the invention is adsorbed; emulsions, including water-in-oil, and oil-in-water (and variants thereof, including double emulsions and reversible emulsions), liposaccharides, lipopolysaccharides, immunostimulatory nucleic acids (such as CpG oligonucleotides), liposomes, Toll-like Receptor agonists (particularly, TLR2, TLR4, TLR7/8 and TLR9 agonists), and various combinations of such components.

An “effective amount” is an amount of the compound(s) or the pharmaceutical composition as described herein that increases antigen presentation. The amount alleviates symptoms as found for the disease and/or condition.

The invention also includes a method for treating a subject at risk for infectious diseases or cancer, wherein a therapeutically effective amount of an annexin core domain conjugate is provided. Being at risk for the disease can result from, e.g., a family history of the disease, a genotype which predisposes to the disease, or phenotypic symptoms which predispose to the disease.

The mammalian patient can be a rat, mouse, goat, rabbit, sheep, horse, monkey or human, preferred is a mouse, rat or human.

Yet another preferred aspect of the present invention then relates to a kit, comprising materials for vaccination according to the present invention as described herein, in one or separate containers, preferably comprising a screening tool according to the present invention. Optionally, the kit comprises instructions for performing a method according to the present invention as described herein.

The kit may further comprise one or more of (iii) a buffer, (iv) a diluent, (v) a filter, (vi) a needle, or (v) a syringe. The container is preferably a bottle, a vial, a syringe or test tube; and it may be a multi-use container. The container may be formed from a variety of materials such as glass or plastic. Preferably the kit and/or container contain/s instructions on or associated with the container that indicates directions for reconstitution and/or use.

Preferred is a kit according to the present invention, wherein said kit comprises materials for a method selected from the group of Western blots and/or Enzyme-Linked Immunosorbent Assay (ELISA). For example, the label may indicate that the lyophilized formulation is to be reconstituted to certain antibody concentrations as suitable for the above methods, such as ELISA.

Further preferred is the use according to the present invention, wherein said kit comprises monoclonal antibodies or fragments thereof specific for the annexin core domain and/or functional parts and variants thereof as described herein.

The following figures, sequences, and examples merely serve to illustrate the invention and should not be construed to restrict the scope of the invention to the particular embodiments of the invention described in the examples. All references as cited herein are hereby incorporated in their entirety by reference.

Figure 1 shows that a fusion protein containing the annexin core domain and the model antigen ovalbumin (Anx-OVA) leads to strongly enhanced antigen cross-presentation in MHC class I molecules on dendritic cells (DC) compared to the antigen OVA alone. A) Schematic presentation of the experiment. Murine bone marrow derived DC were incubated with OVA or Anx-OVA. Cross presented OVA-derived peptide SIINFEKL (SEQ ID NO: 4) within MHC I molecules on DC was detected by a specific antibody (anti-MHC-SIINFEKL, antibody 25-D1.16, eBioscience). B) Representation of DC positive for cross presented OVA-derived peptide SIINFEKL, as detected in flow cytometry after incubation with equal amounts (500 nM) of OVA or Anx-OVA for 12 h. N=3.

Figure 2 shows that incubation of DC with a fusion protein containing the annexin core domain and the model antigen ovalbumin (Anx-OVA) leads to strongly enhanced CD8+ T cell activation compared to incubation with the antigen OVA alone. A) Schematic presentation of the experiment. Murine bone marrow derived DC were incubated with OVA or Anx-OVA. CD8+ T cell activation was detected using CD8+ OT-I T cells that carry a transgenic T cell receptor specific for the OVA-derived SIINFEKL (SEQ ID NO: 4) peptide. T cell activation was detected by secretion of Interferon-γ (IFN-γ). B) Murine bone marrow derived DC were incubated with equal amounts of OVA or Anx-OVA, or with purified SIINFEKL-peptide as positive control. After 12 h of incubation, DC were co-cultured for further 3-5 days with OT-I T cells. OT-I T cell activation was detected by measuring IFN-γ secretion in ELISA. N=3.

Figure 3 shows that incubation of DC with a fusion protein containing the annexin core domain and the model antigen ovalbumin (Anx-OVA) leads to strongly enhanced CD4+ T cell activation compared to incubation with the antigen OVA alone. A) Schematic presentation of the experiment. Murine bone marrow derived DC were incubated with OVA or Anx-OVA. CD4+ T cell activation was detected using CD4+ OT-II T cells that carry a transgenic T cell receptor specific for the OVA-derived ISQAVHAAHAEINEAGR (SEQ ID NO: 5) peptide, T cell activation was detected by secretion of Interleukin-2 (IL-2). B) Murine bone marrow

derived DC were incubated with equal amounts of OVA or Anx-OVA. After 12 h of incubation, DC were co-cultured for 1 day with OT-II T cells. OT-II T cell activation was detected by measuring IL-2 secretion in ELISA.

Figure 4 shows that incubation of DC with a fusion protein containing the annexin core domain and the model antigen ovalbumin (Anx-OVA) leads to strongly enhanced CD4+ T cell activation compared to incubation with the antigen OVA alone. A) Schematic presentation of the experiment. Murine bone marrow derived DC were incubated with OVA or Anx-OVA. CD4+ T cell activation was detected using CD4+ OT-II T cells that carry a transgenic T cell receptor specific for the OVA-derived ISQAVHAAHAEINEAGR (SEQ ID NO: 5) peptide, T cell activation was detected by secretion of Interferon-γ (IFN-γ). B) Murine bone marrow derived DC were incubated with equal amounts of OVA or Anx-OVA. After 12 h of incubation, DC were co-cultured for further 3-5 days with OT-II T cells. OT-II T cell activation was detected by measuring IFN-γ secretion in ELISA.

Figure 5 shows that various annexins bind to the receptor LRP-1 with high affinity. Binding of the indicated recombinant annexins and the annexin A1 core domain to immobilized LRP-1 was detected by quartz crystal microbalance. Recombinant annexins were analyzed at 3 different concentrations. Depicted are fitted binding curves of the indicated annexins and the annexin A1 core domain to LRP-1. The calculated affinities for all annexins and the core annexin A1 domain range from 50-300 nM. Murine annexin A1 (mAnxA1): filled circles; murine annexin A1 core domain (mAnxA1 core): open circles; murine annexin A5 (mAnxA5): filled squares; murine annexin A13 (mAnxA13): open squares.

Figure 6 shows that several annexins bind to the receptor Dectin-1 with high affinity. A) Analysis of the binding of recombinant annexin A1 (Annexin I) and annexin A5 (Annexin V) to the indicated, immobilized C-type lectin molecules in ELISA. B) Surface plasmon resonance spectroscopy sensorgrams of the binding of murine annexin A1, annexin A5, annexin A13 and the annexin A1 core domain to the surface molecule Dectin-1. The indicated concentrations of the indicated recombinant annexins were allowed to bind to immobilized Dectin-1 and bound molecules were measured by surface plasmon resonance. Annexin affinities to Dectin-1 were calculated to be in the nanomolar range (~100 nM).

Figure 7 shows the domain structures of representative annexin proteins. Orthologs of the 12 human annexins shown in other vertebrates have the same structures, with strict conservation of the four repeats in the core region (black) and variation in length and sequence in the amino-terminal regions (shaded). Human ANXA1 and ANXA2 are shown as dimers, with the member of the S100 protein family that they interact with. Domain structures for other model organisms are derived from public data made available by the relevant genome-sequencing projects. Features: S100Ax, sites for attachment of the indicated member of the S100 family of calcium-binding proteins; P, known phosphorylation sites; K, KGD synapomorphy (a conserved, inherited characteristic of proteins); I, codon insertions (+x denotes the number of codons inserted); S-A/b, nonsynonymous coding polymorphisms (SNPs) with the amino acid in the major variant (A) and that in the minor variant (b); N, putative nucleotide-binding sites; D, codon deletions (-x denotes the number of codons deleted); A, alternatively spliced exons; Myr, myristoylation. The total length of each protein is indicated on the right. Taken from Moss and Morgan. The annexins. Genome Biol. 2004; 5(4): 219.

Figure 8 shows the accession numbers in FASTA format and an alignment of the protein sequences of human and murine annexins A1, A5 and A13. The conserved sequence of the core domain of the annexins is boxed. An * (asterisk) indicates positions which have a single, fully conserved residue. A : (colon) indicates conservation between groups of strongly similar properties. A . (period) indicates conservation between groups of weakly similar properties.

Figure 9 demonstrates that vaccination with a fusion protein containing the annexin core domain and the model antigen ovalbumin (Anx-OVA) strongly improves vaccination efficacy compared to antigen OVA alone. A) Schematic presentation of the experiment. C57BL/6 wt mice were immunized with 400 pMol OVA or Anx-OVA per animal. Induction of antigen (OVA)-specific CD8+ T cells was detected 7 days after vaccination using fluorescently labeled SIINFEKL - MHC class I tetramers. B) and C) Results indicating the frequency of OVA-specific CD8+ T cells within all CD8+ T cells after indicated vaccinations as average of 3 mice per group (B) and for each animal individually (C). OVA: ovalbumin, Anx-OVA: Fusionsprotein containing the annexin core domain, a linking sequence and ovalbumin,
- : no vaccination

Figure 10 shows the DNA-sequence [SEQ ID NO: 13] (A) and amino acid sequence [SEQ ID NO: 14] (B) of the Anx-OVA fusionprotein used for vaccination. light grey shading: human Annexin A1-core domain; no shading: linker sequence; dark grey shading: ovalbumin (OVA).

SEQ ID Nos. 1 to 3 and 6 to 8 show the sequences of the human and mouse annexin 1, 5, and 13, respectively, as used in the context of the present invention.

SEQ ID Nos. 4 and 5 show peptide sequences as used in the context of the present invention.

SEQ ID Nos: 9 to 12 show primer sequences as used in the present invention.

Examples

Sequences

The sequences are as follows:

SeqID	UniProt Protein ID	Range	referred to in the text
1	P04083	41-344	human Annexin A1 core domain
2	P08758	14-317	human Annexin A5 core domain
3	P27216	13-316	human Annexin A13 core domain
4	P01012	257-267	ova peptide SIINFEKL
5	P01012	323-339	ova peptide ISQAVHAAHAEINEAGR
6	P10107	41-344	murine Annexin A1 core domain
7	P48036	12-315	murine Annexin A5 core domain
8	Q99JG3	14-317	murine Annexin A13 core domain

Mice.

C57BL/6 mice were purchased from the Jackson Laboratory. All mice were maintained in specific-pathogen-free facilities.

Cells.

For differentiation of BM precursors to BMDCs using recombinant murine GM-CSF, 1 x 10^6 cells were seeded at a density of 1 x 10^6 cells/ml in RPMI 1640 complete medium (10% FCS, 10 U/ml penicillin/streptomycin, 300 mg/l L-glutamine, 20 ng/ml GM-CSF (Immunotools)) in a 24-well plate. After 2 days the medium was replaced by fresh medium. After 4 d, half of the medium was removed and replaced by fresh medium. Experiments were conducted 7-8 d after differentiation.

Generation of recombinant core domain-antigen fusionprotein.

The mouse (m)AnxA1-OVA-pET41a plasmid was generated by cloning chicken Ovalbumin (OVA; NM_205152 or NP_990483, respectively, from amino acid 140) into a modified version of pET41a harboring a C-terminal FLAG tag, a PreScission Protease cleavage site, and a protein A tag. In addition, two flexible linkers and a Tobacco Etch Virus (TEV) cleavage site were introduced between mAnxA1 and OVA. Successive PCRs were performed using the following primers:

Fw_1:5'GGCGGAGGTTCAGGCGGAGGTTCAGATCAAGCCAGAGAGCTCATC 3'; (SEQ ID NO: 9),
Fw_2: 5' GAAAACTTGTATTTCCAGGGCGGCGGAGGTTCAGGCG 3'; (SEQ ID NO: 10),
Fw_3: 5' GGATCCGGCGGAGGTTCAGGCGGAGGTTCAGAAAACTTGTATTTCCAGGGCGG 3' (SEQ ID NO: 11) and
Rev: 5' GGATCCAGGGGAAACACATCTGCCAAAG 3' (SEQ ID NO: 12).

The final PCR product was subcloned using the pGEM® -T easy vector system from Promega. Escherichia coli BL21(DE3)pLysS strain (Promega) was used to express the fusion-protein. Overnight cultures of E. coli transformed with the vector described above were used to inoculate 4 L of LB containing 50 µg/ml kanamycin and 34 µg/ml chloramphenicol. Cultures were agitated at 180 rpm until A600nm reached 0.6. Expression was induced using 1 mM isopropyl-D-thiogalactopyranoside (IPTG) for 4 hrs at 37°C. Cells were harvested by centrifugation and stored frozen at -20°C. Cell pellets containing Protein A-tagged recombinant fusion protein were resuspended in native bacterial lysis buffer and disrupted by six cycles of freeze and thaw. Cell extract was loaded onto IgG Sepharose 6 Fast Flow beads (GE Healthcare). Removal of LPS was achieved by washing with TBS containing 0.1 % Triton X-114 (Sigma-Aldrich) as described previously (Reichelt, Schwarz et al. 2006, Zimmerman, Petit Frere et al. 2006). Triton X-114 was removed by washing with TBS containing 0.05% Tween-20. After cleavage of the fusion protein with PreScission Protease (GE Healthcare) and removal of PreScission Protease using Glutathione Sepharose Beads 4B (Amersham Biosciences), the recombinant protein was dialyzed against PBS. After sterile filtration, protein concentration was measured using BCA-Assay (Pierce) and LPS-content was determined using Limulus Amoebocyte Lysate Assay (Lonza).

Recombinant proteins were expressed in the Escherichia coli BL21(DE3)pLysS strain (Promega) from the pET41a vector (Novagen). PCR products encoding a fusionprotein of the annexin A1 core domain and full length chicken ovalbumin were cloned into pET41a harboring a C-terminal FLAG_tag, a PreScission protease cleavage site and a Protein A_tag. Bacterial lysates (10,000 x g, 4°C for 40 min) were loaded onto pre-equilibrated IgG Sepharose 6 Fast Flow beads (GE Healthcare). Removal of LPS was achieved by washing

with TBS containing 0.1% Triton X-114 (Sigma). Triton X_114 was removed by washing with TBS containing 0.05 % Tween-20 (Gerbu). After cleavage of the fusion protein with PreScission protease (GE Healthcare) and PreScission protease removal, the recombinant protein was dialysed against PBS. LPS content in all annexin A1 preparations was determined to be below 5 EU/mg using the Limulus Amoebocyte Lysate Assay (Lonza) according to the manufacturers' instructions.

Detection of antigen presentation *in vitro*.

2 x 10^5 BMDCs from C57BL/6 wildtype mice were incubated with 500 nM or the indicated amount of recombinant Ovalbumin (OVA,Sigma) or annexin core domain-OVA fusionprotein. After 8-12 h, DC were washed with PBS and incubated with a fluorescently labeled antibody against the OVA-derived peptide SIINFEKL in MHC class I (antibody 25-D1.16, eBioscience). SIINFEKL-positive cells were detected in FACS (FACS-Canto, Becton-Dickinson).

Coculture of DC and T cells and T cell activation.

2 x 10^5 BMDCs from C57BL/6 wildtype mice were incubated with 500 nM or the indicated amount of recombinant Ovalbumin (OVA,Sigma) or annexin core domain-OVA fusionprotein. After 12h, 1x 10^6 magnetically purified (Easysep, Stemcell Technologies) CD8+ or CD4+ T cells from spleens of OT-I or OT-II mice, respectively, were added to the DC cultures. After 1-2 days (Interleukin-2) or 3-5 days (Interferon-γ) indicated cytokines were determined in the culture supernatants by ELISA (Becton-Dickinson).

Measuring the affinity of the binding between Annexin and LRP-1.

For measuring the affinity of the binding of LRP-1 to different annexins (annexin A1, A5, and A13) the device A100 (ATTANA) was used. LRP-1 was immobilized on an LNB carboxychip according to the manufacturers' instructions. In order to achieve this, first, the chip was activated with EDC/SulfoNHS according to the manufacturers' instructions, and then purified LRP1 (5-15 µg/ml) in a sodium acetate buffer (pH 4.0) was injected onto the chip until an increase of the frequency at 70-100 Hz was reached. Then, remaining binding spots on the chip were saturated using two injections of ethanolamine, and the chip was buffered in PBS. For the incubation with the different annexins, they were prepared in six different concentrations in PBS with 2mM calcium, and measured in triplicates. After each

Anx-injection the chip was regenerated with 5 mM EDTA/PBS and 3M NaCl before the next Anx-injection.

Annexin binding measurement for different receptors by ELISA.

To test for binding to annexins, putative receptor molecules, fragments thereof or fusion proteins (*e.g.* LRP-11, single LRP-1 domains or Dectin-1 Fc protein) are immobilized on an ELISA plate at 10 µg/ml in coating buffer (Carbonate-Bicarbonate - 1.5 g $Na_2 CO_3$; 2.93 g $NaH CO_3$; Distilled water, 1 liter, pH to 9.6). After washing (3x PBS Tween 0.01%) and blocking (1% Casein in PBS), different concentrations of recombinant annexins are incubated in the wells for 2h, followed by 5 wash steps (PBS-Tween 0.05%). Bound annexins are then detected by suitable secondary reagents (*e.g.* horse radish peroxidase (HRP) labeled secondary antibodies or biotin-labeled secondary antibodies plus streptavidin-labeled HRP) to the recombinant annexin-proteins and measured by reactivity with a suitable substrate (e.g. OPD) in an ELISA plate reader. The assay can also be performed by immobilizing different annexins on a plate and probing with recombinant receptor molecules, fragments thereof or fusion proteins (*e.g.* LRP-11, single LRP-1 domains or Dectin-1 Fc protein).

Binding affinity measurements for annexin – Dectin 1 by surface plasmon resonance.

Surface plasmon resonance (SPR) is a valuable tool for analyzing receptor ligand interactions in real time and for providing insights into the affinity and kinetics of binding. SPR is a technique for measuring the association and dissociation kinetics of ligand, termed analyte, with a receptor. The analyte or the receptor can be immobilized on a sensor chip which bears a gold film. The association of the analyte and receptor with one or the other, depending which one is immobilized, induces a change in the refractive index of the layer in contact with the gold film. This is measured as a change in the refractive index at the surface layer and is recorded as the SPR signal in resonance units (RU). For the preparation of Dectin-1-coated surfaces, Dectin-1 was immobilized at a flow rate of 10 µl/min. The CM5 chip was activated by injection of a mixture of N-ethyl-N'-(diethylaminopropyl)- carbodiimide (EDC) and N-hydroxysuccinimide (NHS) for 10 minutes and functionalized by injecting 100 µg/mL and 10 µg/mL Dectin- 1 in acetate buffer pH 5.5 for 7 minutes. The remaining activated carboxyl groups were then capped by injection of 1 M ethanolamine for 10 minutes. Control flow cells were treated with EDC/NHS followed by ethanolamine as described. Concentration gradients of the different annexins were injected over the Dectin-1-functionalized surfaces at 10 µL/min, allowing 60 seconds for contact and 300 seconds for dissociation times, followed

by regeneration using 100 mM methyl-α-D-mannopyranoside at 30 µL/min for 30 seconds. Experimental data were analyzed using Biacore S20 T100 Evaluation Software. Kinetic analyses based on a 1:1 interaction model for the annexin-dectin-1 complexes interaction were performed using Scrubber2 (BioLogic Software, Campbell, Australia).

In figure 9 an *in vivo* experiment demonstrates that vaccination with a fusion protein containing the annexin core domain and the model antigen ovalbumin (Anx-OVA) strongly improves vaccination efficacy compared to antigen OVA alone.

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Claims

1. An isolated annexin core domain comprising an amino acid sequence of a core domain as comprised in a sequence selected from the group of SEQ ID Nos. 1 to 3 and 6 to 8, or an amino acid sequence that is at least 50% identical to an amino acid sequence of an annexin core domain as comprised in a sequence selected from the group of SEQ ID Nos. 1 to 3 and 6 to 8.

2. A protein conjugate or fusion protein comprising (i) at least one annexin core domain according to claim 1, and (ii) at least one antigenic peptide that is presented by MHC, preferably HLA.

3. The protein conjugate or fusion protein according to claim 2, wherein said antigen is derived from a protein selected from the group consisting of βhCG, gp100 or Pmel17, HER2/neu, WT1, mesothelin, CEA, gp100, MART1, TRP-2, NY-BR-1, NY-CO-58, MN (gp250), idiotype, Tyrosinase, Telomerase, SSX2, MUC-1, MART1, melan-A, NY-ESO-1, MAGE-1, MAGE-3, MAGE-A3, and high molecular weight-melanoma associated antigen (HMW-MAA).

4. The protein conjugate or fusion protein according to claim 2 or 3, wherein said conjugate or said fusion protein is further conjugated/fused to a co-stimulatory molecule or an immunogenic fragment thereof or a costimulatory second peptide sequence.

5. A nucleic acid encoding for the fusion protein according to any one of claims 1 to 4.

6. The nucleic acid according to claim 5, wherein the coding sequence of the antigen is encoding for an antigen derived from a protein selected from the group consisting of βhCG, gp100 or Pmel17, HER2/neu, WT1, mesothelin, CEA, gp100, MART1, TRP-2, NY-BR-1, NY-CO-58, MN (gp250), idiotype, Tyrosinase, Telomerase, SSX2, MUC-1, MART1, melan-A, NY-ESO-1, MAGE-1, MAGE-3, MAGE-A3, and high molecular weight-melanoma associated antigen (HMW-MAA).

7. The nucleic acid according to claim 5 or 6, wherein said coding sequence is fused to at least one DC-stimulatory nucleic acid sequence.

8. A recombinant expression vector expressing the nucleic acid according to any one of claims 5 to 7.

9. A pharmaceutical composition comprising the protein conjugate or fusion protein of any one of claims 2 to 4, or the nucleic acid according to any one of claims 5 to 7, or the expression vector according to claim 8, and a carrier.

10. The pharmaceutical composition according to claim 9, which is a vaccine.

11. The pharmaceutical composition according to claim 9 or 10 for use in treatment or prevention of an infectious disease or cancer in a subject.

12. A method for treating or preventing an infectious disease or cancer in a subject comprising administering to said subject the pharmaceutical composition according to claim 9 or 10.

Figure 1A

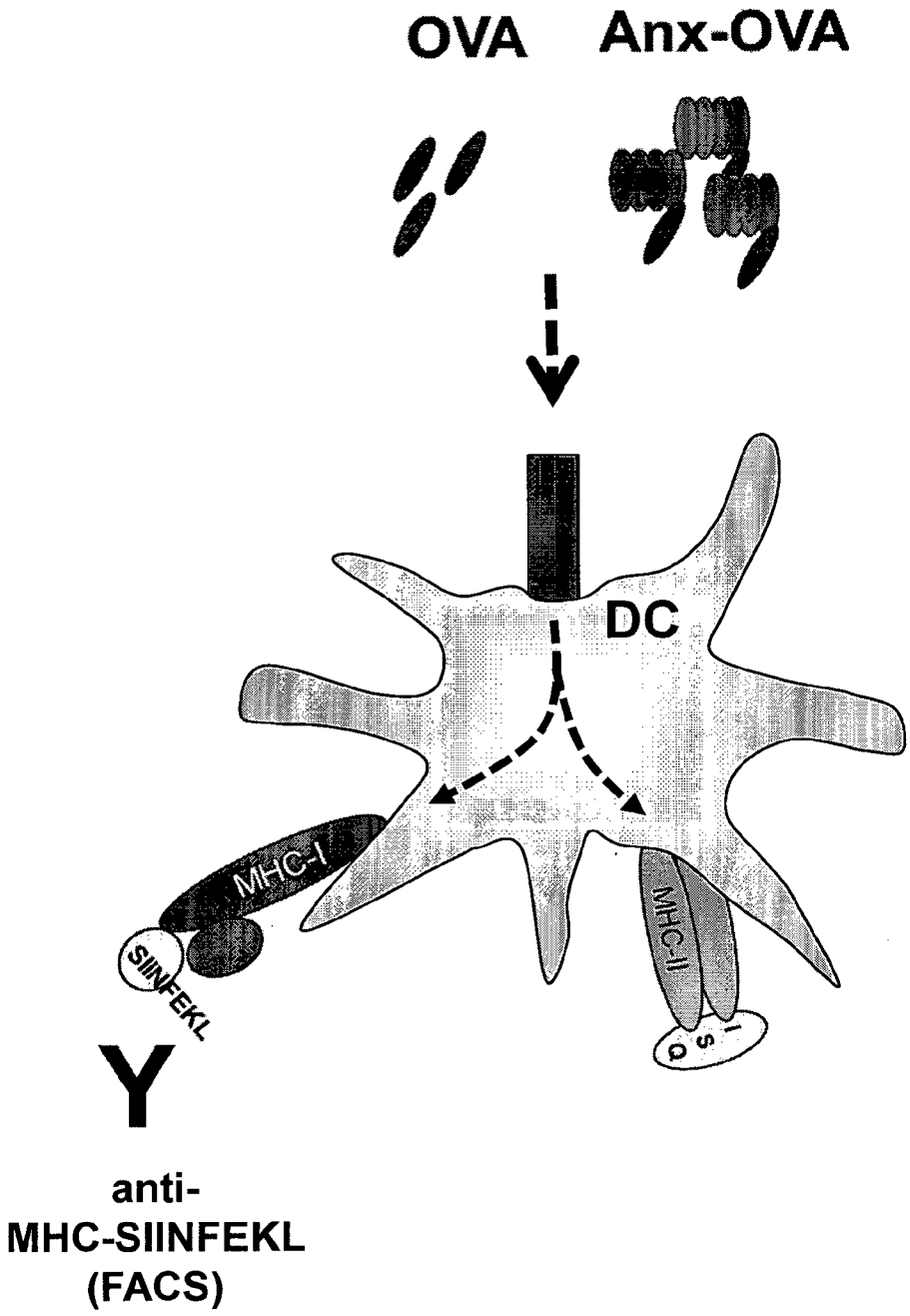
OVA
Anx-OVA
DC
MHC-I
SIINFEKL
MHC-II
I
s
o
Y
anti-
MHC-SIINFEKL
(FACS)

Figure 1B

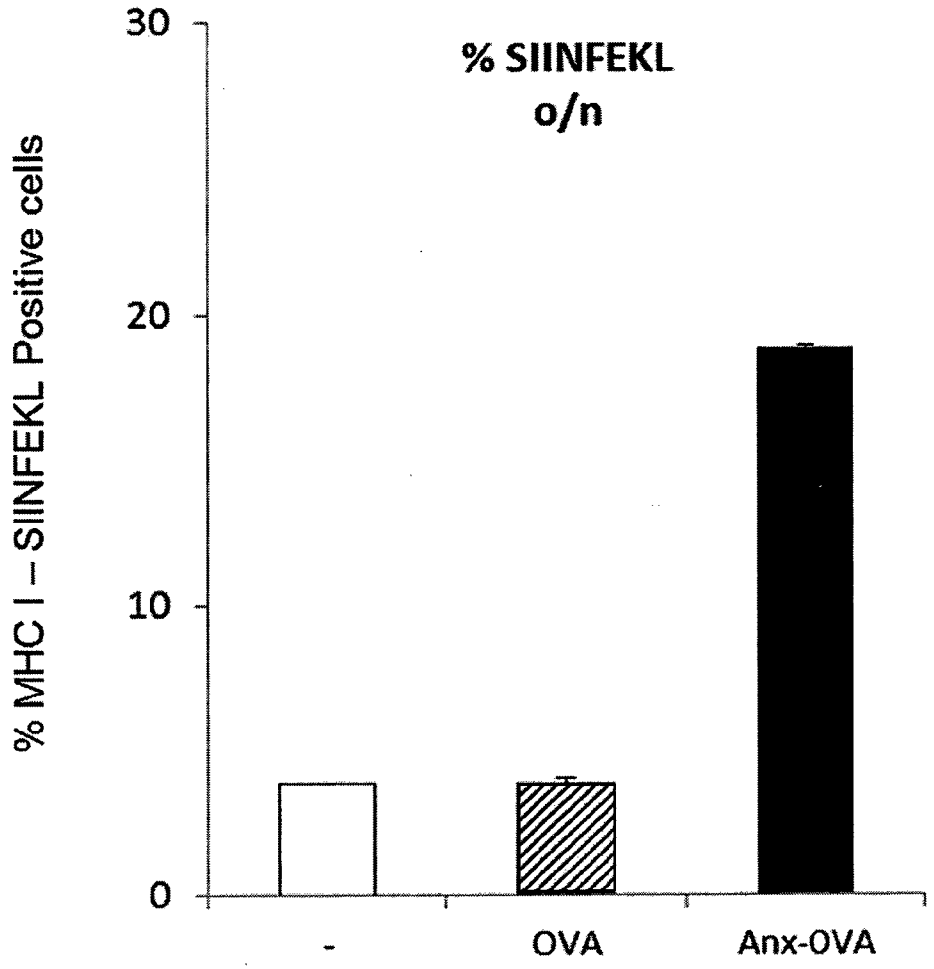
% SIINFEKL
o/n
% MHC I – SIINFEKL Positive cells
30
20
10
0
-
OVA
Anx-OVA

Figure 2A

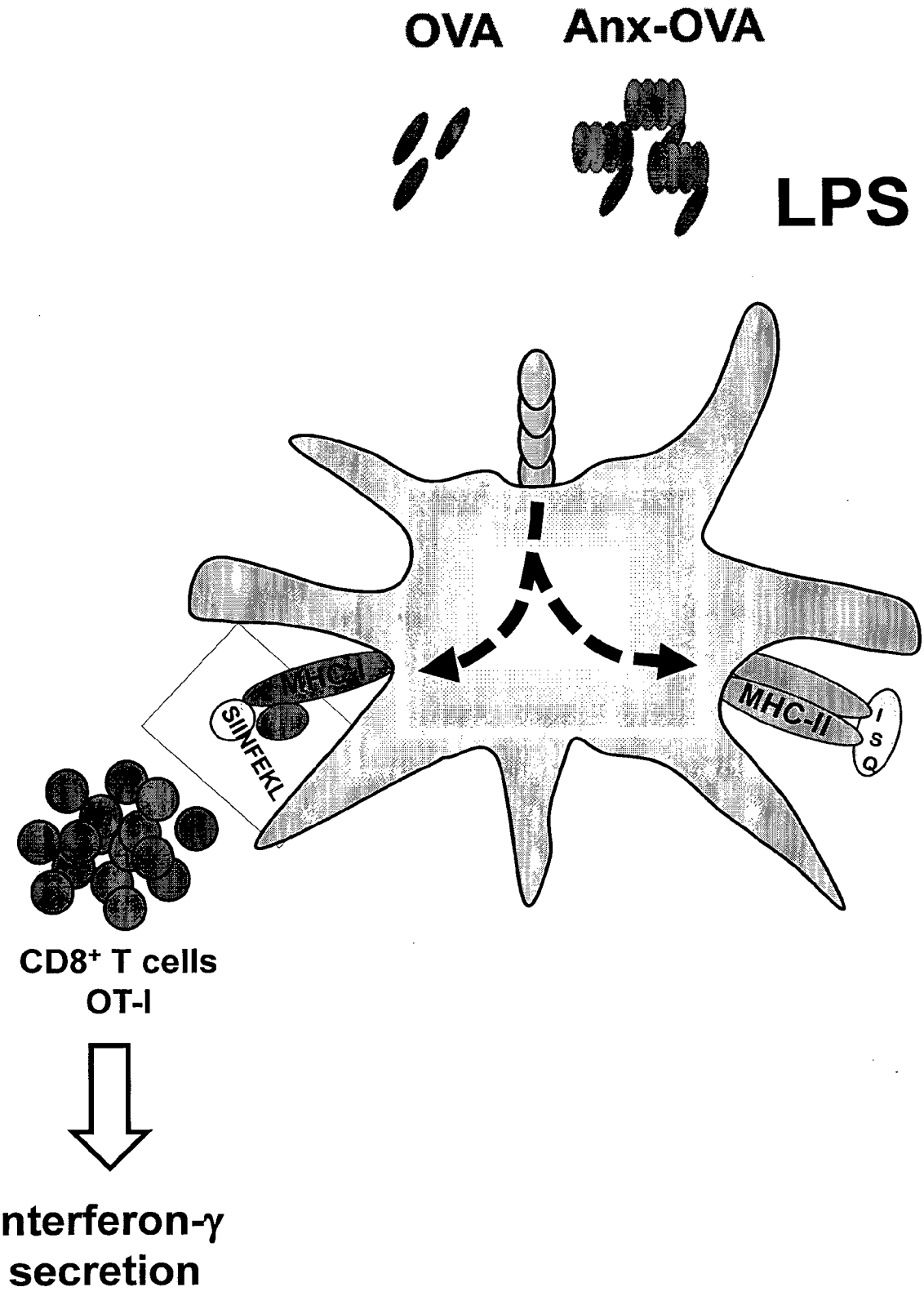
OVA
Anx-OVA
LPS
MHC-I
SIINFEKL
MHC-II
I
S
Q
CD8+ T cells
OT-I
Interferon-γ
secretion

Figure 2B

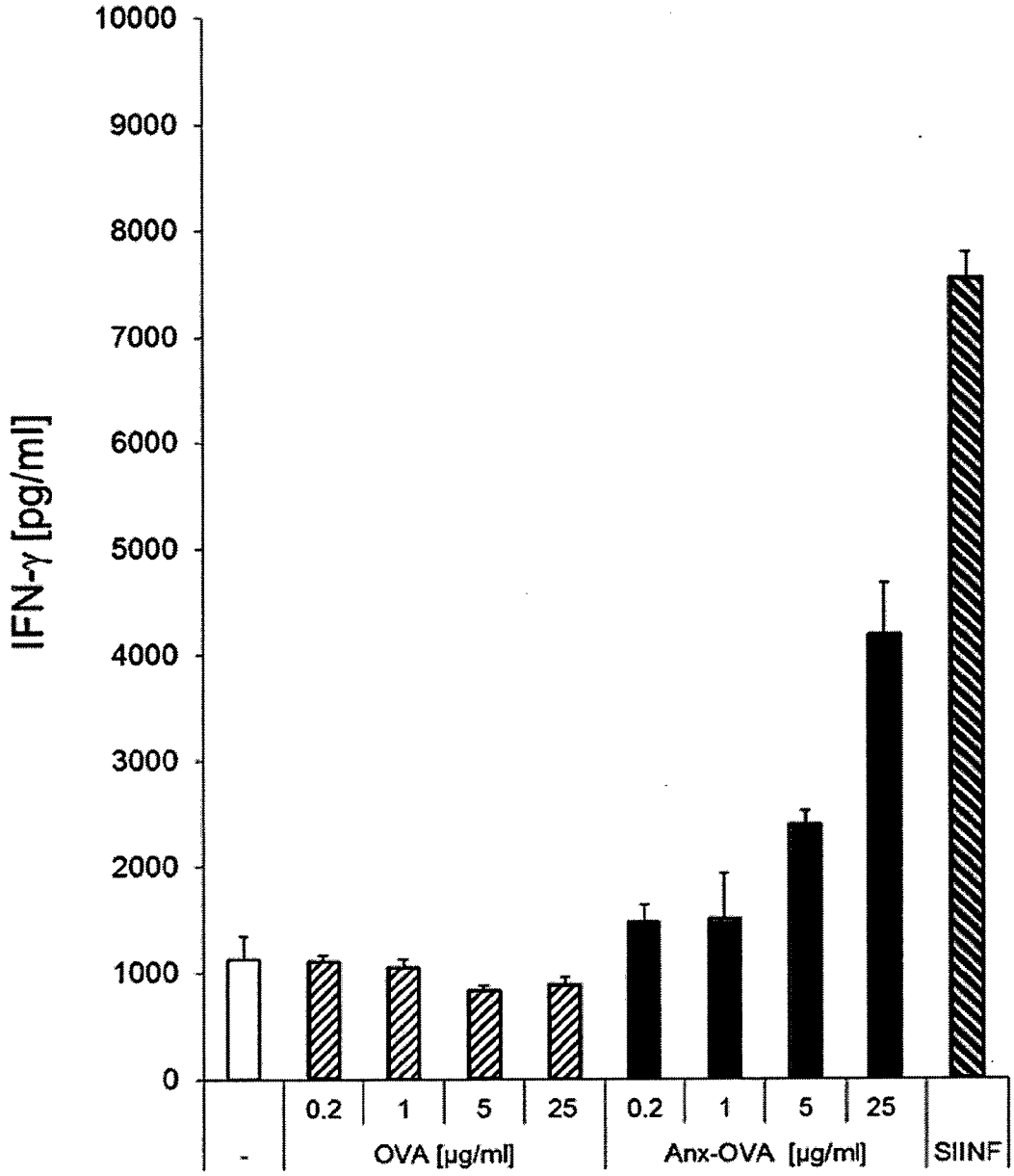
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
IFN-γ [pg/ml]
-
0.2
1
5
25
OVA [µg/ml]
0.2
1
5
25
Anx-OVA [µg/ml]
SIINF

Figure 3A

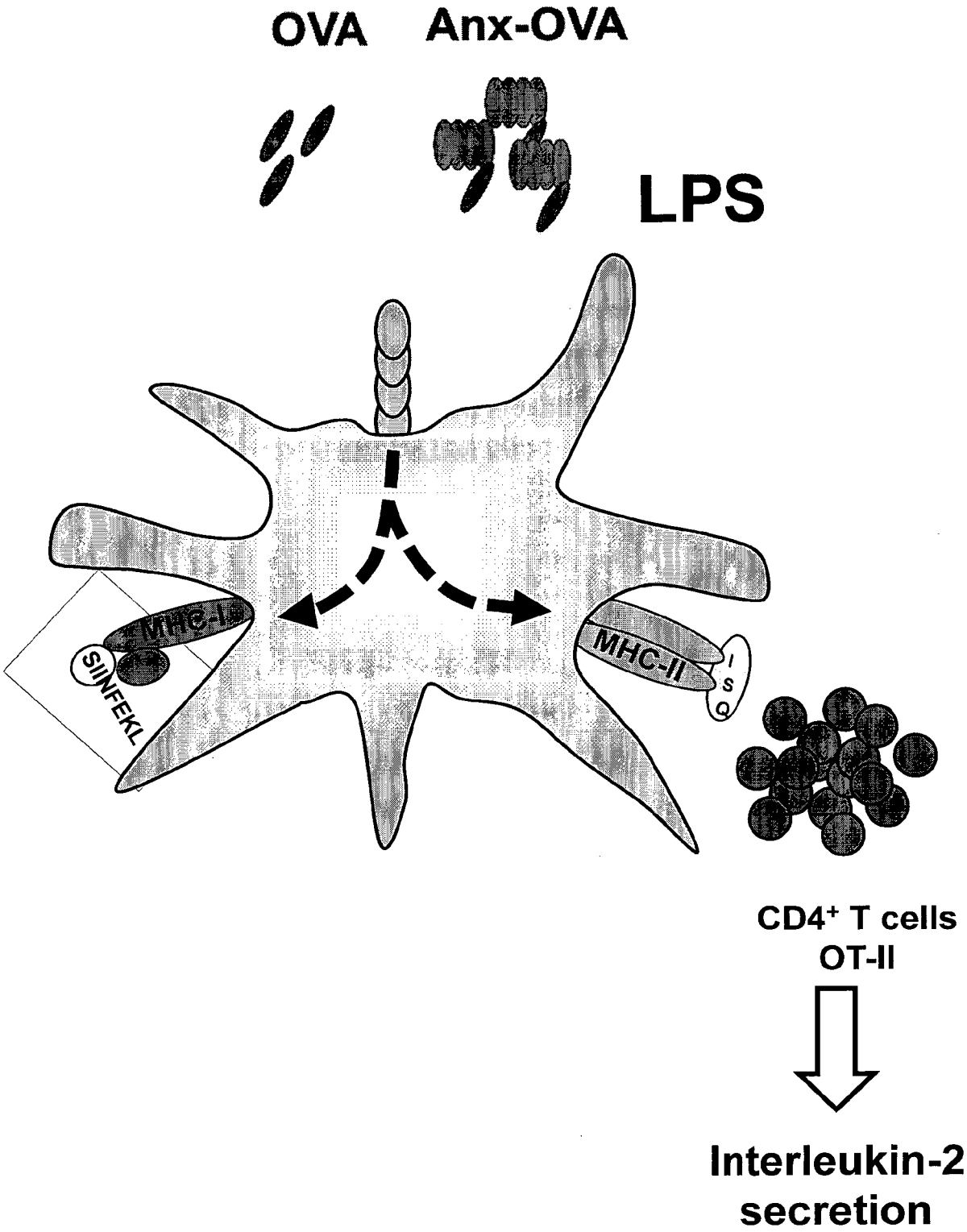
OVA
Anx-OVA
LPS
MHC-I
SIINFEKL
MHC-II
I
S
Q
CD4+ T cells
OT-II
Interleukin-2
secretion

Figure 3B

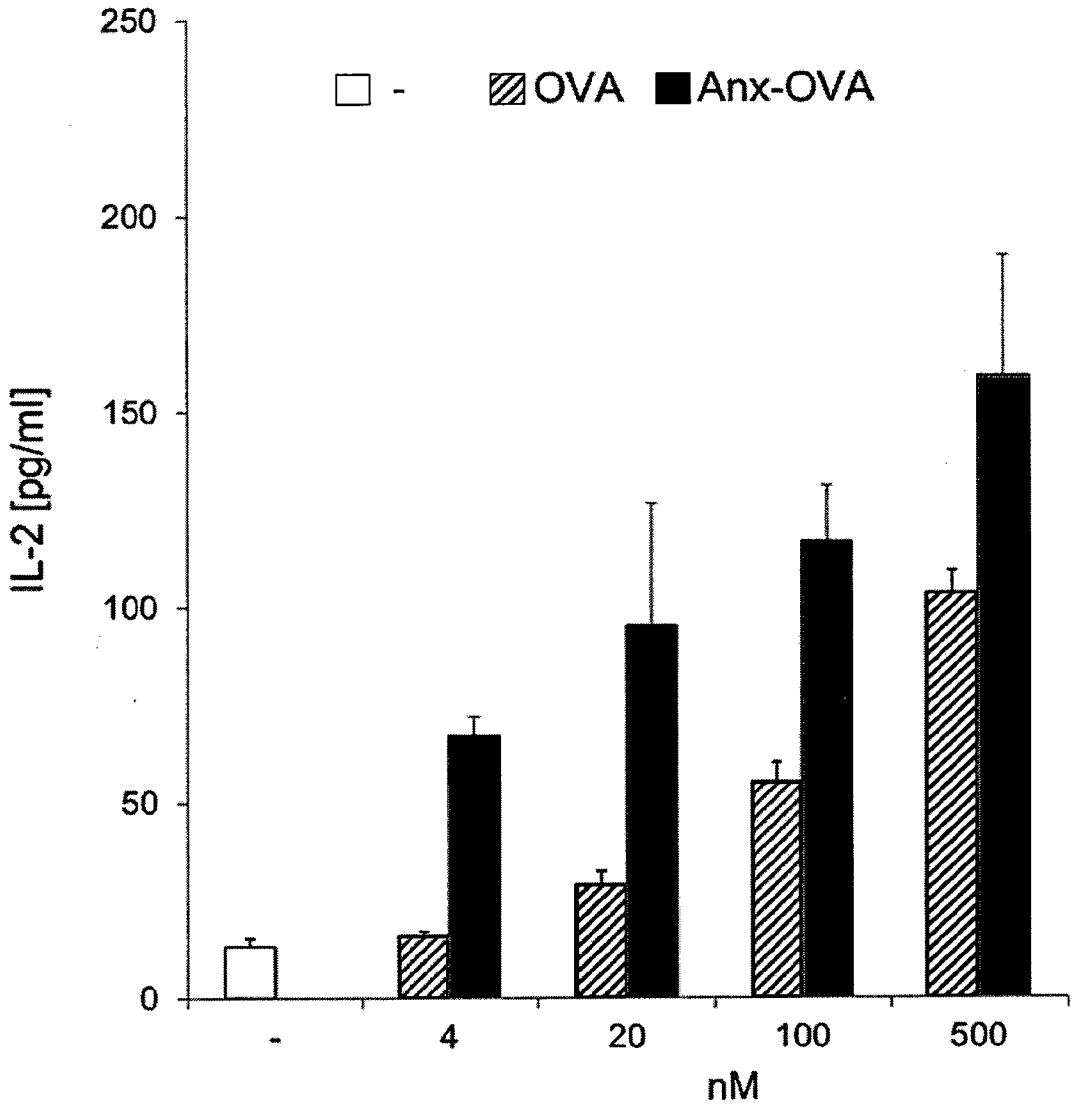

Figure 4A

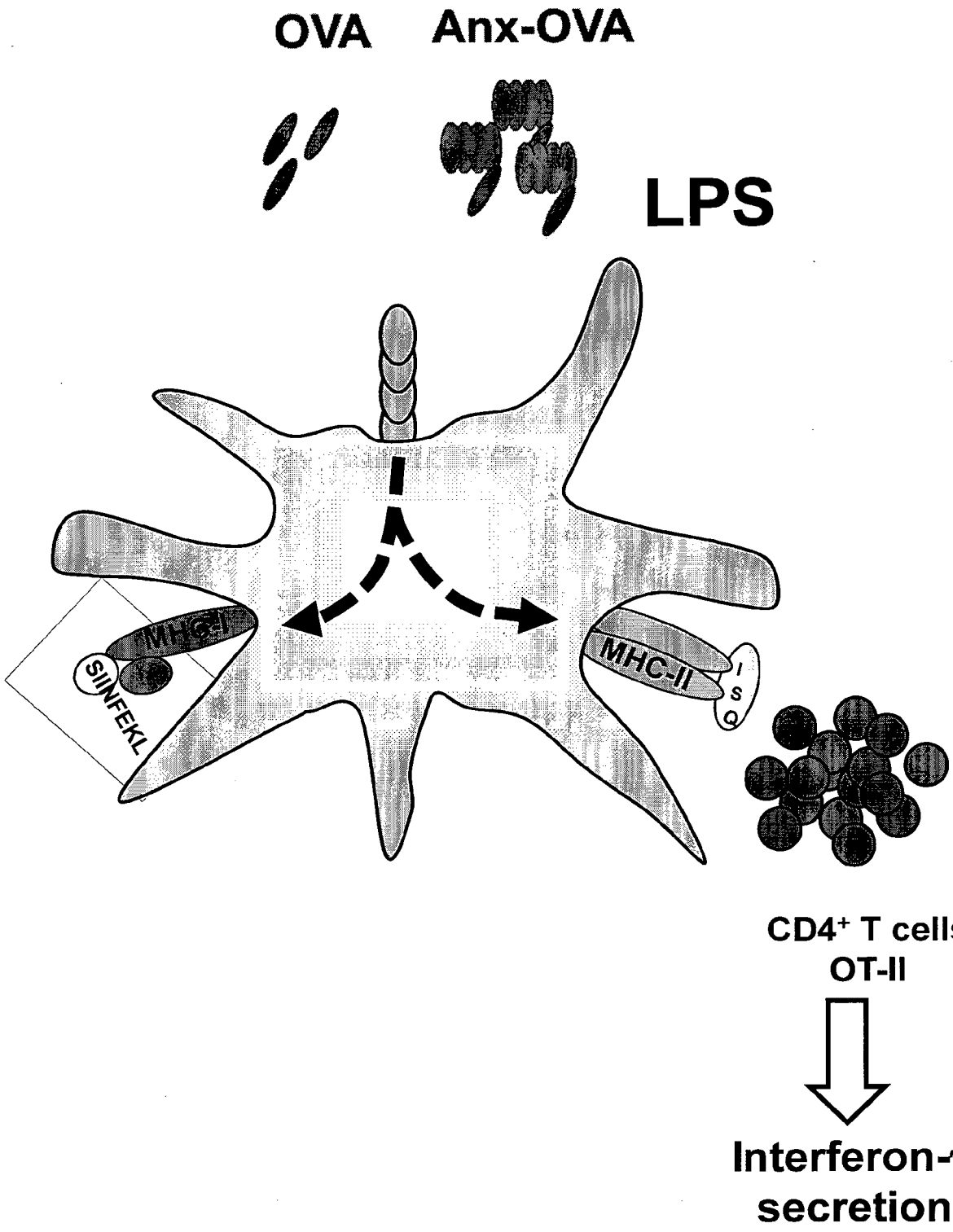
OVA
Anx-OVA
LPS
MHC-I
SIINFEKL
MHC-II
I
S
Q
CD4+ T cells
OT-II
Interferon-γ
secretion

Figure 4B

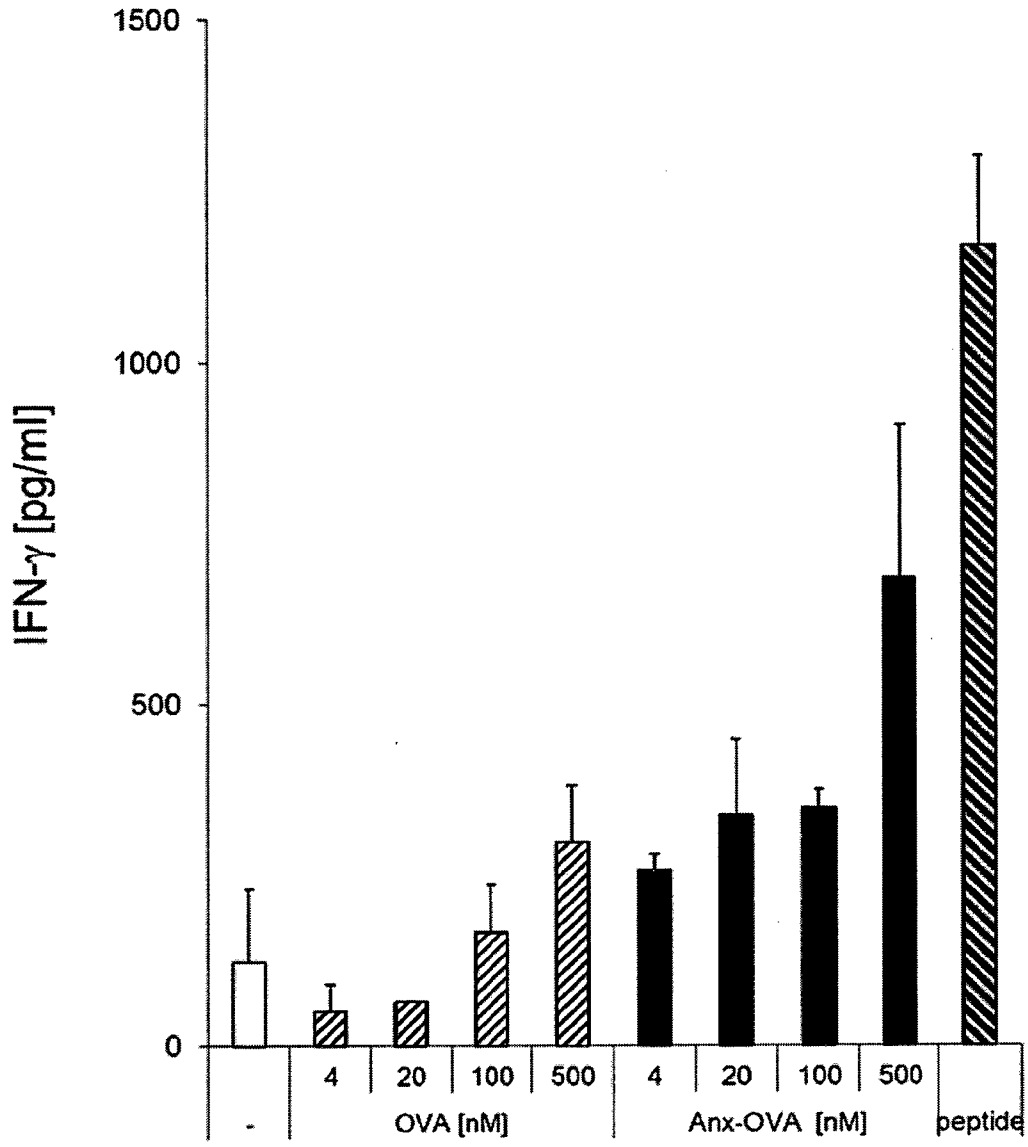
1500
1000
500
0
IFN-γ [pg/ml]
-
4
20
100
500
4
20
100
500
OVA [nM]
Anx-OVA [nM]
peptide

Figure 5

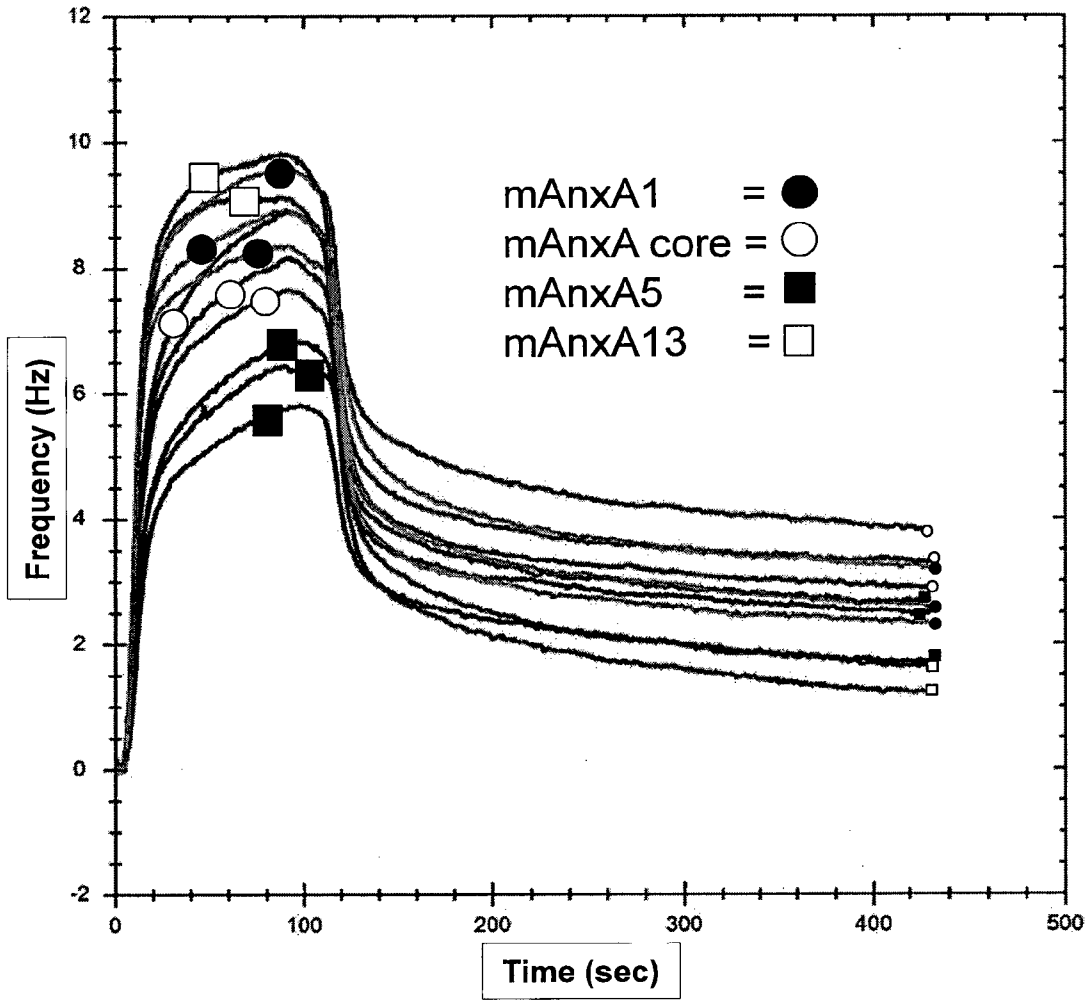
mAnxA1 = ●
mAnxA core = ○
mAnxA5 = ■
mAnxA13 = □
Frequency (Hz)
Time (sec)
12
10
8
6
4
2
0
-2
0
100
200
300
400
500

Figure 6

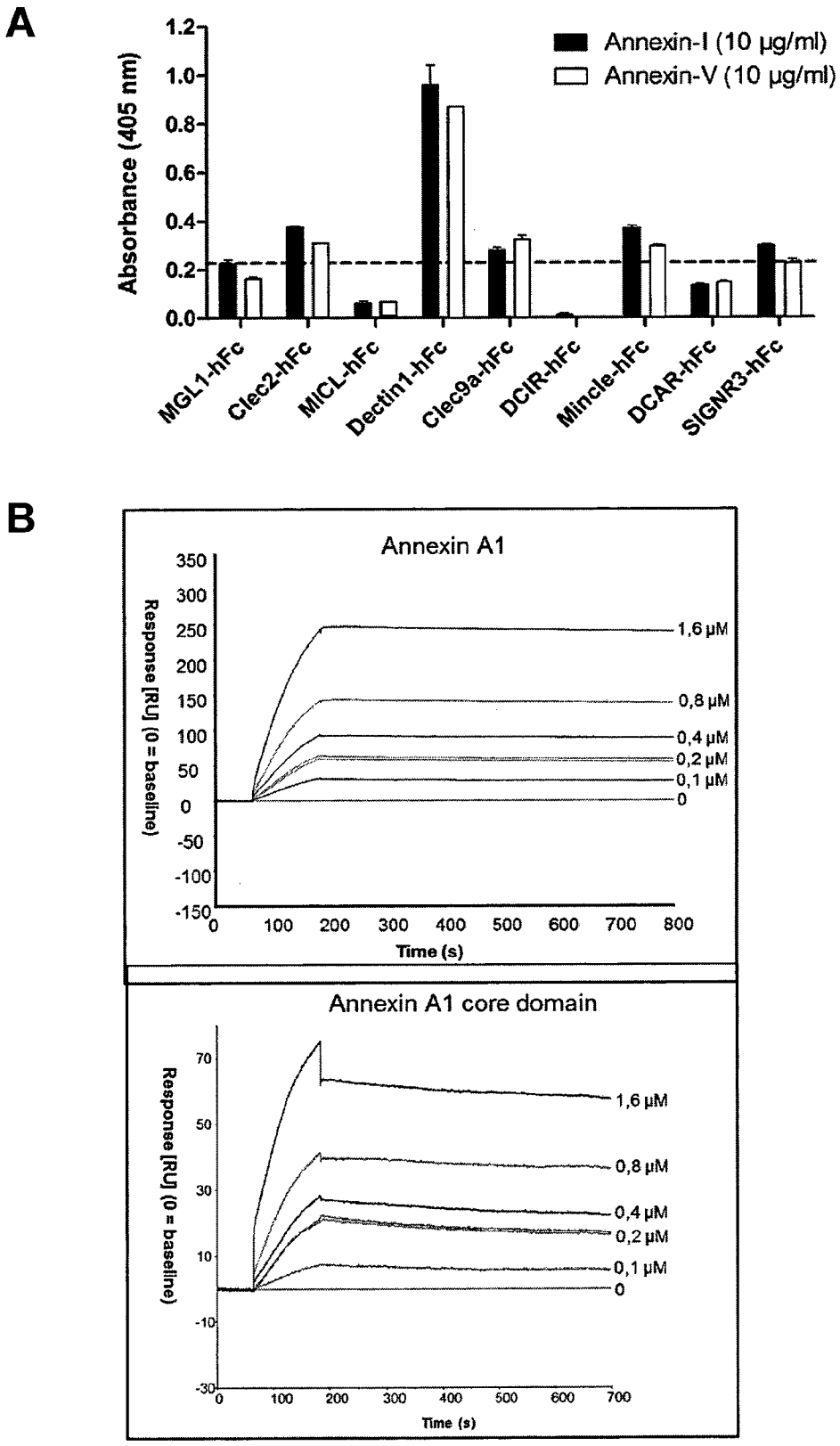
A
Absorbance (405 nm)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Annexin-I (10 µg/ml)
Annexin-V (10 µg/ml)
MGL1-hFc
Clec2-hFc
MICL-hFc
Dectin1-hFc
Clec9a-hFc
DCIR-hFc
Mincle-hFc
DCAR-hFc
SIGNR3-hFc
B
Annexin A1
Response [RU] (0 = baseline)
350
300
250
200
150
100
50
0
-50
-100
-150
1,6 µM
0,8 µM
0,4 µM
0,2 µM
0,1 µM
0
0
100
200
300
400
500
600
700
800
Time (s)
Annexin A1 core domain
Response [RU] (0 = baseline)
70
50
30
10
-10
-30
1,6 µM
0,8 µM
0,4 µM
0,2 µM
0,1 µM
0
0
100
200
300
400
500
600
700
Time (s)

Figure 6

B
(continued)

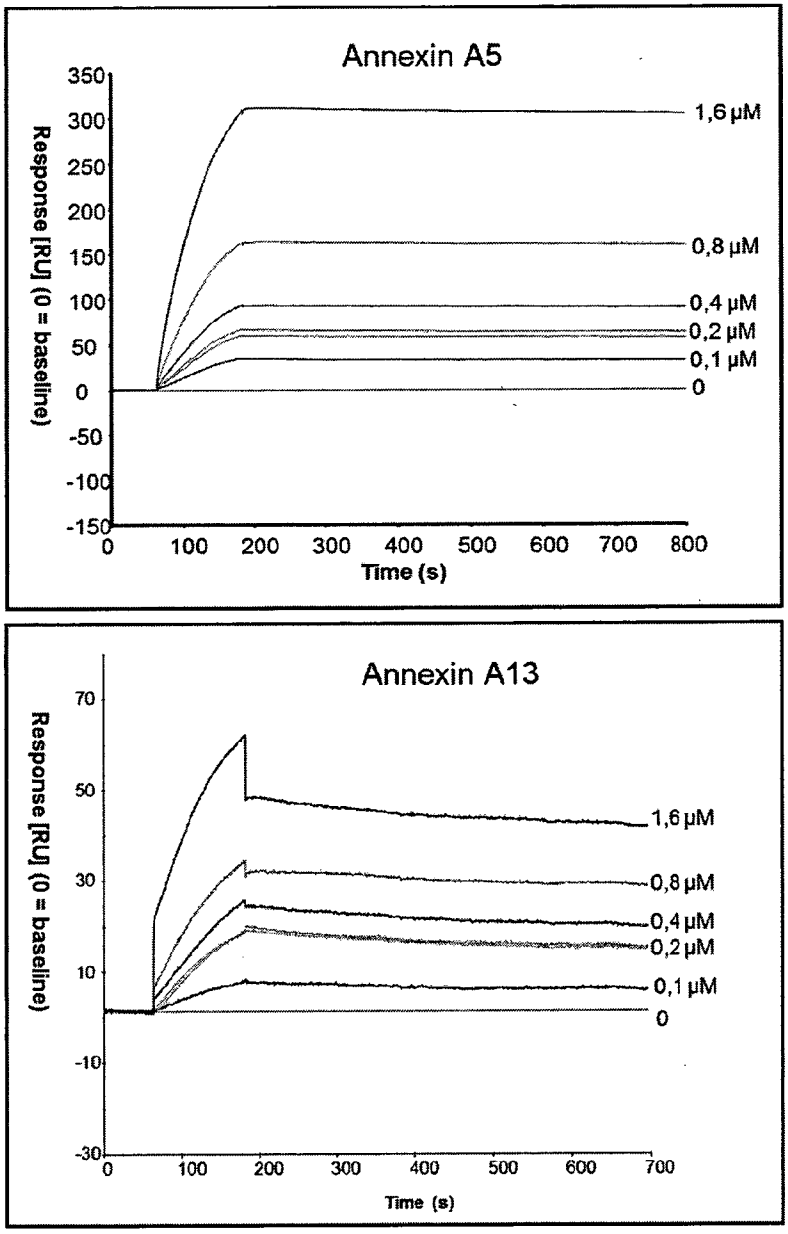

Figure 7

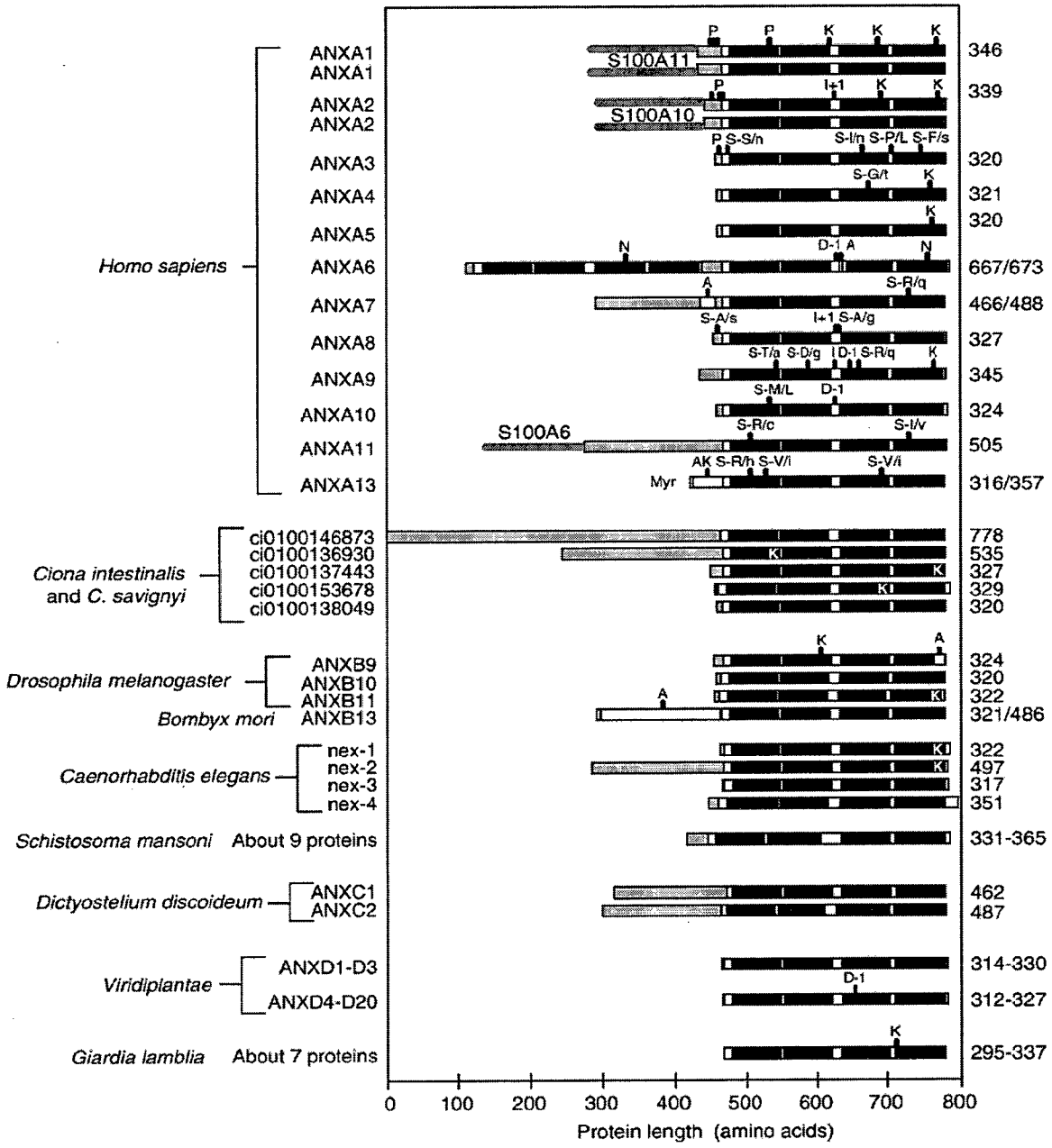
Homo sapiens
ANXA1
ANXA1
ANXA2
ANXA2
ANXA3
ANXA4
ANXA5
ANXA6
ANXA7
ANXA8
ANXA9
ANXA10
ANXA11
ANXA13
S100A11
S100A10
S100A6
346
339
320
321
320
667/673
466/488
327
345
324
505
316/357
Ciona intestinalis and C. savignyi
ci0100146873
ci0100136930
ci0100137443
ci0100153678
ci0100138049
778
535
327
329
320
Drosophila melanogaster
Bombyx mori
ANXB9
ANXB10
ANXB11
ANXB13
324
320
322
321/486
Caenorhabditis elegans
nex-1
nex-2
nex-3
nex-4
322
497
317
351
Schistosoma mansoni
About 9 proteins
331-365
Dictyostelium discoideum
ANXC1
ANXC2
462
487
Viridiplantae
ANXD1-D3
ANXD4-D20
314-330
312-327
Giardia lamblia
About 7 proteins
295-337
0
100
200
300
400
500
600
700
800
Protein length (amino acids)

Figure 8:

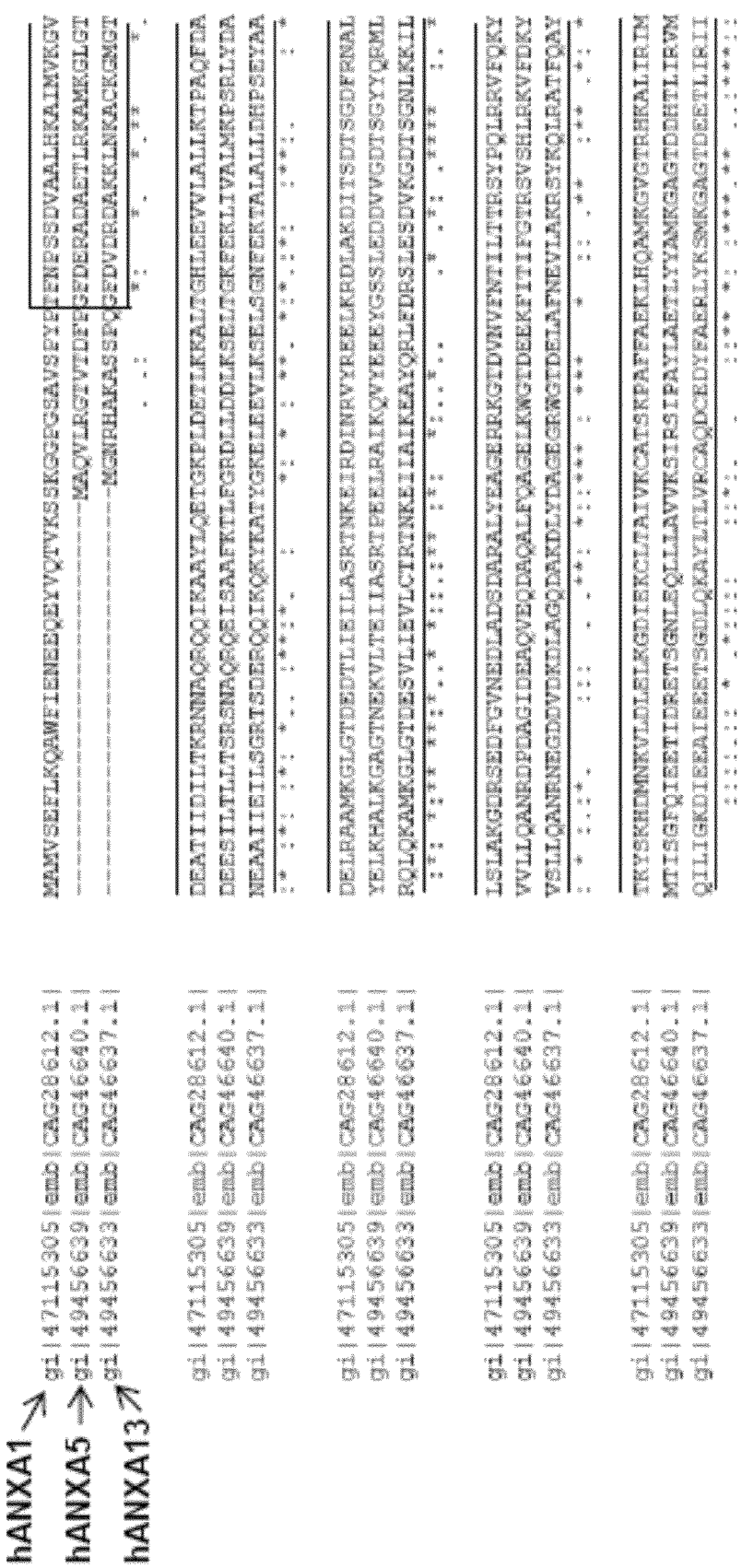
hANXA1
hANXA5
hANXA13
gi|47115305|emb|CAG28612.1|
gi|49456639|emb|CAG46640.1|
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Figure 8 (continued):

Figure 9:

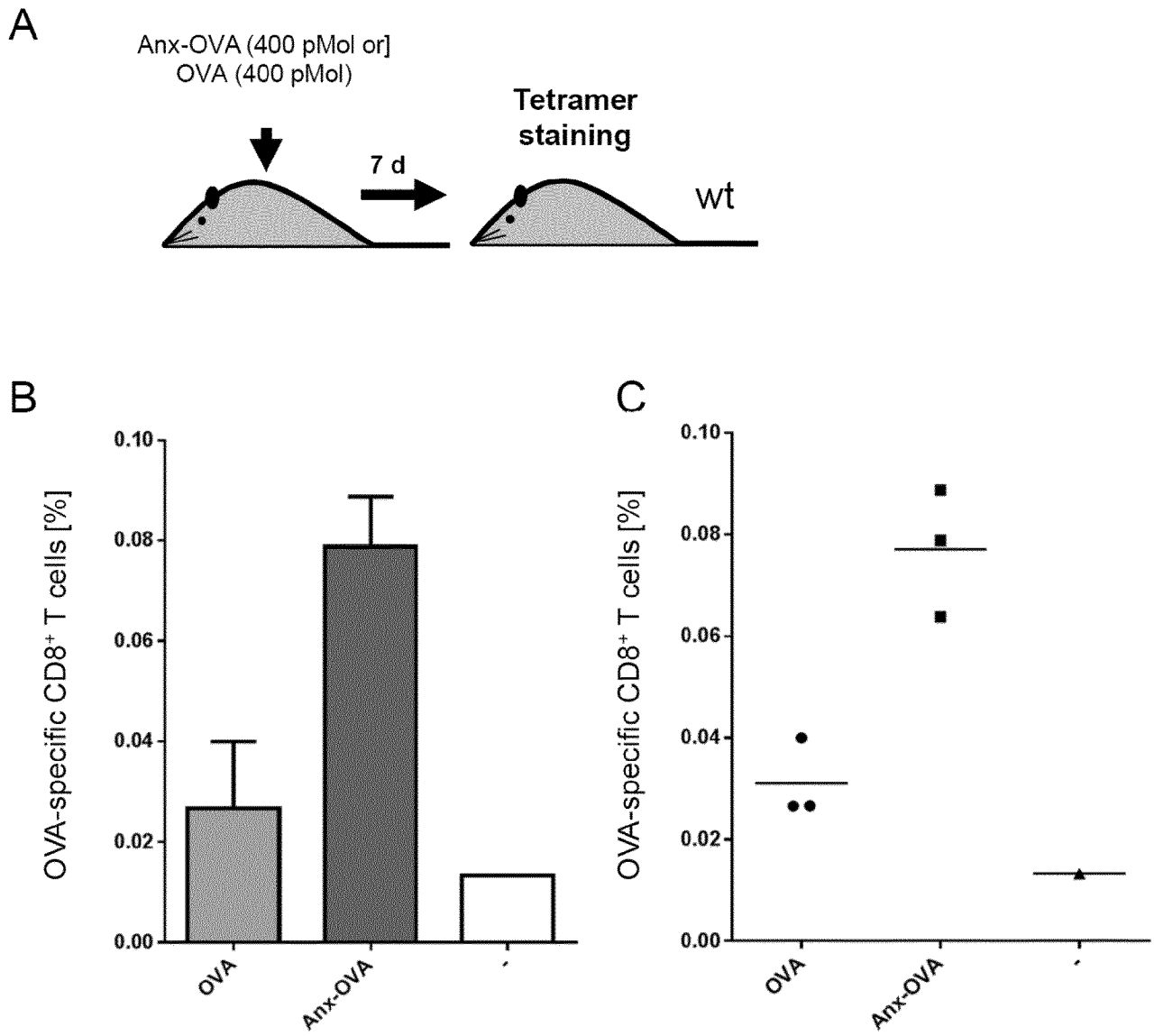
A
Anx-OVA (400 pMol or]
OVA (400 pMol)
7 d
Tetramer staining
wt
B
OVA-specific CD8+ T cells [%]
0.10
0.08
0.06
0.04
0.02
0.00
OVA
Anx-OVA
-
C
OVA-specific CD8+ T cells [%]
0.10
0.08
0.06
0.04
0.02
0.00
OVA
Anx-OVA
-

Figure 10

A) Anx-OVA fusionprotein, DNA-sequence

ATGAATCCATCCTCGGATGTCGCTGCCTTGCATAAGGCCATAATGGTTAAAGGTGTGGATGAGGCAACCATCATT
GACATTCTAACTAAGCGAAACAATGCACAGCGTCAACAGATCAAAGCAGCATATCTCCAGGAAACAGGAAAGCCC
CTGGATGAAACACTGAAGAAAGCCCTTACAGGTCACCTTGAGGAGGTTGTTTTAGCTCTGCTAAAAACTCCAGCG
CAATTTGATGCTGATGAACTTCGTGCTGCCATGAAGGGCCTTGGAACTGATGAAGATACTCTAATTGAGATTTTG
GCATCAAGAACTAACAAAGAAATCAGAGACATTAACAGGGTCTACAGAGAGGAACTGAAGAGAGATCTGGCCAA
AGACATAACGTCAGACACATCTGGAGATTTTCGGAACGCTTTGCTTTCTCTTGCTAAGGGTGACCGATCTGAGGA
CTTTGGTGTGAATGAAGACTTGGCTGATTCAGATGCCAGGGCCTTGTATGAAGCAGGAGAAAGGAGAAAGGGGA
CAGACGTAAACGTGTTCAATACCATCCTTACCACCAGAAGCTATCCACAACTTCGCAGAGTGTTTCAGAAATACAC
CAAGTACAGTAAGCATGACATGAACAAAGTTCTGGACCTGGAGTTGAAAGGTGACATTGAGAAATGCCTCACAGC
TATCGTGAAGTGCGCCACAAGCAAACCAGCTTTCTTTGCAGAGAAGCTTCATCAAGCCATGAAAGGTGTTGGAAC
TCGCCATAAGGCATTGATCAGGATTATGGTTTCCCGTTCTGAAATTGACATGAATGATATCAAAGCATTCTATCA
GAAGATGTATGGTATCTCCCTTTGCCAAGCCATCCTGGATGAAACCAAAGGAGATTATGAGAAAATCCTGGTGGC
TCTTTGTGGAGGAAAC-

catcggggatccggcggaggttcaggcggaggttcagaaaacttgtatttccagggcggcggaggttcaggcggaggttc-

GATCAAGCCAGAGAGGCTCATCAATTCCTGGGTAGAAAGTCAGACAAATGGAATTATCAGAAATGTCCTTCAGCCA
AGCTCCGTGGATTCTCAAACTGCAATGGTTCTGGTTAATGCCATTGTCTTCAAAGGACTGTGGGAGAAAGCATTT
AAGGATGAAGACACACAAGCAATGCCTTTCAGAGTGACTGAGCAAGAAAGCAAACCTGTGCAGATGATGTACCAG
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CTGACTGAATGGACCAGTTCTAATGTTATGGAAGAGAGGAAGATCAAAGTGTACTTACCTCGCATGAAGATGGA
GGAAAAATACAACCTCACATCTGTCTTAATGGCTATGGGCATTACTGACGTGTTTAGCTCTTCAGCCAATCTGTC
TGGCATCTCCTCAGCAGAGAGCCTGAAGATATCTCAAGCTGTCCATGCAGCACATGCAGAAATCAATGAAGCAGG
CAGAGAGGTGGTAGGGTCAGCAGAGGCTGGAGTGGATGCTGCAAGCGTCTCTGAAGAATTTAGGGCTGACCATCC
ATTCCTCTTCTGTATCAAGCACATCGCAACCAACGCCGTTCTCTTCTTTGGCAGATGTGTTTCCCCT

B) Anx-OVA fusionprotein, aminoacid-sequence

MNPSSDVAALHKAIMVKGVDEATIIDILTKRNNAQRQQIKAAYLQETGKPLDETLKKALTGHLEEVVLALLKTPAQ
FDADELRAAMKGLGTDEDTLIEILASRTNKEIRDINRVYREELKRDLAKDITSDTSGDFRNALLSLAKGDRSEDFGV
NEDLADSDARALYEAGERRKGTDVNVFNTILTTRSYPQLRRVFQKYTKYSKHDMNKVLDLELKGDIEKCLTAIVKC
ATSKPAFFAEKLHQAMKGVGTRHKALIRIMVSRSEIDMNDIKAFYQKMYGISLCQAILDETKGDYEKILVALCGGN-

HRGSGGGSGGGSENLYFQGGGGSGGGS-

DQARELINSWVESQTNGIIRNVLQPSSVDSQTAMVLVNAIVFKGLWEKAFKDEDTQAMPFRVTEQESKPVQMMYQ
IGLFRVASMASEKMKILELPFASGTMSMLVLLPDEVSGLEQLESIINFEKLTEWTSSNVMEERKIKVYLPRMKMEEK
YNLTSVLMAMGITDVFSSSANLSGISSAESLKISQAVHAAHAEINEAGREVVGSAEAGVDAASVSEEFRADHPFLFCIK
HIATNAVLFFGRCVSP

huAnxA1 Core

flexible Linker

ovalbumin (OVA)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/063985

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61K51/08 A61K39/00 A61K47/64
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 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, EMBASE, FSTA, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/130525 A2 (SIDNEY KIMMEL CANCER CT [US]; TANG YUCHENG [US]; DEISSEROTH ALBERT [US) 7 December 2006 (2006-12-07) par.8, 36, 37, 56, 100, 102, 182 par.15, 16 par.13, 14, 41-45, 51, 94; sequence 1 ----- -/--	1-12

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
14 September 2017	25/09/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Bonello, Steve

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	B. LINKE ET AL: "The Tolerogenic Function of Annexins on Apoptotic Cells Is Mediated by the Annexin Core Domain", THE JOURNAL OF IMMUNOLOGY, vol. 194, no. 11, 27 April 2015 (2015-04-27), pages 5233-5242, XP055240591, US ISSN: 0022-1767, DOI: 10.4049/jimmunol.1401299	1
A	p.5233 col.2 par.2- p.5234 col.1 par.1 p.5239 col.2 par.3- p.5240 col.1 par.1 -----	2-12
A	FANNY TZELEPIS ET AL: "Annexin1 regulates DC efferocytosis and cross-presentation during Mycobacterium tuberculosis infection", JOURNAL OF CLINICAL INVESTIGATION, vol. 125, no. 2, 22 December 2014 (2014-12-22), pages 752-768, XP055404600, US ISSN: 0021-9738, DOI: 10.1172/JCI77014 p.753 col.1 par.2- col.2 par.1, p.762 Fig.10 p.763 col.1 par.1, p.764 col.1 par.1 -----	1-12
T	EP 3 045 470 A1 (DEUTSCHES KREBSFORSCH [DE]) 20 July 2016 (2016-07-20) Par.19-21, 30 -----	

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/063985

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2006130525 A2	07-12-2006
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		WO 2016113022 A1	21-07-2016