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(54) **Title**: PLANT LECTINS AS CARRIERS OF ASSOCIATED DRUG SUBSTANCES INTO ANIMAL AND HUMAN CELLS

(57) **Abstract**: The current invention involves the use of protein lectins produced by plants including the non-toxic carbohydrate binding subunits (B subunits) of plant "AB toxins" (PTB lectins) as delivery vehicles for mobilizing associated drug substances for delivery to animal and human cells. The resulting protein fusions or conjugates retain lectin carbohydrate specificity for binding to cells and cellular trafficking activity so as to deliver an associated drug compound to the site of disease manifestation. One embodiment of this invention concerns the ability of ricin toxin B subunit, as a model PTB lectin, to deliver enzyme replacement therapeutic drugs to cells of several organs of the body including the brain and central nervous system, eyes, ears, lungs, bone, heart, kidney, liver, and spleen for treating lysosomal diseases.

DESCRIPTION

PLANT LECTINS AS CARRIERS OF ASSOCIATED DRUG SUBSTANCES INTO ANIMAL AND HUMAN CELLS

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CROSS-REFERENCE TO RELATED APPLICATION

The present application claims the benefit of U.S. Provisional Application Serial No. 61/653,062, filed May 30, 2012, which is hereby incorporated by reference herein in its entirety, including any figures, tables, nucleic acid sequences, amino acid sequences, or
10 drawings.

BACKGROUND OF THE INVENTION

Human and animal diseases can often be treated by supplying drug substances that correct disease symptoms by supplying a biochemical substance not made properly by the
15 body. Examples include but are not limited to enzyme replacement therapies (ERTs) for the treatment of Lysosomal Diseases (LDs) like Hurlers Syndrome (MPS I) or Alzheimer's with corrective enzymes for these genetic or age related developmental diseases. These types of diseases are associated with failure of metabolic processes or function of specific cells and biochemical pathways within the body. A goal of many drug advancement programs is,
20 therefore, focused on directing drugs more efficiently to the specific cells or tissues that are responsible for these functions. And the discovery described in this patent application is directed toward facilitating this goal.

Many plants produce specific carbohydrate binding lectins, agglutinins, and toxalbumins which are "AB" toxins that comprise a toxic A subunit protein (*e.g.*, a ribosome-
25 inactivating protein) and a non-toxic B subunit that is typically a lectin (carbohydrate binding protein) responsible for binding to the target cell surface, triggering endocytosis, and mediating intracellular trafficking. A classic example of this AB class of toxins is ricin toxin (from Castor beans) which incorporates a ricin A subunit (RTA) having ribosome-inactivating activity and a ricin B subunit (RTB) having galactose- and galactosamine-
30 binding activity that directs cell uptake and trafficking. As with other AB toxins, the lectin binding capacity of cell surfaces allows binding with carbohydrate binding domains of lectin

sequences on the RTB subunit of Ricin triggering endocytosis of the toxin into the cell and transcytosis of the toxin across cell layers by several different mechanisms including Receptor-Mediated Transcytosis (RMT) and Adsorptive-Mediated Transcytosis (AMT).

The development of effective therapeutic drugs to treat many diseases that produce significant impairment of cellular and metabolic function would be facilitated by the discovery of new ways to deliver these drugs to sites of disease pathology in cells and organs of the body. Lysosomal Diseases (LDs), also commonly called lysosomal storage diseases (LSDs) are representative of this class of diseases. LDs are a group of approximately 50 rare inherited metabolic disorders that result from defects in lysosomal function (Winchester *et al.* (2000)). Lysosomal storage diseases result when a specific organelle in the body's cells – the lysosome – malfunctions. Lysosomal storage disorders are caused by lysosomal dysfunction often as a consequence of deficiency of a single enzyme required for the metabolism of both large molecules or small compounds such as lipids, glycoproteins (sugar containing proteins) or so-called mucopolysaccharides. The lysosome is commonly referred to as the cell's recycling center because it reprocesses or catabolyzes metabolic waste material into substances that the body can recycle into useful substances or eliminate though the kidneys and urinary tract. Lysosomes break down this waste matter via enzymes that are highly specialized proteins that perform most of the chemical reactions essential for cellular functions. Lysosomal disease disorders are triggered when a particular enzyme is defective and suffers from loss of function or is present in too small amounts to perform normal metabolic functions or is missing altogether. When this happens, waste substances may build up to toxic levels that interfere with normal healthy metabolism leading to serious disease symptoms and even death.

Defects in cellular metabolic machinery caused by genetic mutations of lysosomal enzyme genes are a major cause of LDs and are usually expressed in all cells of the body. The level of threat to life of genetically defective lysosomal enzymes varies, however, depending on how much the mutation reduces the function of a particular enzyme and what bodily functions are most impaired. Research during the last few decades has led to the development of effective enzyme replacement (ERT) therapeutics drugs whereby defective enzymes in LD patients are replaced by intravenous delivery of normal enzymes produced by recombinant manufacturing technologies. Although these drugs are now available for a half a dozen of LDs their effectiveness in reducing disease symptoms varies depending on which

cells and organs are affected, the severity of symptoms, and the stage of disease progression. Current drugs are more effective in certain organs such as liver and spleen but often much less effective in treating symptoms in such organs as bone, heart, lungs, kidneys, and the CNS (central nervous system) including brain where severe symptoms occur in many LDs. The invention described in this patent is designed to more effectively target ERT's to these recalcitrant organs and also improve treatments in organs such as liver where current therapies could use improvement.

Poor brain development and neural degeneration of the brain and CNS are some of the most devastating symptoms in LDs. The effect of LDs on brain function has been well studied and is a representative example of currently untreatable symptoms of LDs. Homeostasis of the central nervous system (CNS) microenvironment is essential for its normal function. It is maintained by the blood-brain barrier (BBB) which regulates the transport of molecules from blood into brain and backwards. The function of this highly specialized barrier is to (1) protect the brain from blood-borne substances that are potentially detrimental to brain function and (2) to provide nutrients and other required substances to the brain parenchyme by specialized transport systems. The main structures responsible for this barrier property are the tight junctions (TJ). TJ are highly developed in endothelial cells of the brain and CNS vasculature but only moderately formed between endothelial cells of the peripheral vasculature: leaky blood capillaries in the body allow many molecules to cross through to tissue, but the TJ construction of the vessels in the CNS guards against this less restricted entry to the brain (Förster (2008)).

The tight control in transport of chemicals and proteins across the BBB poses a significant challenge to the delivery of diagnostic/therapeutic proteins, nucleic acids, and other drugs to the brain. Small molecules such as lipophilic drugs, gases, glucose, and essential nutrients cross the BBB by a number of passive and active transport mechanisms. In contrast, macromolecules such as proteins and nucleic acids are generally excluded from the brain and only a selective subset of proteins is transported across the BBB using either Receptor-Mediated Transcytosis (RMT) or Absorptive-Mediated Transcytosis (AMT). For substances transported via RMT mechanisms, a specific receptor (*e.g.*, the insulin receptor or the transferrin receptor) is present on the luminal surface of the CNS endothelial cells which mediates uptake, transcytosis, and release of proteins or other therapeutic substances at the abluminal or basal surface where they can access the glial and neuronal cells of the brain.

RMT mechanisms are "saturable" and the amount of product and rate by which substances can be mobilized across the BBB are limited by the number of available receptors present on the luminal surface.

In contrast to RMT mechanisms, Absorptive-Mediated Transcytosis (AMT) is independent of specific receptors and involves the binding of specific proteins or substances to the endothelial cell surface by interactions that trigger endocytosis and vesicular trafficking such that a proportion of the endocytosed substance is carried across the endothelial cell layer and subsequently released on the basal/abluminal side providing access to cells of the CNS. The selectivity and control of AMT mechanisms are not well understood but proteins such as cationated albumin and the TAT protein of HIV are known to enter the brain by this mechanism. AMT is considered non-saturable and may have the potential to deliver 10-fold greater amounts of product across the BBB compared to transport via the RMT. The present invention has the advantage that it can utilize multiple trans-cellular transport mechanisms including the AMT and RMT systems.

Role of Lectin in Toxicity of the AB Toxins such as Ricin:

Many plant derived AB toxins are toxic because they inhibit protein synthesis and ricin toxin is considered a model of this class which includes, but is not limited to, ricins, abrins, nigrins, the mistletoe lectins and the viscumin toxins, ebulins, pulchellin, pharatoxin, hurin, and phasin toxins. Many, but not all, of these protein toxins are dimers made up of A and B protein subunits. Subunit A is the actual toxin, while subunit B is a lectin (carbohydrate-binding protein) that helps deliver the toxic subunit protein inside cells by binding to components on the cell surface or cell membrane and triggering uptake by cells. Once inside a cell, the subunit A protein of ribosome inactivating toxins like Ricin is able to selectively catalyze the cleavage of an N-glycosidic bond in the 28S ribosomal RNA that is a crucial part of eukaryotic ribosomes (en.wikipedia.org/wiki/ribosome), the organelles inside cells that make proteins, thus inhibiting protein synthesis and essentially shutting down the cell.

AB toxins may enter the body through many routes including via mucosal surfaces such as the gut, nose, lungs or may be administered transdermally or by injection. Research on the metabolism of AB toxins in animals has led to key insights in the uptake of proteins and other compounds into animal cells. For example, ricin toxin targets cells with galactose

residues on their external surfaces. Research studies have identified at least five different biochemical uptake mechanisms. These studies have shown that ricin uses both dynamin-dependent and-independent routes of uptake into cells. Additionally, ricin has been observed to trigger endocytosis by interaction with the high mannose receptors based on its own mannose terminated glycans in addition to clathrin-dependent and -independent pathways. Clearly an important feature leading to the effectiveness of AB plant toxins in animals is the specialization of the A and B subunits of these proteins and the functional optimization of each subunit (A subunit: toxicity and B subunit: delivery) presumable thru evolution. Because of toxicity of AB toxins they have not been exploited systematically in drug discovery programs; this patent presents an invention which overcomes this drawback.

There are also other classes of lectins that do not specifically comprise AB toxins but possess lectin-mediated ability to bind to cell surface components and to direct uptake into cells and transcytosis across cells and to carry or deliver associated molecules. The best characterized lectins in this class typically have been identified from plants and include, but are not limited to, lectins such as wheat germ agglutinin, phytohemagglutin, Concanavalin A, the peanut and soybean lectins, and Jacalins.

BRIEF SUMMARY OF THE INVENTION

The present invention concerns materials and methods for delivering therapeutic proteins or other substances to the sites of disease manifestation in the body, including the brain and central nervous system (CNS), the skeletal system, the heart and pulmonary system, as well as other organs. Compounds of the invention comprise a therapeutic compound or agent operatively linked or fused to a plant lectin (such as the non-toxic B subunit of an AB toxin (referred to herein as PTB-lectin)). The therapeutic compound or agent is one which is useful or effective for treating or ameliorating a disease or disorder afflicting a person or animal. Methods of the invention comprise administering a therapeutically effective amount of a compound of the invention to a person or animal in need of treatment. In one embodiment, the method is used to treat an LD. In another embodiment, the method is used to treat any disease in which development of the disease is manifest in abnormal functions of the brain, CNS, or other organ of the body.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1. **RTB-mediated transcytosis**. RTB carries fused interleukin-12 (IL-12) across a confluent HT29 cell layer and activates the production of interferon-γ in splenocytes below (Liu, Dolan, Cramer, unpublished data). Using an *in vitro* transcytosis model, mouse IL-12 alone or the PTB-lectin –mouse IL-12 genetic fusion product (RTB:IL-12), were added to the top of cells grown to tight confluence on an “insert” permeable membrane that had been placed over a cell layer of primary mouse splenocytes. The media of the lower splenocyte culture was subsequently analyzed for the presence of interferon-gamma (IFN-γ), the signature readout of IL-12 activity in splenocytes. RTB:IL-12, but not IL-12 alone, stimulated IFN-γ production. This stimulation was substantially blocked by addition of anti-RTB antibodies to the upper chamber indicating that the RTB lectin activity was fundamental in mediating transport across the epithelial layer for delivery to the cells below.

Figures 2A and 2B. **Gene structure and purification of the PTB-lectin – lysosomal fusion product, IDUA:RTB**. Figure 2A. Diagram of the fusion gene construct which encoded an N-terminal plant signal peptide (PSP; signal peptide modified from the potato patatin gene), the human IDUA coding region ($IDUA_{OPT}$; DNA synthesized using tobacco codon preferences), the RTB coding region (RTB), and a C-terminal hexa-histidine tag (6xHIS). Figure 2B. Gel analyses of purification fractions from leaves of *Nicotiana benthamiana* expressing the construct in Figure 2A. IDUA:RTB-containing leaf material was extracted in a pH7.5 Tris/NaCl buffer containing 20 mM galactose, and crude protein extracts were subjected to ammonium sulfate precipitation, and then further purified by lactose affinity and size exclusion chromatography. The IDUA:RTB containing fractions were size separated by SDS-polyacrylamide gel electrophoresis and analyzed by Western immunoblotting using anti-IDUA antibodies for detection (WB) and by silver-staining which detects all proteins in the fraction (SS). Location of the molecular weight size markers are indicated for each gel.

Figures 3A and 3B. Correction of lysosomal disease phenotype of Hurler/Scheie fibroblasts by treatment with IDUA:NBB as an example of PTB-lectin-mediated delivery of active lysosomal enzyme into cells and into the site of disease substrate accumulation leading to a reduction in lysosomal size. Normal and Hurler/Scheie fibroblasts were grown in multiple wells of 96-well plates (normal: 10 wells; Hurler/Scheie: 16 wells). IDUA:NBB was added to half of the wells (8) containing Hurler/Scheie cells at a

concentration of 6 ng/ml and the plate was further incubated at 37° C. After 24 hr incubation, cells were stained with Lysotracker-Red (30 min), fixed and then nuclei were stained with DAPI blue. Cells were then imaged by confocal microscopy using a BD Pathway 855 Bioimaging System at 20X magnification with uniform settings that captured 4 images per well (each with average of ~200 cell). Figure 3A. Images were analyzed based on total red pixels per image divided by number of cells (DAPI-stained nuclei). Figure 3B. Relative lysosomal numbers were compared by defining red "regions of interest" using BD Pathway Bioimaging software.

Figure 4. PTB-lectins deliver associated lysosomal enzymes by mechanisms that are independent of the mannose-6-phosphate (M6P) receptor. Hurler/Scheie fibroblasts were incubated with (+M6P) or without (-M6P) inhibitory levels of mannose-6-phosphate (3 mm M6P sodium salt) for 2 hours prior to addition of 40 ng/ml IDUA equivalents as either a) plant-made IDUA:RTB or b) commercial human iduronidase (rhIDUA) synthesized in mammalian cells and containing M6P-modified glycans. After 24 hr incubation, cells were stained with Lysotracker-Red and DAPI and analyzed as described in Figure 3. IDUA:RTB, but not rhIDUA, corrected the enlarged lysosomal phenotype of Hurler/Scheie cells in the presence of M6P indicating that RTB-mediated delivery functioned via M6P receptor-independent pathways.

BRIEF DESCRIPTION OF THE SEQUENCES

SEQ ID NO:1 is an amino acid sequence of a fusion protein of the invention comprising PoSP signal sequence, IDUA, RTB (truncated), and 6x His tag.

SEQ ID NO:2 is an amino acid sequence of a fusion protein of the invention comprising PoSP signal sequence, IDUA, NBB, and 6x His tag.

SEQ ID NO:3 is an amino acid sequence of a fusion protein of the invention comprising PoSP signal sequence, DsRed, NBB, and 6x His tag.

SEQ ID NO:4 is an amino acid sequence of a fusion protein of the invention comprising PoSP signal sequence, NBB, SGSH, and 6x His tag.

SEQ ID NO:5 is an amino acid sequence of a fusion protein of the invention comprising hSP, SGSH, RTB (truncated), and 6x His tag.

SEQ ID NO:6 is an amino acid sequence of a fusion protein of the invention comprising IDUA and RTB (truncated).

SEQ ID NO:7 is an amino acid sequence of a fusion protein of the invention comprising IDUA and NBB.

SEQ ID NO:8 is an amino acid sequence of a fusion protein of the invention comprising DsRed and NBB.

5 **SEQ ID NO:9** is an amino acid sequence of a fusion protein of the invention comprising NBB and SGSH.

SEQ ID NO:10 is an amino acid sequence of a fusion protein of the invention comprising SGSH and RTB (truncated).

SEQ ID NO:11 is an amino acid sequence of a modified patatin signal sequence.

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DETAILED DESCRIPTION OF THE INVENTION

The present invention concerns materials and methods for delivering therapeutic proteins or other substances, such as drugs, to the sites of disease manifestation in the body, including, but not limited to the brain and central nervous system (CNS), bone, lungs, and 15 heart, eyes, ears, kidney, liver and spleen. In some embodiments, the system employs compounds comprising a plant lectin, such as the subunit B lectin proteins responsible for delivering toxin subunit A proteins to cells in the class of toxins known as AB protein exotoxins which utilize lectin binding sites on a targeted cell surface to gain entrance to cells via an endocytic pathway. AB toxins include the family of plant-made AB toxins (also called 20 Toxalbumins) which include but are not limited to ricins, abrins, nigrins, the mistletoe lectins and the viscumin toxins, ebulins, pulchellin, pharatoxin, hurin, and phasin. These AB toxins are typically delivered to the cell via diverse endocytic pathways including the clathrin-dependent, clathrin-independent, and caveolae pathways. In one embodiment of the present invention, a therapeutic protein or other compound is fused or linked to the subunit B, or a 25 fragment or variant thereof, as a substitution for the natural toxic subunit A component. In some embodiments, the subunit B lectin protein is from ricin. In specific embodiments, the ricin B subunit that is utilized is truncated by removal of about 1 to 10 amino acids at the N-terminus of the protein. In an exemplified embodiment, the ricin B subunit is truncated wherein the first six amino acids of the protein are removed. This fusion protein (or other 30 compound) may be produced by construction of a fusion gene incorporating a nucleotide sequence encoding a plant lectin (such as the subunit B lectin) and a nucleotide sequence encoding the therapeutic protein, and introducing this new genetic fusion (fusion gene) into a

protein expression system, expressing the fusion protein encoded by the fusion gene, and isolating the fused protein for use as a therapeutic drug. Alternatively, the fusion may be accomplished by direct chemical fusion or conjugation yielding fusion of the plant lectin (such as a subunit B protein) with the therapeutic agent. In one embodiment, the fusion protein comprises a linker or spacer sequence of amino acids between the plant lectin and the therapeutic protein or compound. Examples of linker or spacer sequences are well known in the art. Methods for preparing fusion genes and fusion protein are also well known in the art and have been described, for example, in U.S. Patent Nos. 7,964,377; 7,867,972; 7,410,779; 7,011,972; 6,884,419; and 5,705,484. In an additional embodiment of the invention, inter- and intracellular trafficking dynamics are directed or modified to enhance effectiveness as managed by sequence or chemical modifications of the fusion product of the invention. These modifications may include, for example, glycans, amino acids, nucleotides, peptides, and methylation. In still another embodiment, fusion products of the invention are produced in a stable or transient transgenic plant expression system. In one embodiment, a method for preparing a fusion product of the invention comprises expressing a polynucleotide encoding the fusion product in a cell and isolating the expressed fusion product from the cell.

Plant lectins that are contemplated within the scope of the invention include, but are not limited to those B subunits from AB toxins such as ricins, abrins, nigrins, and mistletoe toxins, viscumin toxins, ebulins, pharatoxin, hurin, phasin, and pulchellin. They may also include lectins such as wheat germ agglutinin, peanut agglutinin, and tomato lectin that, while not part of the AB toxin class, are still capable of binding to animal cell surfaces and mediating endocytosis and transcytosis. Specific examples of plant lectins including their binding affinities and trafficking behavior are discussed further below. Therapeutic compounds and agents contemplated within the scope of the invention include, but are not limited to large molecular weight molecules including therapeutic proteins and peptides, siRNA, antisense oligonucleotides, and oligosaccharides. Other therapeutic compounds and agents contemplated within the scope of the invention include small molecular weight drug compounds including but not limited to vitamins, co-factors, effector molecules, and inducers of health promoting reactions. Examples of therapeutic compounds and agents are discussed further below.

Within the scope of the present invention, selection of a specific plant lectin candidate to use in delivery of a particular therapeutic compound or agent is based on the specific sugar

affinity of the lectin, its uptake efficiency into specific target cells, its pattern of intracellular trafficking, its *in vivo* biodistribution and pharmacodynamics, or other features of the lectin or therapeutic compound. Alternatively, multiple lectins can be tested to identify the lectin - therapeutic compound combination that provides greatest efficacy. For example, two lectins, RTB and NNB, were selected for proof-of-concept of the invention based on trafficking of their respective AB toxins, ricin from *Ricinus communis* and nigrin-b from *Sambucus nigra* (e.g., see Sandvig, K. and van Deurs, B. (1999); Simmons *et al.* (1986); Citores *et al.* (1999); Citores *et al.* (2003)). The uptake and trafficking of ricin and/or RTB, a galactose/galactosamine-specific lectin, has been extensively studied. This lectin has high affinity for surface glycolipids and glycoproteins providing access to a broad array of cells and enters cells by multiple endocytotic routes. These include absorptive-mediated endocytosis involving clathrin-dependent and clathrin-independent routes; caveolin-dependent and independent routes; dynamin-dependent and independent routes, and macropinocytosis based on the lectin binding to cell surface glycoproteins and glycolipids. RTB also accesses cells by receptor-mediated endocytosis based on interaction with its N-linked glycans with the high-mannose receptor (MMR) of animal cells. Upon endocytosis, RTB traverses preferentially to lysosomes (lysosomal pathway) or cycles back to the cell membrane (transcytosis pathway), with a small amount (generally less than 5%) moving "retrograde" to the endoplasmic reticulum. The NBB lectin, Nigrin B B-subunit from *Sambucus nigra*, exploits different uptake and intracellular trafficking routes compared to RTB, and thus provides unique *in vivo* pharmacodynamics. In contrast to RTB, NBB has strong affinity for N-acetyl-galactosamine, low affinity for lactose, very limited retrograde trafficking but strong accumulation in lysosomes. Plant-made DsReD:NNB (red fluorescent protein – NBB fusion) is rapidly taken up into multiple mammalian cells and efficiently delivered to lysosomes. As delineated further in the *Examples*, recombinantly produced RTB and NBB have been operatively associated with both small molecules (by chemical conjugation technologies) and protein macromolecule by genetic fusion that retain selective lectin binding as well as functionality of the associated protein or agent. These operatively associated products are rapidly endocytosed into multiple cell types and tissues and deliver fully functional 'payload' into internal structures including lysosomes, endosomes, endoplasmic reticulum, and sarcoplasmic reticulum. Of particular significance, these PTB-lectins mobilize delivery of enzymes and other large proteins into critical cells of the central

nervous system (including but limited to brain capillary endothelial cells, neurons, and astrocytes), skeletal systems (including but not limited to cartilage, chondrocytes, fibroblasts, and monocytes), and the respiratory system (including but not limited to lung airway epithelium, lung smooth muscle cells, and macrophages) (Radin et al, unpublished). These
5 cells and tissues represent some of the most challenging targets for delivery of therapeutic agents highlighting the utility and novelty of the invention to address currently unmet needs in therapeutic compound delivery in human and animal medicine.

Additional plant lectins that are contemplated within the scope of the invention are those having particular carbohydrate binding affinities including but not limited to lectins that
10 bind glucose, glucosamine, galactose, galactosamine, N-acetyl-glucosamine, N-acetyl-galactosamine, mannose, fucose, sialic acid, neuraminic acid, and/or N-acetylneuraminic acid, or have high affinity for certain target tissue or cells of interest. There are hundreds of plant lectins that have been identified and experimental strategies to identify plant lectins, their respective genes, and their sugar binding affinities are widely known by those skilled in
15 the art. The diversity of plant sources for lectins and their sugar binding affinities is exemplified in the table below (adapted from Table 3 of Van Damme *et al*., (1998)).

Type 2 Ribosome-inactivating Proteins and Related Lectins: Occurrence, Molecular Structure, and Specificity

Species	Tissue	Structure[a]	Specificity	Sequence available[b]
Merolectins				
Sambucus nigra	Bark	[P22]	NANA	Nu
	Fruit	[P22]	NANA	Nu
Hololectins				
Sambucus nigra	Bark	II $[P30]_2$	GalNAc>Gal	Nu
	Seed	III $[P30]_2$	GalNAc>Gal	
	Fruit	IVf $[P32]_2$	Gal/GalNAc	Nu (SNA-IV)
	Leaf	IVl $[P32]_2$	Gal/GalNAc	Nu
	Leaf	IV4l $[P32]_4$	Gal/GalNAc	
Chimerolectins				
Abrus precatorius	Seed	[P(34 + 32)]	Gal>GalNAc	Pr, Nu (Abrin)
	Seed	$[P(33 + 29)]_2$	Gal	Pr (APA)
Adenia digitata	Root	[P(28 + 36)]	Gal>GalNAc	
Adenia volkensii	Root	[P(29 + 36)]	Gal	
Cinnamomum camphora	Seed	$[P(30 + 33)]_2$	Unknown	
Eranthis hyemalis	Tuber	[P(30 + 32)]	GalNAc	
Iris hybrid	Bulb	[P(27 + 34)]	GalNAc	
Momordica charantia	Seed	$[P(28 + 30)]_2$	Gal>GalNAc	
Phoradendron californicum	Plant	[P(31 + 35)]	Gal	
Ricinus communis	Seed	[P(32 + 34)]	Gal>GalNAc	Pr, Nu (Ricin)
	Seed	$[P(32 + 36)]_2$	Gal>>GalNAc	Pr, Nu (RCA)
Sambucus canadensis	Bark	I $[P(32 + 35)]_4$	NANA	
Sambucus ebulus	Bark	I $[P(32 + 37)]_4$	NANA	
	Leaf	$[P(26 + 30)]_2$	GalNAc	
Sambucus nigra	Seed	Vs $[P(26 + 32)]_2$	GalNAc>Gal	
	Bark	I $[P(32 + 35)]_4$	NANA	Nu (SNA-I)
	Bark	I' $[P(32 + 35)]_2$	NANA	Nu (SNA-I')
	Bark	V $[P(26 + 32)]_2$	GalNAc>Gal	Nu (SNA-V)
	Fruit	If $[P(32 + 35)]_2$	NANA	Nu
	Fruit	Vf $[P(26 + 32)]_2$	GalNAc>Gal	Nu
Sambucus racemosa	Bark	I $[P(30 + 36)]_4$	NANA	
Sambucus sieboldiana	Bark	I $[P(31 + 37)]_4$	NANA	Nu (SSA-I)
	Bark	[P(27 + 32)]	GalNAc>Gal	Nu (Sieboldin)
Viscum album	Plant	I $[P(29 + 34)]_{1-2}$	Gal	
	Plant	II [P(29 + 34)]	Gal/GalNAc	
	Plant	III [P(25 + 30)]	GalNAc>Gal	
Type 2 RIP with inactive B chain				
Sambucus nigra	Bark	[P(32 + 32)]	...	Nu (LRPSN)

[a] [PX] stands for protomer with a molecular mass of X kDa. [P(Y + Z)] indicates that the protomer is cleaved in two polypeptides of Y and Z kDa.

[b] Pr, protein sequence; Nu, nucleotide sequence. The abbreviation in brackets refers to the sequence name used in the dendrogram (Figure 20).

As a further example of plant lectins contemplated herein, the table below exemplifies the large number of different lectins identified from the *Sambucus* species alone. This group includes nigrin B, the source on NBB.

Ribosome-inactivating proteins (RIPs) and lectins from *Sambucus* species. Adapted from Table 1 of Ferreras *et al.* (2011)

Proteins	Species	Tissues
Type 1 RIPs		
Ebulitins α, β and γ	*S. ebulus*	Leaves
Nigritins f1 and f2	*S. nigra*	Fruits
Heterodimeric type 2 RIPs		
Ebulin l	*S. ebulus*	Leaves
Ebulin f	*S. ebulus*	Fruits
Ebulins r1 and r2	*S. ebulus*	Rhizome
Nigrin b, basic nigrin b, SNA I', SNLRPs	*S. nigra*	Bark
Nigrins l1 and l2	*S. nigra*	Leaves
Nigrin f	*S. nigra*	Fruits
Nigrin s	*S. nigra*	Seeds
Sieboldin b	*S. sieboldiana*	Bark
Basic racemosin b	*S. racemosa*	Bark
Tetrameric type 2 RIPs		
SEA	*S. ebulus*	Rhizome
SNA I	*S. nigra*	Bark
SNAIf	*S. nigra*	Fruits
SNAflu-I	*S. nigra*	Flowers
SSA	*S. sieboldiana*	Bark
SRA	*S. racemosa*	Bark
Monomeric lectins		
SELlm	*S. ebulus*	Leaves
SEA II	*S. ebulus*	Rhizome
SNA II	*S. nigra*	Bark
SNAlm and SNAIV1	*S. nigra*	Leaves
SNA IV	*S. nigra*	Fruits
SNA III	*S. nigra*	Seeds
SSA-b-3 and SSA-b-4	*S. sieboldiana*	Bark
SRAbm	*S. racemosa*	Bark
Homodimeric lectins		
SELld	*S. ebulus*	Leaves
SELfd	*S. ebulus*	Fruits
SNAld	*S. nigra*	Leaves

The subject invention also concerns polynucleotides that comprise nucleotide sequences encoding a fusion protein (or compound) of the invention. In one embodiment, the polynucleotides comprise nucleotide sequences that are optimized for expression in a particular expression system, *e.g.*, a plant expression system, such as a tobacco plant. The subject invention also concerns the fusion polypeptides encoded by polynucleotides of the invention.

Any disease or disorder that can be treated or prevented using a therapeutic compound or agent is contemplated within the scope of the present invention. In one embodiment, the disease or disorder is one of the brain or CNS. Lysosomal diseases and (parenthetically) related enzymes and proteins associated with diseases that are contemplated within the scope of the invention include, but are not limited to, Activator Deficiency/GM2 Gangliosidosis (beta-hexosaminidase), Alpha-mannosidosis (alpha-D-mannosidase), Aspartylglucosaminuria

(aspartylglucosaminidase), Cholesteryl ester storage disease (lysosomal acid lipase), Chronic Hexosaminidase A Deficiency (hexosaminidase A), Cystinosis (cystinosin), Danon disease (LAMP2), Fabry disease (alpha-galactosidase A), Farber disease (ceramidase), Fucosidosis (alpha-L-fucosidase), Galactosialidosis (cathepsin A), Gaucher Disease (Type I, Type II,
5 Type III) (beta-glucocerebrosidase), GM1 gangliosidosis (Infantile, Late infantile/Juvenile, Adult/Chronic) (beta-galactosidase), I-Cell disease/Mucolipidosis II (GlcNAc-phosphotransferase), Infantile Free Sialic Acid Storage Disease/ISSD (sialin), Juvenile Hexosaminidase A Deficiency ((hexosaminidase A), Krabbe disease (Infantile Onset, Late Onset) (galactocerebrosidase), Metachromatic Leukodystrophy (arylsulfatase A),
10 Mucopolysaccharidoses disorders [Pseudo-Hurler polydystrophy/Mucolipidosis IIIA (N-acetylglucosamine-1-phosphotransferase), MPSI Hurler Syndrome (alpha-L iduronidase), MPSI Scheie Syndrome (alpha-L iduronidase), MPS I Hurler-Scheie Syndrome (alpha-L iduronidase), MPS II Hunter syndrome (iduronate-2-sulfatase), Sanfilippo syndrome Type A/MPS III A (heparan N-sulfatase), Sanfilippo syndrome Type B/MPS III B (N-acetyl-alpha-
15 D-glucosaminidase), Sanfilippo syndrome Type C/MPS III C (acetyl-CoA, alpha-glucosaminide acetyltransferase, Sanfilippo syndrome Type D/MPS III D (N-acetylglucosamine-G-sulfate-sulfatase), Morquio Type A/MPS IVA (N-acetylgalatosamine-6-sulfate-sulfatase), Morquio Type B/MPS IVB (β-galactosidase-1), MPS IX Hyaluronidase Deficiency (hyaluronidase), MPS VI Maroteaux-Lamy (arylsulfatase B), MPS VII Sly
20 Syndrome (beta-glucuronidase), Mucolipidosis I/Sialidosis (alpha-N -acetyl neuraminidase), Mucolipidosis IIIC (N-acetylglucosamine-1-phosphotransferase), Mucolipidosis type IV (mucolipin1)], Multiple sulfatase deficiency (multiple sulfatase enzymes), Niemann-Pick Disease (Type A, Type B, Type C) (sphingomyelinase), Neuronal Ceroid Lipofuscinoses [(CLN6 disease - Atypical Late Infantile, Late Onset variant, Early Juvenile (ceroid-
25 lipofuscinosis neuronal protein 6); Batten-Spielmeyer-Vogt/Juvenile NCL/CLN3 disease (battenin); Finnish Variant Late Infantile CLN5 (ceroid-lipofuscinosis neuronal protein 5); Jansky-Bielschowsky disease/Late infantile CLN2/TPP1 Disease (tripeptidyl peptidase 1); Kufs/Adult-onset NCL/CLN4 disease; Northern Epilepsy/variant late infantile CLN8 (ceroid-lipofuscinosis neuronal protein 8); Santavuori-Haltia/Infantile CLN1/PPT disease (palmitoyl-
30 protein thioesterase 1); Beta-mannosidosis (beta-mannosidase)], Tangier disease (ATP-binding cassette transporter ABCA1), Pompe disease/Glycogen storage disease type II (acid maltase), Pycnodysostosis (cathepsin K), Sandhoff disease/Adult Onset/GM2 Gangliosidosis

(beta-hexosaminidases A and B), Sandhoff disease/GM2 gangliosidosis - Infantile, Sandhoff disease/GM2 gangliosidosis – Juvenile (beta-hexosaminidases A and B), Schindler disease (alpha-N-acetylgalactosaminidas), Salla disease/Sialic Acid Storage Disease (sialin), Tay-Sachs/GM2 gangliosidosis (beta-hexosaminidase), and Wolman disease (lysosomal acid lipase), Sphingolipidosis, Hurmansky-Pudiak Syndrome (HPS1, HPS3, HPS4, HPS5, HPS6 and HPS7) Type 2 - AP-3 complex subunit beta-1, Type 7 -dysbindin), Chediak-Higashi Syndrome (lysosomal trafficking regulator protein), and Griscelli disease (Type 1: myosin-Va, Type 2: ras-related protein Rab-27A, Type 3: melanophilin).

Additional diseases (including related proteins) that may be therapeutically addressed by this invention include the neurodegenerative diseases which include but are not limited to Parkinson's, Alzheimer's, Huntington's, and Amyotrophic Lateral Sclerosis ALS (superoxide dismutase), Hereditary emphysema (α1-Antitrypsin), Oculocutaneus albinism (tyrosinase), Congenital sucrase-isomaltase deficiency (Sucrase-isomaltase), and Choroideremia (Rep1) Lowe's Oculoceribro-renal syndrome (PIP2-5-phosphatase). Many other genetic diseases are caused by deficiencies in specific proteins or enzymes leading to disease specific tissue and organ pathologies. ERT's or other protein replacement therapeutics may be of value for these diseases. PTB-lectins may facilitate protein delivery to critical organs, cells and subcellular organelles or compartments for these diseases as well. For example, genetic diseases affecting bone and connective tissues including, but are not limited to osteoporosis and osteogenesis imperfecta, may be treated by using this invention to deliver corrective proteins to bones, joints, and other connective tissues.

The enzymes or other proteins that can be used therapeutically in a fusion protein of the present invention can be identified by a person of ordinary skill in the art. For example, in treating MPS I disease, the therapeutic protein can provide iduronidase enzymatic activity. For treating Fabry disease, the therapeutic protein can provide α-galactosidase A enzymatic activity. Enzymes suitable for treating other LSDs are known in the art.

The present invention contemplates products in which the plant lectin is operatively associated with the therapeutic component by one of many methods known in the art. For example, genetic fusions between a plant lectin protein and a therapeutic protein can orient the lectin partner on either the C- or N-terminus of the therapeutic component. The coding regions can be linked precisely such that the last C-terminal residue of one protein is adjacent to the first N-terminal residue of the mature (*i.e.*, without signal peptide sequences) second

protein. Alternatively, additional amino acid residues can be inserted between the two proteins as a consequence of restriction enzyme sites used to facilitate cloning at the DNA level. Additionally, the fusions can be constructed to have amino acid linkers between the proteins to alter the physical spacing. These linkers can be short or long, flexible (*e.g.*, the
5 commonly used $(Gly_4Ser)_3$ 'flexi' linker) or rigid (*e.g.*, containing spaced prolines), provide a cleavage domain (*e.g.*, see Chen *et al.* (2010)), or provide cysteines to support disulfide bond formation. The plant lectins are glycoproteins and in nature are directed through the plant endomembrane system during protein synthesis and post-translational processing. For this reason, production of recombinant fusion proteins comprising a plant lectin and a therapeutic
10 protein partner may require that a signal peptide be present on the N- terminus of the fusion product (either on the lectin or on the therapeutic protein depending on the orientation of the fusion construct) in order to direct the protein into the endoplasmic reticulum during synthesis. This signal peptide can be of plant or animal origin and is typically cleaved from the mature plant lectin or fusion protein product during synthesis and processing in the plant
15 or other eukaryotic cell. In one embodiment, a modified patatin signal sequence (PoSP) is utilized: MASSATTKSFLILFFMILATTSSTCAVD (SEQ ID NO:11) (see GenBank accession number CAA27588.1, version GI:21514 by Bevan *et al.* and referenced at "The structure and transcription start site of a major potato tuber protein gene" *Nucleic Acid Res.* 14 (11), 4625-4638 (1986)).
20 Compounds of the subject invention can also be prepared by producing the plant lectin and the therapeutic drug or protein separately and operatively linking them by a variety of chemical methods. Examples of such *in vitro* operative associations include conjugation, covalent binding, protein-protein interactions or the like (see, *e.g.*, Lungwitz *et al.* (2005); Lovrinovic and Niemeyer (2005)). For example, N-hydroxysuccinimde (NHS)-derivatized
25 small molecules and proteins can be attached to recombinant plant lectins by covalent interactions with primary amines (N-terminus and lysine residues). This chemistry can also be used with NHS-biotin to attach biotin molecules to the plant lectin supporting subsequent association with streptavidin (which binds strongly to biotin) and which itself can be modified to carry additional payload(s). In another example, hydrazine-derivatized small
30 molecules or proteins can be covalently bound to oxidized glycans present on the N-linked glycans of the plant lectin. Proteins can also be operatively linked by bonding through intermolecular disulfide bond formation between a cysteine residue on the plant lectins and a

cysteine residue on the selected therapeutic protein. It should be noted that the plant AB toxins typically have a single disulfide bond that forms between the A and B subunits. Recombinant production of plant B subunit lectins such as RTB and NBB yield a product with an 'unpaired' cysteine residue that is available for disulfide bonding with a "payload" protein. Alternatively, this cysteine (*e.g.*, Cys_4 in RTB) can be eliminated in the recombinant plant lectin product by replacement with a different amino acid or elimination of the first 4-6 amino acids of the N-terminus to eliminate the potential for disulfide bonding with itself or other proteins.

Exemplified amino acid sequences of plant lectin fusion proteins of the present invention are provided (see SEQ ID NOs:1-10) and include genetic fusion wherein a) the plant lectin is either RTB (the B subunit of ricin) or NBB (the B subunit of nigrin B), b) the associated protein is either human α-L-iduronidase (IDUA), human sulfaminidase (SGSH), or DsRed fluorescent protein, c) the plant lectin comprises either the C-terminal or N-terminal partner of the fusion protein, d) the fusion protein comprises a precise fusion between partners adding no additional amino acids, e) the fusion protein includes at least one or two additional amino acids resulting from an added restriction site in cloning, and/or f) modifications are made at the C- or N- termini of one or both protein partners to add or eliminate a signal peptide, remove a cysteine residue, or add a C-terminal histidine tag. All fusion products are tested for functionality of both partners (*e.g.*, plant lectin carbohydrate binding selectivity and enzyme activity or fluorescence of its fusion partner) and optimal activity of one or both partners can be affected by the fusion arrangement (N- versus C-terminal) and physical spacing. Development of effective dual function fusions between the plant lectin and the therapeutic protein can be readily accomplished using standard materials and methods known in the art by an ordinarily skilled artisan.

Additional information concerning IDUA, SGSH, DsRed, NBB, and RTB can be found at:

IDUA: See GenBank accession number pbd/4JXP_A version GI:480312357 by Bie *et al.* and referenced at "Crystal structure analysis of human alpha-L-iduroni two crystal forms" *Unpublished*, and see GenBank accession number AAA81589.1, version GI:184559 by Scott *et al.* and referenced at "Human alpha-L-iduronidase: cDNA isolation and expression" *Proc. Natl. Acad. Sci. U.S.A.* 88 (21), 9695-9699 (1991).

DsRed: See GenBank accession number pbd/1G7K (Chain A, B, C, D) versions GI:12084491, 12084492, 12084493, 12084494 by Matz *et al.* and referenced at “Fluorescent proteins from nonbioluminescent Anthozoa species” *Nat. Biotechnol.* 17(10), 969-973 (1999).

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NBB: See GenBank accession number P33183.2, version GI:17433713 (containing subunits A and B) by Van Damme *et al.* and referenced at “Characterization and molecular cloning of Sambucus nigra agglutinin V (nigrin b), a GalNAc-specific type-2 ribosome-inactivating protein from the bark of elderberry (Sambucus nigra)” *Eur. J. Biochem.* 237 (2), 505-513
10 (1996). PDB ID: 3CA3 (for B subunit) by Maveyraud *et al.* and referenced at “Structural basis for sugar recognition, including the tn carcinoma antigen, by the lectin sna-ii from sambucus nigra” *Proteins* 75 p.89 (2009).

SGSH: See GenBank accession number NP_000190.1, version GI:4506919 by Van de Kamp
15 *et al.* and referenced at “Genetic heterogeneity and clinical variability in the Sanfilippo syndrome (type A, B, and C)” *Clin. Genet.* 20 (2), 152-160 (1981).

RTB: See GenBank accession number pbd/2AAI/B, version GI:494727 (containing subunits A and B) by Montfort *et al.* and referenced at “The three-dimensional structure of ricin at
20 2.8A” *J. Biol Chem.* 262 (11), 5398-5403 (1987).

In vivo administration of the subject compounds, polynucleotides and compositions containing them, can be accomplished by any suitable method and technique presently or prospectively known to those skilled in the art. The subject compounds can be formulated in
25 a physiologically- or pharmaceutically-acceptable form and administered by any suitable route known in the art including, for example, oral, nasal, rectal, transdermal, vaginal, and parenteral routes of administration. As used herein, the term parenteral includes subcutaneous, intradermal, intravenous, intramuscular, intraperitoneal, and intrasternal administration, such as by injection. Administration of the subject compounds of the
30 invention can be a single administration, or at continuous or distinct intervals as can be readily determined by a person skilled in the art. In one embodiment, a polynucleotide encoding a therapeutic fusion product of the invention is stably incorporated into the genome

of a person of animal in need of treatment. Methods for providing gene therapy are well known in the art. In one embodiment, a polynucleotide is provided in an expression construct and encodes an amino acid sequence of any of SEQ ID NOs:1-10.

The compounds of the subject invention, and compositions comprising them, can also 5 be administered utilizing liposome and nano-technology, slow release capsules, implantable pumps, and biodegradable containers, and orally or intestinally administered intact plant cells expressing the therapeutic product. These delivery methods can, advantageously, provide a uniform dosage over an extended period of time.

Compounds of the subject invention can be formulated according to known methods 10 for preparing physiologically acceptable compositions. Formulations are described in detail in a number of sources which are well known and readily available to those skilled in the art. For example, *Remington's Pharmaceutical Science* by E.W. Martin describes formulations which can be used in connection with the subject invention. In general, the compositions of the subject invention will be formulated such that an effective amount of the compound is 15 combined with a suitable carrier in order to facilitate effective administration of the composition. The compositions used in the present methods can also be in a variety of forms. These include, for example, solid, semi-solid, and liquid dosage forms, such as tablets, pills, powders, liquid solutions or suspension, suppositories, injectable and infusible solutions, and sprays. The preferred form depends on the intended mode of administration and therapeutic 20 application. The compositions also preferably include conventional physiologically-acceptable carriers and diluents which are known to those skilled in the art. Examples of carriers or diluents for use with the subject compounds include ethanol, dimethyl sulfoxide, glycerol, alumina, starch, saline, and equivalent carriers and diluents. To provide for the administration of such dosages for the desired therapeutic treatment, compositions of the 25 invention will advantageously comprise between about 0.1% and 99%, and especially, 1 and 15% by weight of the total of one or more of the subject compounds based on the weight of the total composition including carrier or diluent.

Compounds and agents of the invention, and compositions thereof, may be locally administered at one or more anatomical sites, optionally in combination with a 30 pharmaceutically acceptable carrier such as an inert diluent. Compounds and agents of the invention, and compositions thereof, may be systemically administered, such as intravenously or orally, optionally in combination with a pharmaceutically acceptable carrier such as an

inert diluent, or an assimilable edible carrier for oral delivery. They may be enclosed in hard or soft shell gelatin capsules, may be compressed into tablets, or may be incorporated directly with the food of the patient's diet. For oral therapeutic administration, the active compound may be combined with one or more excipients and used in the form of ingestible tablets, buccal tablets, troches, capsules, elixirs, suspensions, syrups, wafers, aerosol sprays, and the like.

The tablets, troches, pills, capsules, and the like may also contain the following: binders such as gum tragacanth, acacia, corn starch or gelatin; excipients such as dicalcium phosphate; a disintegrating agent such as corn starch, potato starch, alginic acid and the like; a lubricant such as magnesium stearate; and a sweetening agent such as sucrose, fructose, lactose or aspartame or a flavoring agent such as peppermint, oil of wintergreen, or cherry flavoring may be added. When the unit dosage form is a capsule, it may contain, in addition to materials of the above type, a liquid carrier, such as a vegetable oil or a polyethylene glycol. Various other materials may be present as coatings or to otherwise modify the physical form of the solid unit dosage form. For instance, tablets, pills, or capsules may be coated with gelatin, wax, shellac, or sugar and the like. A syrup or elixir may contain the active compound, sucrose or fructose as a sweetening agent, methyl and propylparabens as preservatives, a dye and flavoring such as cherry or orange flavor. Of course, any material used in preparing any unit dosage form should be pharmaceutically acceptable and substantially non-toxic in the amounts employed. In addition, the active compound may be incorporated into sustained-release preparations and devices.

Compounds and agents, and compositions of the invention, including pharmaceutically acceptable salts or analogs thereof, can be administered intravenously, intramuscularly, or intraperitoneally by infusion or injection. Solutions of the active agent or its salts can be prepared in water, optionally mixed with a nontoxic surfactant. Dispersions can also be prepared in glycerol, liquid polyethylene glycols, triacetin, and mixtures thereof and in oils. Under ordinary conditions of storage and use, these preparations can contain a preservative to prevent the growth of microorganisms.

The pharmaceutical dosage forms suitable for injection or infusion can include sterile aqueous solutions or dispersions or sterile powders comprising the active ingredient which are adapted for the extemporaneous preparation of sterile injectable or infusible solutions or dispersions, optionally encapsulated in liposomes. The ultimate dosage form should be

sterile, fluid and stable under the conditions of manufacture and storage. The liquid carrier or vehicle can be a solvent or liquid dispersion medium comprising, for example, water, ethanol, a polyol (for example, glycerol, propylene glycol, liquid polyethylene glycols, and the like), vegetable oils, nontoxic glyceryl esters, and suitable mixtures thereof. The proper fluidity can be maintained, for example, by the formation of liposomes, by the maintenance of the required particle size in the case of dispersions or by the use of surfactants. Optionally, the prevention of the action of microorganisms can be brought about by various other antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars, buffers or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the inclusion of agents that delay absorption, for example, aluminum monostearate and gelatin.

Sterile injectable solutions are prepared by incorporating a compound and/or agent of the invention in the required amount in the appropriate solvent with various other ingredients enumerated above, as required, followed by filter sterilization. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum drying and the freeze drying techniques, which yield a powder of the active ingredient plus any additional desired ingredient present in the previously sterile-filtered solutions.

Useful dosages of the compounds and agents and pharmaceutical compositions of the present invention can be determined by comparing their *in vitro* activity, and *in vivo* activity in animal models. Methods for the extrapolation of effective dosages in mice, and other animals, to humans are known to the art; for example, see U.S. Patent No. 4,938,949.

The present invention also concerns pharmaceutical compositions comprising a compound and/or agent of the invention in combination with a pharmaceutically acceptable carrier. Pharmaceutical compositions adapted for oral, topical or parenteral administration, comprising an amount of a compound constitute a preferred embodiment of the invention. The dose administered to a patient, particularly a human, in the context of the present invention should be sufficient to achieve a therapeutic response in the patient over a reasonable time frame, without lethal toxicity, and preferably causing no more than an acceptable level of side effects or morbidity. One skilled in the art will recognize that dosage will depend upon a variety of factors including the condition (health) of the subject, the body

weight of the subject, kind of concurrent treatment, if any, frequency of treatment, therapeutic ratio, as well as the severity and stage of the pathological condition.

To provide for the administration of such dosages for the desired therapeutic treatment, in some embodiments, pharmaceutical compositions of the invention can comprise between about 0.1% and 45%, and especially, 1 and 15%, by weight of the total of one or more of the compounds based on the weight of the total composition including carrier or diluents. Illustratively, dosage levels of the administered active ingredients can be: intravenous, 0.01 to about 20 mg/kg; intraperitoneal, 0.01 to about 100 mg/kg; subcutaneous, 0.01 to about 100 mg/kg; intramuscular, 0.01 to about 100 mg/kg; orally 0.01 to about 200 mg/kg, and preferably about 1 to 100 mg/kg; intranasal instillation, 0.01 to about 20 mg/kg; and aerosol, 0.01 to about 20 mg/kg of animal (body) weight.

The subject invention also concerns kits comprising a composition comprising a compound and/or agent and/or polynucleotide of the invention in one or more containers. Kits of the invention can optionally include pharmaceutically acceptable carriers and/or diluents. In one embodiment, a kit of the invention includes one or more other components, adjuncts, or adjuvants as described herein. In one embodiment, a kit of the invention includes instructions or packaging materials that describe how to administer a compound or composition of the kit. Containers of the kit can be of any suitable material, *e.g.*, glass, plastic, metal, *etc.*, and of any suitable size, shape, or configuration. In one embodiment, a compound and/or agent and/or polynucleotide of the invention is provided in the kit as a solid, such as a tablet, pill, or powder form. In another embodiment, a compound and/or agent and/or polynucleotide of the invention is provided in the kit as a liquid or solution. In one embodiment, the kit comprises an ampoule or syringe containing a compound and/or agent of the invention in liquid or solution form.

Mammalian species which benefit from the disclosed methods include, but are not limited to, primates, such as apes, chimpanzees, orangutans, humans, monkeys; domesticated animals (*e.g.*, pets) such as dogs, cats, guinea pigs, hamsters, Vietnamese pot-bellied pigs, rabbits, and ferrets; domesticated farm animals such as cows, buffalo, bison, horses, donkey, swine, sheep, and goats; exotic animals typically found in zoos, such as bear, lions, tigers, panthers, elephants, hippopotamus, rhinoceros, giraffes, antelopes, sloth, gazelles, zebras, wildebeests, prairie dogs, koala bears, kangaroo, opossums, raccoons, pandas, hyena, seals, sea lions, elephant seals, otters, porpoises, dolphins, and whales. Other species that may

benefit from the disclosed methods include fish, amphibians, avians, and reptiles. As used herein, the terms "patient" and "subject" are used interchangeably and are intended to include such human and non-human species. Likewise, *in vitro* methods of the present invention can be carried out on cultured cells or tissues of such human and non-human species.

5 The subject invention also concerns bacterial cells, and animals, animal tissue, and animal cells, and plants, plant tissue, and plant cells of the invention that comprise or express a polynucleotide or the protein encoded by the polynucleotide of the invention, or a fragment or variant thereof. Plant tissue includes, but is not limited to, seed, scion, and rootstock. Plants within the scope of the present invention include monocotyledonous plants, such as, 10 for example, rice, wheat, barley, oats, rye, sorghum, maize, sugarcane, pineapple, onion, bananas, coconut, lilies, turfgrasses, and millet. Plants within the scope of the present invention also include dicotyledonous plants, such as, for example, tomato, cucumber, squash, peas, alfalfa, melon, chickpea, chicory, clover, kale, lentil, soybean, beans, tobacco, potato, sweet potato, yams, cassava, radish, broccoli, spinach, cabbage, rape, apple trees, 15 citrus (including oranges, mandarins, grapefruit, lemons, limes and the like), grape, cotton, sunflower, strawberry, lettuce, and hop. Herb plants containing a polynucleotide of the invention are also contemplated within the scope of the invention. Herb plants include parsley, sage, rosemary, thyme, and the like. In one embodiment, a plant, plant tissue, or plant cell is a transgenic plant, plant tissue, or plant cell. In another embodiment, a plant, 20 plant tissue, or plant cell is one that has been obtained through a breeding program.

Polynucleotides encoding a fusion product of the present invention can be provided in an expression construct. Expression constructs of the invention generally include regulatory elements that are functional in the intended host cell in which the expression construct is to be expressed. Thus, a person of ordinary skill in the art can select regulatory elements for use 25 in bacterial host cells, yeast host cells, plant host cells, insect host cells, mammalian host cells, and human host cells. Regulatory elements include promoters, transcription termination sequences, translation termination sequences, enhancers, and polyadenylation elements. As used herein, the term "expression construct" refers to a combination of nucleic acid sequences that provides for transcription of an operably linked nucleic acid sequence. 30 As used herein, the term "operably linked" refers to a juxtaposition of the components described wherein the components are in a relationship that permits them to function in their intended manner. In general, operably linked components are in contiguous relation. In one

embodiment, an expression construct comprises a polynucleotide encoding an amino acid sequence of any of SEQ ID NOs:1-10.

An expression construct of the invention can comprise a promoter sequence operably linked to a polynucleotide sequence of the invention, for example a sequence encoding a fusion polypeptide of the invention. Promoters can be incorporated into a polynucleotide using standard techniques known in the art. Multiple copies of promoters or multiple promoters can be used in an expression construct of the invention. In a preferred embodiment, a promoter can be positioned about the same distance from the transcription start site in the expression construct as it is from the transcription start site in its natural genetic environment. Some variation in this distance is permitted without substantial decrease in promoter activity. A transcription start site is typically included in the expression construct.

If the expression construct is to be provided in or introduced into a plant cell, then plant viral promoters, such as, for example, a cauliflower mosaic virus (CaMV) 35S (including the enhanced CaMV 35S promoter (see, for example U.S. Patent No. 5,106,739)) or a CaMV 19S promoter or a cassava vein mosaic can be used. Other promoters that can be used for expression constructs in plants include, for example, prolifera promoter, Ap3 promoter, heat shock promoters, T-DNA 1'- or 2'-promoter of *A. tumefaciens*, polygalacturonase promoter, chalcone synthase A (CHS-A) promoter from petunia, tobacco PR-1a promoter, ubiquitin promoter, actin promoter, alcA gene promoter, pin2 promoter (Xu *et al.*, 1993), maize WipI promoter, maize trpA gene promoter (U.S. Patent No. 5,625,136), maize CDPK gene promoter, and RUBISCO SSU promoter (U.S. Patent No. 5,034,322) can also be used. Tissue-specific promoters, for example fruit-specific promoters, such as the E8 promoter of tomato (accession number: AF515784; Good *et al.* (1994)) can be used. Fruit-specific promoters such as flower organ-specific promoters can be used with an expression construct of the present invention for expressing a polynucleotide of the invention in the flower organ of a plant. Examples of flower organ-specific promoters include any of the promoter sequences described in U.S. Patent Nos. 6,462,185; 5,639,948; and 5,589,610. Seed-specific promoters such as the promoter from a β-phaseolin gene (for example, of kidney bean) or a glycinin gene (for example, of soybean), and others, can also be used. Endosperm-specific promoters include, but are not limited to, MEG1 (EPO application No. EP1528104) and those described by Wu *et al.* (1998), Furtado *et al.* (2002), and Hwang *et al.*

(2002). Root-specific promoters, such as any of the promoter sequences described in U.S. Patent No. 6,455,760 or U.S. Patent No. 6,696,623, or in published U.S. patent application Nos. 20040078841; 20040067506; 20040019934; 20030177536; 20030084486; or 20040123349, can be used with an expression construct of the invention. Constitutive
5 promoters (such as the CaMV, ubiquitin, actin, or NOS promoter), developmentally-regulated promoters, and inducible promoters (such as those promoters than can be induced by heat, light, hormones, or chemicals) are also contemplated for use with polynucleotide expression constructs of the invention.

Expression constructs of the invention may optionally contain a transcription
10 termination sequence, a translation termination sequence, a sequence encoding a signal peptide, and/or enhancer elements. Transcription termination regions can typically be obtained from the 3' untranslated region of a eukaryotic or viral gene sequence. Transcription termination sequences can be positioned downstream of a coding sequence to provide for efficient termination. A signal peptide sequence is a short amino acid sequence typically
15 present at the amino terminus of a protein that is responsible for the relocation of an operably linked mature polypeptide to a wide range of post-translational cellular destinations, ranging from a specific organelle compartment to sites of protein action and the extracellular environment. Targeting gene products to an intended cellular and/or extracellular destination through the use of an operably linked signal peptide sequence is contemplated for use with
20 the polypeptides of the invention. Classical enhancers are cis-acting elements that increase gene transcription and can also be included in the expression construct. Classical enhancer elements are known in the art, and include, but are not limited to, the CaMV 35S enhancer element, cytomegalovirus (CMV) early promoter enhancer element, and the SV40 enhancer element. Intron-mediated enhancer elements that enhance gene expression are also known in
25 the art. These elements must be present within the transcribed region and are orientation dependent. Examples include the maize *shrunken-1* enhancer element (Clancy and Hannah, 2002).

DNA sequences which direct polyadenylation of mRNA transcribed from the expression construct can also be included in the expression construct, and include, but are not
30 limited to, an octopine synthase or nopaline synthase signal. The expression constructs of the invention can also include a polynucleotide sequence that directs transposition of other genes, *i.e.*, a transposon.

Polynucleotides of the present invention can be composed of either RNA or DNA. Preferably, the polynucleotides are composed of DNA. The subject invention also encompasses those polynucleotides that are complementary in sequence to the polynucleotides disclosed herein. Polynucleotides and polypeptides of the invention can be
5 provided in purified or isolated form.

Because of the degeneracy of the genetic code, a variety of different polynucleotide sequences can encode polypeptides and enzymes of the present invention. A table showing all possible triplet codons (and where U also stands for T) and the amino acid encoded by each codon is described in Lewin (1985). In addition, it is well within the skill of a person
10 trained in the art to create alternative polynucleotide sequences encoding the same, or essentially the same, polypeptides and enzymes of the subject invention. These variant or alternative polynucleotide sequences are within the scope of the subject invention. As used herein, references to "essentially the same" sequence refers to sequences which encode amino acid substitutions, deletions, additions, or insertions which do not materially alter the
15 functional activity of the polypeptide encoded by the polynucleotides of the present invention. Allelic variants of the nucleotide sequences encoding a wild type polypeptide of the invention are also encompassed within the scope of the invention.

Substitution of amino acids other than those specifically exemplified or naturally present in a wild type polypeptide or enzyme of the invention are also contemplated within
20 the scope of the present invention. For example, non-natural amino acids can be substituted for the amino acids of a polypeptide, so long as the polypeptide having the substituted amino acids retains substantially the same biological or functional activity as the polypeptide in which amino acids have not been substituted. Examples of non-natural amino acids include, but are not limited to, ornithine, citrulline, hydroxyproline, homoserine, phenylglycine,
25 taurine, iodotyrosine, 2,4-diaminobutyric acid, α-amino isobutyric acid, 4-aminobutyric acid, 2-amino butyric acid, γ-amino butyric acid, ε-amino hexanoic acid, 6-amino hexanoic acid, 2-amino isobutyric acid, 3-amino propionic acid, norleucine, norvaline, sarcosine, homocitrulline, cysteic acid, τ-butylglycine, τ-butylalanine, phenylglycine, cyclohexylalanine, β-alanine, fluoro-amino acids, designer amino acids such as β-methyl
30 amino acids, C-methyl amino acids, N-methyl amino acids, and amino acid analogues in general. Non-natural amino acids also include amino acids having derivatized side groups. Furthermore, any of the amino acids in the protein can be of the D (dextrorotary) form or L

(levorotary) form. Allelic variants of a protein sequence of a wild type polypeptide or enzyme of the present invention are also encompassed within the scope of the invention.

Amino acids can be generally categorized in the following classes: non-polar, uncharged polar, basic, and acidic. Conservative substitutions whereby a polypeptide or
5 enzyme of the present invention having an amino acid of one class is replaced with another amino acid of the same class fall within the scope of the subject invention so long as the polypeptide having the substitution still retains substantially the same biological or functional activity (*e.g.*, enzymatic) as the polypeptide that does not have the substitution. Polynucleotides encoding a polypeptide or enzyme having one or more amino acid
10 substitutions in the sequence are contemplated within the scope of the present invention. Table 1 below provides a listing of examples of amino acids belonging to each class.

Table 1.

Class of Amino Acid	Examples of Amino Acids
Nonpolar	Ala, Val, Leu, Ile, Pro, Met, Phe, Trp
Uncharged Polar	Gly, Ser, Thr, Cys, Tyr, Asn, Gln
Acidic	Asp, Glu
Basic	Lys, Arg, His

The subject invention also concerns variants of the polynucleotides of the present invention that encode functional polypeptides of the invention. Variant sequences include
15 those sequences wherein one or more nucleotides of the sequence have been substituted, deleted, and/or inserted. The nucleotides that can be substituted for natural nucleotides of DNA have a base moiety that can include, but is not limited to, inosine, 5-fluorouracil, 5-bromouracil, hypoxanthine, 1-methylguanine, 5-methylcytosine, and tritylated bases. The sugar moiety of the nucleotide in a sequence can also be modified and includes, but is not
20 limited to, arabinose, xylulose, and hexose. In addition, the adenine, cytosine, guanine, thymine, and uracil bases of the nucleotides can be modified with acetyl, methyl, and/or thio groups. Sequences containing nucleotide substitutions, deletions, and/or insertions can be prepared and tested using standard techniques known in the art.

Fragments and variants of a polypeptide or enzyme of the present invention can be generated as described herein and tested for the presence of biological or enzymatic function using standard techniques known in the art. Thus, an ordinarily skilled artisan can readily prepare and test fragments and variants of a polypeptide or enzyme of the invention and determine whether the fragment or variant retains functional or biological activity (*e.g.*, enzymatic activity) relative to full-length or a non-variant polypeptide.

Polynucleotides and polypeptides contemplated within the scope of the subject invention can also be defined in terms of more particular identity and/or similarity ranges with those sequences of the invention specifically exemplified herein. The sequence identity will typically be greater than 60%, preferably greater than 75%, more preferably greater than 80%, even more preferably greater than 90%, and can be greater than 95%. The identity and/or similarity of a sequence can be 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99% as compared to a sequence exemplified herein. Unless otherwise specified, as used herein percent sequence identity and/or similarity of two sequences can be determined using the algorithm of Karlin and Altschul (1990), modified as in Karlin and Altschul (1993). Such an algorithm is incorporated into the NBLAST and XBLAST programs of Altschul *et al.* (1990). BLAST searches can be performed with the NBLAST program, score = 100, wordlength = 12, to obtain sequences with the desired percent sequence identity. To obtain gapped alignments for comparison purposes, Gapped BLAST can be used as described in Altschul *et al.* (1997). When utilizing BLAST and Gapped BLAST programs, the default parameters of the respective programs (NBLAST and XBLAST) can be used. *See* NCBI/NIH website.

As used herein, the terms “nucleic acid” and “polynucleotide” refer to a deoxyribonucleotide, ribonucleotide, or a mixed deoxyribonucleotide and ribonucleotide polymer in either single- or double-stranded form, and unless otherwise limited, would encompass known analogs of natural nucleotides that can function in a similar manner as naturally-occurring nucleotides. The polynucleotide sequences include the DNA strand sequence that is transcribed into RNA and the strand sequence that is complementary to the DNA strand that is transcribed. The polynucleotide sequences also include both full-length sequences as well as shorter sequences derived from the full-length sequences. Allelic variations of the exemplified sequences also fall within the scope of the subject invention.

The polynucleotide sequence includes both the sense and antisense strands either as individual strands or in the duplex.

Techniques for transforming plant cells with a polynucleotide or gene are known in the art and include, for example, *Agrobacterium* infection, transient uptake and gene
5 expression in plant seedlings, biolistic methods, electroporation, calcium chloride treatment, PEG-mediated transformation, *etc.* U.S. Patent No. 5,661,017 teaches methods and materials for transforming an algal cell with a heterologous polynucleotide. Transformed cells can be selected, redifferentiated, and grown into plants that contain and express a polynucleotide of the invention using standard methods known in the art. The seeds and other plant tissue and
10 progeny of any transformed or transgenic plant cells or plants of the invention are also included within the scope of the present invention. In one embodiment, the cell is transformed with a polynucleotide sequence comprising a sequence encoding the amino acid sequence shown in SEQ ID NOs:1-10, or a biologically active fragment or variant thereof.

The subject invention also concerns cells transformed with a polynucleotide of the
15 present invention encoding a polypeptide or enzyme of the invention. In one embodiment, the cell is transformed with a polynucleotide sequence comprising a sequence encoding the amino acid sequence shown in SEQ ID NOs:1-10, or a biologically active fragment or variant thereof. In one embodiment, the polynucleotide sequence of the invention is provided in an expression construct of the invention. The transformed cell can be a prokaryotic cell, for
20 example, a bacterial cell such as *E. coli* or *B. subtilis*, or the transformed cell can be a eukaryotic cell, for example, a plant cell, including protoplasts, or an animal cell. Plant cells include, but are not limited to, dicotyledonous, monocotyledonous, and conifer cells. Animal cells include human cells, mammalian cells, avian cells, and insect cells. Mammalian cells include, but are not limited to, COS, 3T3, and CHO cells.
25 Single letter amino acid abbreviations are defined in Table 2.

Table 2.

Letter Symbol	Amino Acid	Letter Symbol	Amino Acid
A	Alanine	M	Methionine
B	Asparagine or aspartic acid	N	Asparagine
C	Cysteine	P	Proline
D	Aspartic Acid	Q	Glutamine
E	Glutamic Acid	R	Arginine
F	Phenylalanine	S	Serine

Table 2.			
Letter Symbol	**Amino Acid**	**Letter Symbol**	**Amino Acid**
G	Glycine	T	Threonine
H	Histidine	V	Valine
I	Isoleucine	W	Tryptophan
K	Lysine	Y	Tyrosine
L	Leucine	Z	Glutamine or glutamic acid

All patents, patent applications, provisional applications, and publications referred to or cited herein are incorporated by reference in their entirety, including all figures and tables, to the extent they are not inconsistent with the explicit teachings of this specification.

5 Following are examples that illustrate procedures for practicing the invention. These examples should not be construed as limiting. All percentages are by weight and all solvent mixture proportions are by volume unless otherwise noted.

Example 1

10 PTB-lectins can carry and deliver fused payloads (genetically fused proteins or conjugated small molecules) into mammalian epithelial cells (*e.g.*, HT29 human gut epithelial cells, HeLa cells, A549 lung epithelial cells). Genetic fusions of RTB (the lectin subunit B of ricin) or NBB (the lectin B subunit of nigrin B) with Green Fluorescent Protein or Red Fluorescent Protein (DsRed) were produced and purified. The lectin:fluorescent fusion 15 proteins were then incubated with cultured cells at 0-4° C to allow binding to the cell surface. Cells were then washed and incubated at 37° C to initiate uptake into the cultured mammalian cells. The fluorescently tagged RTB and NBB was observed to bind to the cell surface at time zero and to move to internal punctuate structures by 30 to 60 minutes indicative of endosomal/lysosomal compartments. In contrast, incubation of cells with Green Fluorescent 20 Protein or Red Fluorescent Protein that lacked the PTB-lectin did not bind to cells or transit to internal compartments indicating that the PTB-lectin was responsible for binding and uptake. Likewise, RTB that was labeled by conjugation with fluors (*e.g.*, fluorescein; DyLight), or conjugation with biotin and then subsequent assembly with labeled strepavidin, also bound to the surface of mammalian endothelial cells and was transported to internal 25 endosomal/lysosomal compartments based on fluorescent punctate structures observed at 30, 60, and 120 minutes incubation at 37° C. Furthermore, uptake into endosomal/lysosomal

compartments was further documented by co-localization of RTB or NBB fusions or conjugates with lysosomal markers (e.g., Lysotracker-Red or Lysotracker-Green) or antibodies directed against the EEA early endosome marker.

5 Example 2

PTB-lectin carries fused proteins across confluent cell layers demonstrating transcytosis (Figure 1). In other studies, we produced RTB fusions with the mouse cytokine interleukin-12 (IL-12). IL-12 triggers induction of interferon-γ (IFN-γ) in splenocytes but not epithelial cells. To demonstrate transcytosis, a confluent monolayer of HT29 cells was
10 developed and placed as an insert over primary mouse splenocytes. IL-12:RTB, but not IL-12 alone, triggered IFN-g induction. Addition of anti-RTB neutralizing antibody blocked this induction (Liu, Dolan, Cramer, unpublished data).

Example 3

15 Plant-based production of recombinant PTB-lectin – human lysosomal fusion proteins yields proteins that simultaneously display selective lectin binding activity and lysosomal enzyme activity. In order to demonstrate that PTB-lectins successfully deliver lysosomal ERT (enzyme replacement therapy) enzymes to the cells and organelles that are critical targets for ameliorating symptoms of lysosomal diseases, we utilized several model ERTs
20 including human α-L-iduronidase (IDUA) and the human sulfaminidase, N-sulfoglucosamine sulfohydrolase (SGSH). Gene constructs were developed that fused the coding region of the plant lectins RTB or NBB to the coding regions of the human lysosomal enzymes. Typically, the fusion partners were tested in both orientations (*e.g.*, NBB:IDUA and IDUA:NBB). The genes encoded a plant signal peptide (the signal peptide from the potato patatin gene) to
25 ensure that the recombinant product was targeted to the endoplasmic reticulum for addition of N-linked glycans. These genes were introduced into plant expression/transfection vectors (derivatives of pBIB-Kan; Becker (1990) and expressed in *Nicotiana benthamiana* leaves using a transient *Agrobacterium*-mediated expression system as described (Medrano *et al.* (2009)).

30 Gene constructs for NBB:IDUA, IDUA:NBB and IDUA:RTB were developed and expressed in *N. benthamiana*. In all cases, plants produced a protein of the expected molecular size (~110 kDa) product that cross-reacted with anti-IDUA specific antibodies on

Western immunoblots (for example see Figure 2). IDUA-specific enzyme activity was demonstrated for these plant-derived PTB-lectin–IDUA fusions using a fluorometric assay with sodium-4-methylumbelliferyl-α-L-iduronide (4-MUI) as substrate. Thus, fusion with the PTB-lectins did not interfere with IDUA enzymatic activity. Furthermore, results using a dual-activity assay involving RTB binding of plant-made products to immobilized asialofetuin (glycoprotein with high affinity for RTB) and detection/quantification of the lectin-bound IDUA activity using the standard 4-MUI enzymatic assay also showed that IDUA:RTB and retained both lectin-specificity and human enzyme activity.

Similarly, PTB-lection fusion constructs with human lysosomal sulfaminidase SGSH were developed in both orientations (*i.e.*, with the human enzyme as either the C- or N-terminal partner) with both NBB and RTB. These constructs were expressed in *N. benthamiana*. To characterize the plant-synthesized products containing SGSH, SGSH-specific enzyme activity can be demonstrated using a fluorometric assay with 4-methylumbelliferyl-α-D-N-sulfoglucosaminide as substrate (*e.g.*, Esposito *et al.* (2000)).

Example 4

PTB-lectin:lysosomal enzyme fusions correct substrate accumulation in LD cells. To demonstrate that PTB-lectins delivery active ERT enzymes to the cellular site of disease substrate, we produced IDUA:RTB, and IDUA:NBB in *N. benthamiana* and used the product to treat cultured fibroblasts from Hurler and Hurler/Scheie patients (patients with IDUA deficiency). The recombinant proteins were purified by a combination of ammonium sulfate precipitation, affinity chromatography, and size exclusion chromatography. The affinity chromatography process utilized lactose resin for RTB-containing products and N-acetyl-galactosamine resin for NBB-containing products. The ability of PTB-lectin:IDUA fusions to correct the lysosomal disease phenotype in Hurler and Hurler/Scheie cells was demonstrated based on reduction of lysosomal size and number. Because Hurler and Hurler Scheie patients cannot effectively clear cells of the glucosaminoglycan (GAG; the disease substrate) macromolecule, a characteristic cellular disease phenotype is enlarged lysosomes, the intracellular site of GAG accumulation. We therefore tested the ability of PTB-lectin fusions with IDUA to reduce the lysosomal volume per cell of diseased fibroblasts to those observed in normal fibroblasts. Untreated normal fibroblasts (NIH Cell Repository; Coriell #GM00010), Hurler fibroblasts (Coriell #01391) and Hurler/Scheie fibroblasts (Coriell

#GM00963) were used as controls to set "normal" and "disease" levels. Commercially available animal-cell-derived recombinant human IDUA (rhIDUA, *e.g.* from R&D Systems), which includes mannose-6-phosphate-modified glycans to facilitate cell uptake, was also included as a positive control.

5 For these analyses, Normal and Hurler/Scheie fibroblasts were plated in a 96 well plate format. To assess correction of lysosomal phenotype, Hurler/Sheie fibroblasts were incubated for 20-24 hours with IDUA:NBB, IDUA:RTB or rhIDUA. Following incubation, lysosomes were detected using LYSOTRACKER red (Invitrogen), cells were fixed and nuclei were stained using DAPI blue (Invitrogen) to facilitate cell count per image. The BD 10 Pathway 855 BioImaging System was used to collect 4X4 montage images per well using confocal image capture at 20X magnification. Fluorescent measurement analyses and cell counts were performed using the same segmentation parameters in all images. Lysosomal area was defined as the total area in pixels of red fluorescent signal per cell as defined by number of DAPI-stained nuclei) in each well. The lysosomal area/cell and lysosomal 15 number/cell were significantly different between normal and Hurler/Scheie fibroblasts using this assay system. Both IDUA:NBB and IDUA:RTB reduced the lysosomal area and lysosomal number per Hurler/Scheie fibroblast to the levels observed in Normal fibroblasts (see representative IDUA:NBB data in Figure 3).

The PTB-lectin technology can be used to deliver other lysosomal replacement 20 enzymes such as the human SGSH acid sulfaminidase for treatment of Mucopolysaccharidosis IIIA (Sanfilippo A Disease). In order to demonstrate that PTB-lectin fusions with human SGSH correct cellular disease phenotypes, the PRT-lectin:SGSH fusion proteins are tested on primary cell cultures from Sanfilippo A patients (Coriell #GM01881) and mouse *sgsh*$^{-/-}$ knockout mice. Primary human fibroblasts from normal individuals and 25 Sanfilippo A patients are cultured to near-confluency in 96-well plates and incubated for 48h with purified PRT-lectin:SGSH fusions. Harvested cells are analyzed for reduction of sulfated GAG substrate levels and lysosomal area following treatment with PRT-lectin:SGSH fusions. Similar uptake and substrate correction experiments are performed using PRT-lectin:SGSH fusions administered to cultured *sgsh*$^{-/-}$ mouse MEFs, macrophages, and 30 neurospheres. The elevated GAG levels present in Sanfilippo A human and mouse cells are expected to be reduced to normal levels following treatment with PRT-lectin:SGSH fusions

indicating delivery of active and corrective enzyme to the site of disease substrate accumulation.

Example 5

PTB-lectin:lysosomal enzyme fusions correct substrate accumulation in LD disease cells by mechanisms that are independent of the mannose-6-phosphate receptor (M6PR). To demonstrate that PTB-lectins carry associated lysosomal enzymes into cells and lysosomes by mechanisms that differ from the current FDA-approved ERTs for Hurler and Hurler/Scheie Syndromes (mucopolysaccharidosis I) which uses the M6P receptor to deliver ERT into cells, we assayed Hurler/Scheie fibroblasts for disease phenotype correction in the presence of M6PR competitive inhibitors. To block the M6P receptor, Hurler/Scheie fibroblasts were incubated with 3 or 4 mM M6P (D-mannose-6-phosphate sodium salt) for 2 hours prior to the addition of IDUA:RTB or animal-cell derived rhIDUA. After 24 hr further incubation at 37° C, the cells were harvested and lysosomal area/cell and lysosome number/cell were determined by high-through-put confocal bioimage analyses following staining with Lysotracker-red and DAPI blue (see Example 4). Hurler cells treated with IDUA:RTB in the presence of M6P showed full correction of the lysosomal disease phenotype to those observed in Normal cells or in Hurler/Scheie cells treated in the absence of M6P (Figure 4). In contrast, Hurler/Scheie cells treated with animal-cell-derived rhIDUA in the presence of M6P showed no correction of GAG levels, lysosomal area/cell or lysosome number/cell indicating that the levels used were fully inhibitory for cell uptake based on the M6P receptor. Our data confirmed that IDUA delivery and efficacy of the PTB-lectin fusions was M6PR-independent.

In addition, GAG levels and lysosomal area of Hurler/Scheie cells treated with IDUA:NBB in the presence of inhibitory levels of M6P or mannan are corrected to normal levels. Likewise, sulfated GAG levels and lysosomal area of SanfilippoA fibroblasts (Coriell #GM01881) treated with RTB:SGSH or SGSH:RTB in the presence of inhibitory levels of M6P or mannan are corrected to normal levels.

Example 6

PTB-lectins can deliver associated payload (genetically fused protein or conjugated compound) into cells, tissue and organs important in human disease pathology. PTB-lectins

genetically fused with fluorescent marker proteins (*e.g.*, GFP green fluorescent protein and the DsRed red fluorescent protein) or fluorescently labeled by conjugation (*e.g.*, with fluorescein or Dylight) have been used to demonstrate delivery into cells and tissues that are associated with disease including lysosomal diseases. As detailed further below, normal and disease cells or tissues were treated by the addition of purified PTB-lectin proteins, incubated at 37° C for various times (typically 0 – 24 hrs), and cell surface binding and uptake into intracellular compartments was monitored by fluorescence and/or confocal microscopy. Cells were often counter-stained with DAPI (blue) to delineate nuclei and organelle-selective compounds such as Lysotracker.

To demonstrate uptake of PTB-lectin and PTB-lectin fusion proteins into key cells of the central nervous system, primary neurosphere cultures were established from brain tissue of normal mice (as described in Tessitore *et al.* (2004)), treated with 1μg/ml lectin equivalent of either a) RTB:GFP and b) DsRed:NBB and incubated overnight, and then stained for 30 minutes with Lysotracker-red or Lysotracker-green, respectively, prior to microscopic imaging. Both RTB:GFP and DsRed:NBB were detected intracellularly in punctate structures indicative of endosomal/lysosomal compartment and the majority co-localized with Lysotraker. All cells showed fusion protein uptake indicating that PTB-lectins mediate uptake into neurons and astrocytes of the brain. In other experiments, RTB:GFP and Dylight-labeled RTB were added to primary bovine brain microvessel endothelial cells that had been grown in vitro to tight confluency as a model of the blood brain barrier (BBB; methods as described in Bachmeier *et al.* (2006)). Both RTB:GFP and $RTB^{Dylight}$ showed efficient binding to brain endothelial cells and uptake into the endomembrane system at 30 and 60 minutes post-incubation. Based on this high level of RTB:GFP endocytosis into the brain endothelial layer that forms the blood brain barrier and documented RTB transcytosis in other cell types (*e.g.*, see Example 2), it is expected that RTB- and NBB-fusions effectively carry associated proteins or drugs across the blood brain barrier and into neurons and astrocytes of the brain in both *in vitro* BBB models and *in vivo*. Likewise, it is expected that PTB-lectins effectively carry associated proteins or drugs across the analogous blood ocular barrier for delivery of payloads to disease cells of the eye.

To demonstrate uptake of PTB-lectin and PTB-lectin fusion proteins into key cells of the respiratory system, sections of metabolically active human lung sections were treated with RTB:GFP. These sections were developed by gently filling the airspace of lungs that

were maintained on ice since harvest with low-melting-point agarose and then culturing excised tissue sections that encompassed airways and surrounding tissues. These tissues were able to mediate chemically-induced constriction and relaxation of airways indicating integrity of the tissue. After 4 hours incubation with RTB:GFP, tissues analyzed by confocal microscopy revealed uptake of RTB:GFP into intracellular compartments of aveolar epithelial cells, macrophages, and lung cartilage tissues and chondrocytes. Uptake was further confirmed in primary cell cultures of airway epithelial and smooth muscle cells from this human lung. Aveolar epithelial cells, analyzed at 30 to 120 min after RTB:GFP addition, showed efficient uptake into the endosomal/lysosomal compartments. Differentiating airway smooth muscle cells showed strong RTB:GFP localization to the sarcoplasmic reticulum.

The PTB-lectin technology could also be used to deliver associated proteins into key cells of the skeletal system. As mentioned above, RTB:GFP was efficiently taken up by the connective tissues of the human lung (cartilage; chondrocytes), macrophages (differentiated monocyte produced in bone marrow), and skin fibroblasts (of skeletal system lineage). Likewise, it is expected that PTB-lectins effectively carry associated proteins or drugs into osteoblasts and other key bone cells. To document this in an *in vitro* model of osteogenesis, fluorescently tagged PTB-lectins (*e.g.*, RTB:GFP, DsRed:NBB) are added to cultures displaying osteogenic "bone nodules" and the uptake and subcellular location determined by confocal microscopy. In these systems which are well known in the field (*e.g.*, Malaval *et al.* (1994); Gaddy-Kurten *et al.* (2002); Jørgensen *et al.* (2004); Lazarenko *et al.* (2006)), bone progenitor cells that have been cultured from rat, mouse, human bone marrow, or other sources multiply and differentiate to form nodules that contain differentiated osteoblasts, fibroblasts, adipocytes, and monocytes.

Example 7

PTB-lectins can deliver genetically fused human enzymes or therapeutic proteins into cells, tissue and organs important in human disease pathology. PTB-lectins genetically fused with human lysosomal enzymes such as IDUA and SGSH, can be used to demonstrate correction of cellular disease phenotype in cells and tissues strongly linked with disease pathology. For example, for Hurler (IDUA deficiency) and Sanfilippo A (SGSH deficiency) lysosomal diseases, disease impacts on the central nervous system can be devastating. To provide an *in vitro* assessment of PTB-lectin-mediated delivery of corrective enzyme to key

cells of the CNS, neurospheres cultures are established from knockout mice for each disease. It is known that cells of neurospheres cultured from the mouse knockout models for lysosomal diseases having significant CNS involvement (*e.g.*, see Tessitore *et al.* (2004)) show a distinctive phenotype including extensive vacuolization due to disease substrate
5 accumulation in lysosome of the neurons and astrocytes. Neurosphere cultures established from *sgsh*$^{-/-}$ mice are treated with various concentrations of RTB:SGSH, SGSH:RTB, NBB:SGSH, or SGSH:NBB for 24 and 48 hours. Following incubation, treated and untreated cells are analyzed by confocal microscopy following staining with antibodies to accumulated disease substrate and/or Lysotracker and DAPI to visualize reduction in disease
10 substrate and lysosomal volume. Use of neuron and astrocyte selective antibodies delineates disease phenotype correction in each cell type. Similarly, neurospheres cultures established from *idua*$^{-/-}$ mice are used to document correction of CNS pathologies at the cell level using PTB-lectin:IDUA fusions.

Likewise, for diseases where bone impairment represents a significant aspect of
15 disease pathology, *in vitro* osteogenesis models (see Example 6) are used to document corrective PTB-lectin-mediated delivery of associated ERT enzymes.

Example 8

PTB-lectins can deliver fused active lysosomal enzymes to animal brains and across
20 the blood brain barrier.

IDUA:RTB at several concentrations are administered into Balb/C mice by injection into a tail vein, the carotid artery, or the heart (left ventricle). Mice are euthanized at various times after injection (1, 2, and 4 hours) and saline perfused to remove fusion protein that remains in the plasma. Brains are removed with one half used for homogenization to assay
25 directly for lectin:enzyme activity and the other half is used for analysis by fluorescence activated cell sorting (FACS) and/or flow cytometry. For direct enzyme assay, tissue is homogenized and used for dual-activity IDUA enzyme assays as described. This assay first captures lectin-active proteins based on binding to asialofetuin glycoprotein and thus detects only IDUA:RTB activity and not endogenous IDUA. Brain levels in animals treated with
30 saline (mock) and IDUA:RTB are compared to show that IDUA activity is significantly higher in brains of animals receiving IDUA:RTB treatment. To demonstrate that RTB delivers IDUA across the BBB, treated brain tissue is dissociated and the resulting single cell

suspension is reacted with cell-type specific surface antibodies for neurons and glial cells (Panchision *et al.* (2007); Yuan *et al.* (2011)) and subjected to FACS to provide selectively enriched populations of neuronal and glial cells. The enriched fractions are then analyzed for IDUA activity using the dual activity assay descripted above. In other experiments, brain
5 cells from untreated or IDUA:RTB-treated mice are treated with neuron-selective surface antibodies and then permeabilized and incubated with anti-RTB antibodies and analyzed by flow cytometry. Similarly, untreated and treated brains cell can be differentially labeled with glial surface antibodies and anti-RTB antibodies and subjected to flow cytometry analyses. These analyses document the presence of the PTB-lectins within neurons and/or glial cells
10 demonstrating transit across the BBB.

Example 9

RTB:lysosomal enzyme fusions deliver active enzyme to CNS tissue in knock-out mouse models.

15 As an example to show that PTB-lectins deliver "corrective" doses of ERT *in vivo*, *idua*$^{-/-}$ mice (mouse model of Hurler syndrome including CNS pathology; Ohmi *et al.* (2003)) are treated with IDUA:RTB. To establish effective test doses and determine short-term biodistribution, *idua*$^{-/-}$ mice are given a single administration by tail-vein injection at varying doses ranging from 0.06 to 6.0 mg IDUA equivalent/kg body weight. Mice are euthanized at
20 1 hour or 4 hours post injection, bled, and perfused with saline. The drug is quantified on the basis of IDUA catalytic activity in key organs (*e.g.*, liver, kidney, spleen, heart, cerebrum, and cerebellum) and in plasma to assess clearance from the circulation.

Disease correcting efficacy of IDUA:RTB is tested in *idua*$^{-/-}$ knockout mice by analyzing disease progression and impact on organ-specific pathologies following repeated
25 administrations of IDUA:RTB for a 4 to 8 week period. *idua*$^{-/-}$ mice are treated weekly by intravenous injection. Normal mice (*idua*$^{+/+}$ or *idua*$^{+/-}$) and untreated *idua*$^{-/-}$ mice are analyzed in parallel with IDUA:RTB-treated mice. Mice are photographed and analyzed for weight, urine GAG levels, and cognitive behavior (swimming T-maze) at onset and weekly starting at the initiation of treatment. *idua*$^{-/-}$ mice treated weekly for four, six or eight weeks,
30 and the control mice, are euthanized, perfused, and selected organs analyzed for biomarkers of disease. Analyses of selected organs (*e.g.*, brain, liver, spleen, lung, kidney, heart) include organ weight; IDUA specific enzyme activity, and GAG levels in tissue homogenates and

histopathology of tissues stained for GAG and, in brain for GM3-gangliosides as done routinely by those skilled in the art (*e.g.*, Ma *et al*. (2007); Hartung *et al.* (2004); Aronovich *et al*. (2009)). Using these techniques, the impact on brain of IDUA:RTB treatment is measured by quantitative morphometric analysis and behavioral testing comparing treated
5 mice with untreated *idua*-/- mice. Additional analyses for assessing drug impacts on other specific organs and tissues such as the bone, eye, ear, and heart/aorta affected in *idua*$^{-/-}$ mice are also performed as described (*e.g.*, Ma *et al.* (2007)). Experiments may also be expanded to included repeat IDUA:RTB administration (*e.g.*, weekly or bi-weekly) of *idua*$^{-/-}$ mice started within 2 weeks of birth and analyzed at various periods to assess whether
10 development of disease pathologies is avoided or significantly delayed compared to untreated *idua*$^{-/-}$ mice.

It should be understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be
15 suggested to persons skilled in the art and are to be included within the spirit and purview of this application and the scope of the appended claims. In addition, any elements or limitations of any invention or embodiment thereof disclosed herein can be combined with any and/or all other elements or limitations (individually or in any combination) or any other invention or embodiment thereof disclosed herein, and all such combinations are
20 contemplated with the scope of the invention without limitation thereto.

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CLAIMS

We claim:

1: A compound comprising:

a) a therapeutic agent or compound; and

b) a protein comprising a lectin or a carbohydrate binding domain that mediates delivery into cells of animals and humans;

wherein the therapeutic compound or agent is operatively linked or fused to the protein comprising the lectin or the carbohydrate binding domain.

2: The compound of claim 1, wherein the lectin is from the B subunit of a plant toxalbumin.

3: The compound of claim 2, wherein the B subunit is from a ricin, abrin, nigrin, mistletoe lectin, viscumin toxis, ebulin, pulchellin, pharatoxin, hurin, or phasin.

4: The compound of claim 1, wherein the lectin activity is from a non-toxalbumin plant lectin.

5: The compound of claim 4, wherein the non-toxalbumin plant lectins are wheat germ agglutinin, peanut agglutinin, tomato agglutinin, phytohemagglutinin, Concanavalin A, the peanut and soybean lectins, and jacalin.

6: The compound of claim 1, wherein the therapeutic agent or compound is a therapeutic protein, peptide, drug, siRNA, antisense oligonucleotide, or oligosaccharide.

7: The compound of claim 6, wherein the therapeutic protein is an enzyme replacement therapeutic.

8: The compound of claim 7, wherein the enzyme replacement therapeutic is a lysosomal protein, lysosomal enzyme, or other enzyme.

9: The compound of claim 8, wherein the lysosomal or other enzyme comprises beta-hexosaminidase, alpha-D-mannosidase, aspartylglucosaminidase, lysosomal acid lipase, hexosaminidase A, cystinosin, LAMP2, alpha-galactosidase A, ceramidase, alpha-L-fucosidase, cathepsin A, beta-glucocerebrosidase, beta-galactosidase, GlcNAc-phosphotransferase, sialin, hexosaminidase A, Infantile galactocerebrosidase, arylsulfatase A, N-acetylglucosamine-1-phosphotransferase, alpha-L iduronidase, iduronate-2-sulfatase, heparan N-sulfatase, sulfatase modifying factor 1, N-acetyl-alpha-D-glucosaminidase, acetyl-CoA alpha-glucosaminide acetyltransferase, β-galactosidase-1, N-acetylglucosamine-G-sulfate-sulfatase, N-acetylgalatosamine-6-sulfate-sulfatase, hyaluronidase, arylsulfatase B, beta-glucuronidase, alpha-N-acetyl neuraminidase, lysosomal protective protein/cathepsin A, neuraminidase 1, N-acetylglucosamine-1-phosphotransferase, mucolipin1, sphingomyelinase, ceroid-lipofuscinosis neuronal protein, battenin; ceroid-lipofuscinosis neuronal protein, tripeptidyl peptidase 1; ceroid-lipofuscinosis neuronal protein, palmitoyl-protein thioesterase, alpha-mannosidase, beta-mannosidase, ATP-binding cassette transporter ABCA, acid maltase, cathepsin K, beta-hexosaminidases A and B, beta-hexosaminidases A and B, alpha-N-acetylgalactosaminidas, sialin, beta-hexosaminidase, lysosomal acid lipase, the Hermansky-Pudlak syndrome proteins (HPS3, HPS4, HPS5, HPS6 and HPS7) Type 2 - AP-3 complex subunit beta-1, Type 7 -dysbindin, trafficking regulator protein, and Type 1: myosin-Va, Type 2: ras-related protein Rab-27A, Type 3: melanophilin, superoxide dismutase, α1-Antitrypsin, tyrosinase, Sucrase-isomaltase, PIP2-5-phosphatase, cartilage-associated protein, prolyl 3-hydroxylase 1, lysyl hydroxylase, cyclophilin B, adenosine deaminase, or an enzyme or protein involved in neurodegenerative diseases including Parkinson's, Alzheimer's, and Huntington's.

10: A method for treating or preventing a disorder or disease in a person or animal, wherein the method comprises providing a polynucleotide of claim 16, or administering a therapeutically effective amount of a compound of any of claims 1 to 9 wherein the therapeutic agent or compound is useful for treating or ameliorating the disorder or disease.

11: The method of claim 10, wherein the disorder or disease is a lysosomal disease.

12: The method of claim 10, wherein the disorder or disease is expressed in any organ, tissue, or cell of the body.

13: The method of claim 12, wherein the organ, tissue, or cell includes brain, central nervous system, heart, lungs, kidney, bone, liver, spleen, eye, and ear.

14: The method of claim 10, wherein the disorder or disease is Activator Deficiency/GM2 Gangliosidosis, Alpha-mannosidosis, Aspartylglucosaminuria, Cholesteryl ester storage disease, Chronic Hexosaminidase A Deficiency, Cystinosis, Danon disease, Fabry disease, Farber disease, Fucosidosis, Galactosialidosis, Gaucher Disease (Type I, Type II, Type III), GM1 gangliosidosis (Infantile, Late infantile/Juvenile, Adult/Chronic), I-Cell disease/Mucolipidosis II, Infantile Free Sialic Acid Storage Disease/ISSD, Juvenile Hexosaminidase A Deficiency, Krabbe disease (Infantile Onset, Late Onset), Metachromatic Leukodystrophy, Mucopolysaccharidoses disorders (Pseudo-Hurler polydystrophy/Mucolipidosis IIIA, MPSI Hurler Syndrome, MPSI Scheie Syndrome, MPS I Hurler-Scheie Syndrome, MPS II Hunter syndrome, Sanfilippo syndrome Type A/MPS III A, Sanfilippo syndrome Type B/MPS III B, Sanfilippo syndrome Type C/MPS III C, Sanfilippo syndrome Type D/MPS III D, Morquio Type A/MPS IVA, Morquio Type B/MPS IVB, MPS IX Hyaluronidase Deficiency, MPS VI Maroteaux-Lamy, MPS VII Sly Syndrome, Mucolipidosis I/Sialidosis, Mucolipidosis IIIC, Mucolipidosis type IV), Multiple sulfatase deficiency, Niemann-Pick Disease (Type A, Type B, Type C), Neuronal Ceroid Lipofuscinoses (CLN6 disease - Atypical Late Infantile, Late Onset variant, Early Juvenile; Batten-Spielmeyer-Vogt/Juvenile NCL/CLN3 disease; Finnish Variant Late Infantile CLN5; Jansky-Bielschowsky disease/Late infantile CLN2/TPP1 Disease; Kufs/Adult-onset NCL/CLN4 disease; Northern Epilepsy/variant late infantile CLN8; Santavuori-Haltia/Infantile CLN1/PPT disease; Beta-mannosidosis), Tangier disease, Pompe disease/Glycogen storage disease type II, Pycnodysostosis, Sandhoff disease/Adult Onset/GM2 Gangliosidosis, Sandhoff disease/GM2 gangliosidosis – Infantile, Sandhoff disease/GM2 gangliosidosis – Juvenile, Schindler disease, Salla disease/Sialic Acid Storage Disease, Tay-Sachs/GM2 gangliosidosis, Wolman disease, Sphingolipidosis, Hurmansky-Pudiak Syndrome, Chediak-Higashi Syndrome, or Griscelli disease.

15: The method of claim 10, wherein the disorder or disease is Parkinson's, Alzheimer's, Huntington's, and ALS (amyotrophic lateral sclerosis), Hereditary emphysema, Oculocutaneus albinism, Congenital sucrase-isomaltase deficiency, Choroideremiand Lowe's Oculoceribro-renal syndrome, Osteogenesis Imperfecta, or osteoporosis.

16: A polynucleotide encoding a compound of any of claims 1 to 9.

17: The polynucleotide of claim 16, wherein said polynucleotide is provided in an expression construct.

18: A plant, or animal, or a plant or animal tissue or cell, comprising a polynucleotide of claim 16 or a compound of any of claims 1 to 9.

19: The plant or animal cell of claim 18, wherein the cell is a plant cell.

20: A method for preparing a compound of any of claims 1 to 9, comprising expressing a polynucleotide of claim 16 in a bacterial, plant, or animal cell, and isolating the expressed compound from the bacterial, plant, or animal cell.

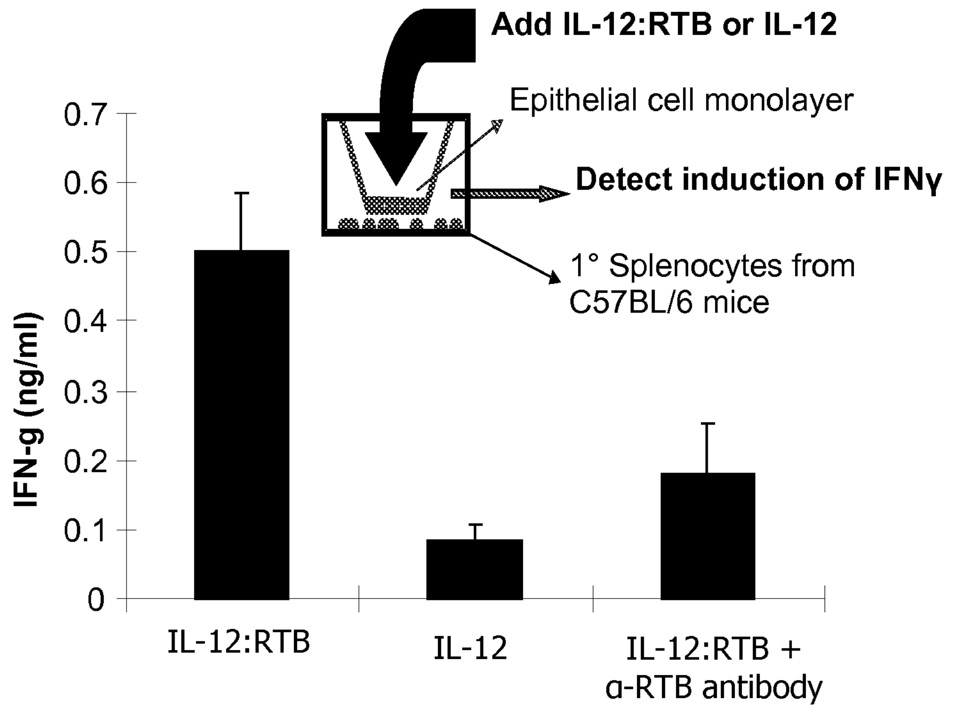


FIG. 1

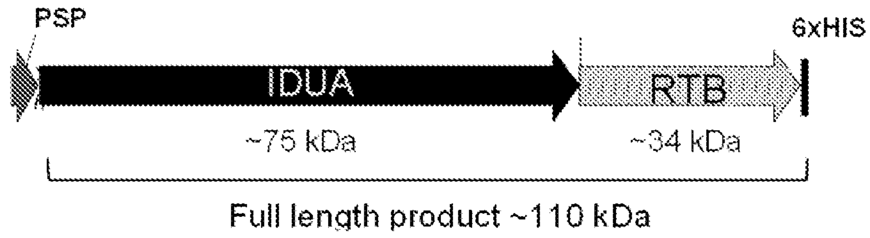


FIG. 2A

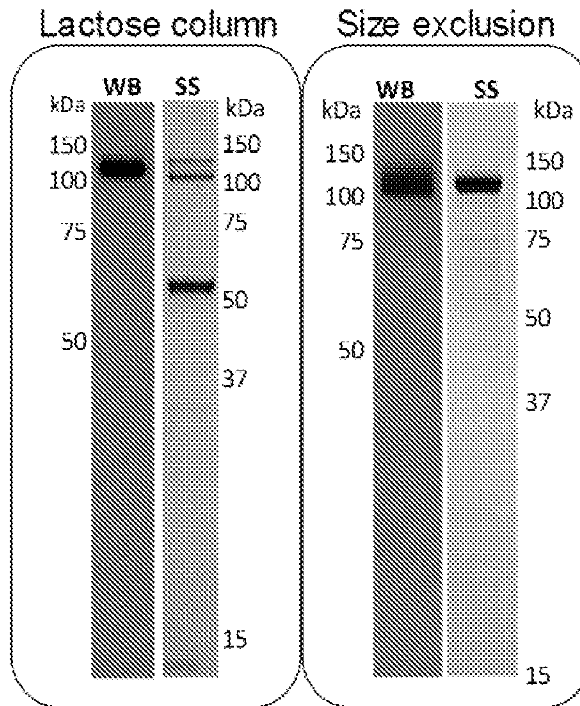


FIG. 2B

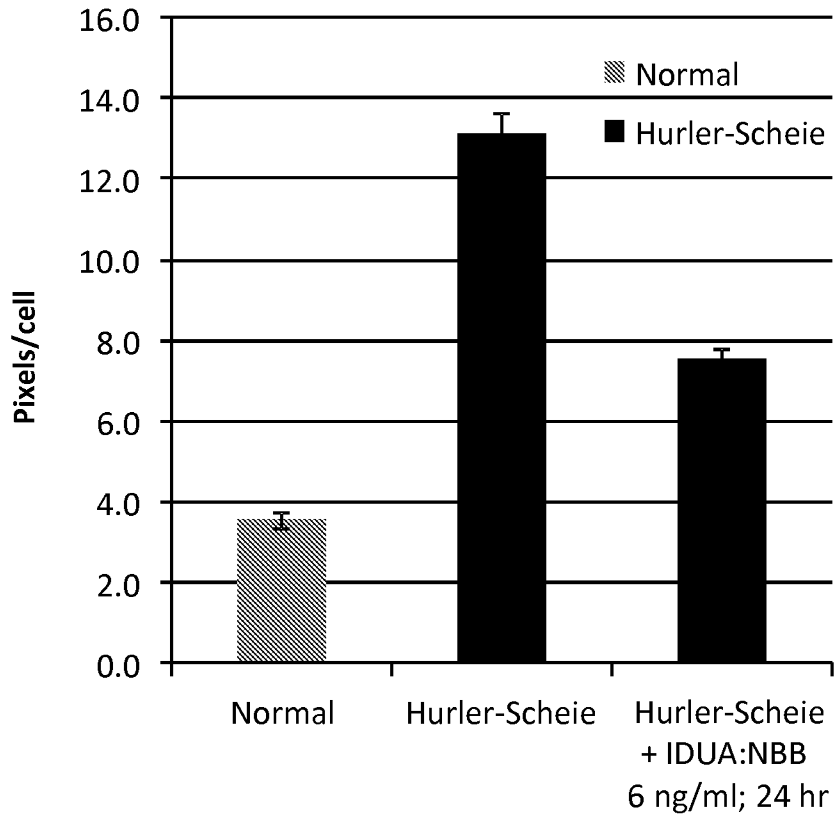


FIG. 3A

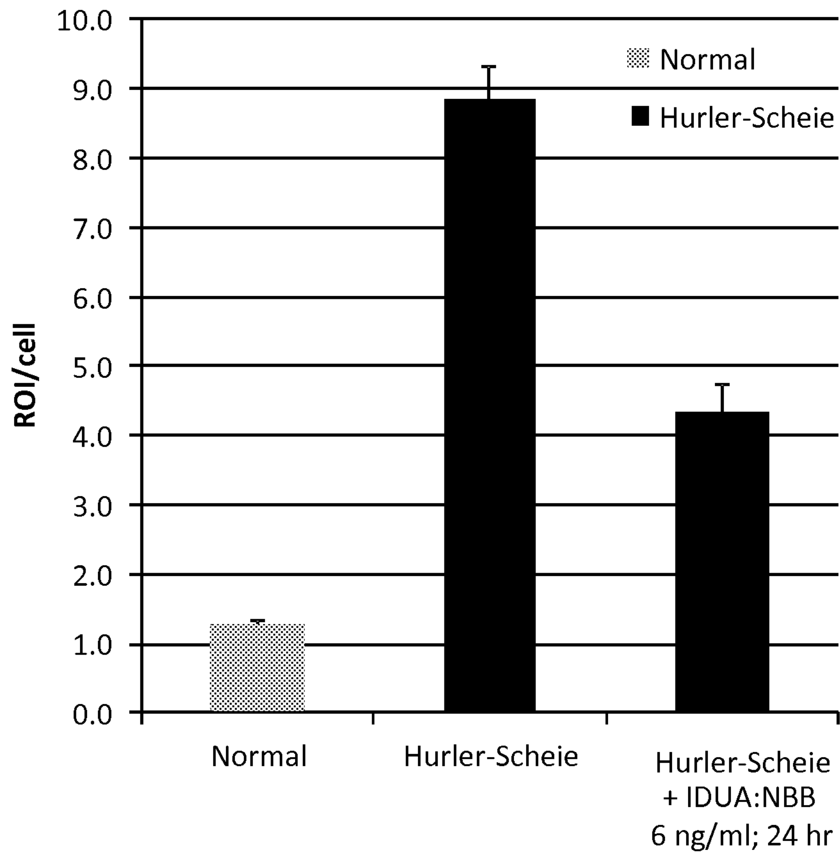


FIG. 3B

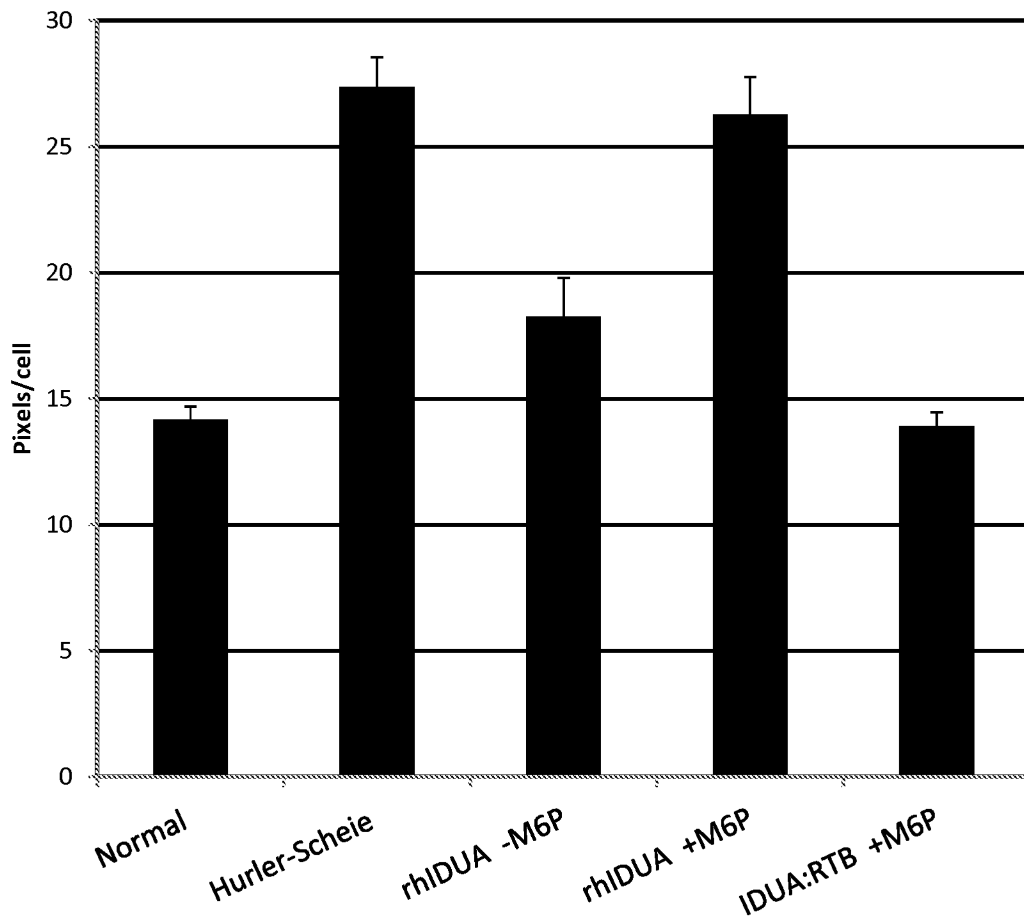


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/043454

A. CLASSIFICATION OF SUBJECT MATTER

A61K 38/16(2006.01)i, A61K 38/17(2006.01)i, A61K 48/00(2006.01)i, A61P 25/00(2006.01)i

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 38/16; A61K 39/39; A61K 38/00; C07K 14/415; A61K 38/17; A61K 48/00; A61P 25/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: lectin, deliver, conjugate, B subunit, lysosomal enzyme

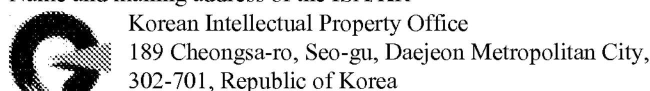
C. DOCUMENTS CONSIDERED TO BE RELEVANT

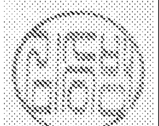
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2008-157263 A2 (ARKANSAS STATE UNIVERSITY) 24 December 2008 See abstract; claims 1-31; and pages 9-16, 42.	1-3,6-9,16-17 4-5
Y	REIDY, `Engineering of the RTB lectin as a carrier platform for proteins and antigens` Dissertation for Doctor of Philosophy, Department of Plant Pathology, Physiology, and Weed Science, Virginia Poletechnic Institute and State University, USA (2007) See abstract and internal pages 1-3, 38-42, 46-61.	4-5
A	US 7858576 B2 (LEBOWITZ et al.) 28 December 2010 See the whole document.	1-9,16-17
A	PASTORES, `Enzyme therapy for the lysosomal storage disorders: principles, patents, practice and prospects` Expert Opinion on Therapeutic Patents, Vol.13, No.8, pp.1157-1172 (2003) See the whole document.	1-9,16-17

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 September 2013 (03.09.2013)	**04 September 2013 (04.09.2013)**

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
KIM Seung Beom

Telephone No. +82-42-481-3371

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RAJENDRAN et al., `Subcellular targeting strategies for drug design and delivery` Nature Reviews Drug Discovery, Vol.9, No.1, pp.29-42 (2010) See the whole document.	1-9,16-17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/043454

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 10-15
because they relate to subject matter not required to be searched by this Authority, namely:
Claims 10-15 pertain to methods for treatment of the human body by therapy, and thus relate to a subject matter which this International Searching Authority is not required, under Article 17(2)(a)(i) of the PCT and Rule 39.1(iv) of the Regulations under the PCT, to search.

2. ☒ Claims Nos.: 11-15, 19
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 11-15 and 19 are unclear since they are referring to multiple dependent claims which do not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: 10, 18, 20
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/043454

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008-157263 A2	24/12/2008	EP 2164863 A2	24/03/2010
		EP 2164863 A4	28/07/2010
		IL 202751 D0	01/08/2011
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		US 8207114 B2	26/06/2012
		US 8492337 B2	23/07/2013
		US 8492338 B2	23/07/2013
		WO 2002-087510 A2	07/11/2002

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/043454

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		WO 2002-087510 A3	06/05/2004
		WO 2003-032727 A1	24/04/2003
		WO 2003-032913 A2	24/04/2003
		WO 2003-032913 A3	12/08/2004
		WO 2003-102583 A1	11/12/2003