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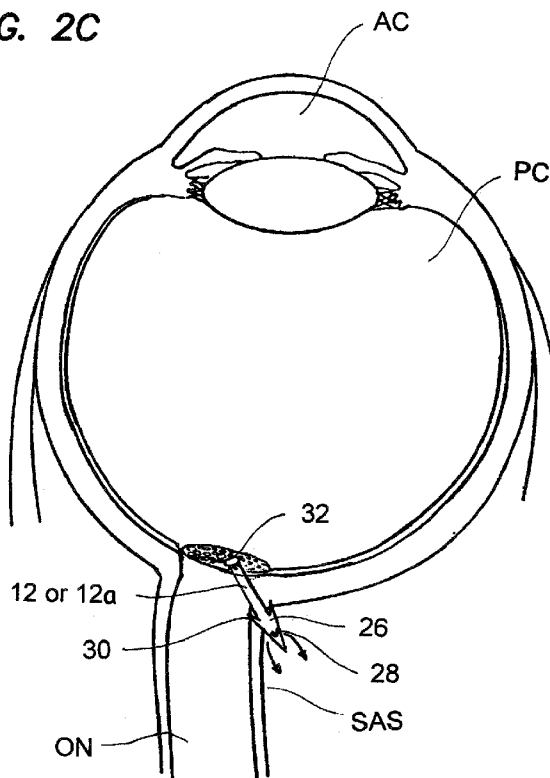
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(54) Title: OPTIC NERVE IMPLANTS

(57) Abstract: Methods and devices for delivering therapeutic substances into the eye. An implant containing the therapeutic substance is implanted at least partially within the optic nerve and the therapeutic substance then elutes from the implant. The implant may have a lumen or it may be solid.

FIG. 2C



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## OPTIC NERVE IMPLANTS

### Related Applications

[0001] This PCT international patent application claims priority to United States Patent Application Serial No. 12/099,127 filed April 7, 2008, which is a continuation in part of copending United States Patent Application Serial No. 10/781,343 filed February 18, 2004, which claims priority to United States Provisional Patent Application No. 60/447,999 filed on February 18, 2003, the entirety of each such application being expressly incorporated herein by reference.

### Field of the Invention

[0002] This invention relates generally to medicine and surgery, and more particularly to methods and devices for lowering intraocular pressure and delivering drugs or therapeutic substances to the optic nerve in human or veterinary patients.

### Background of the Invention

[0003] In normal adults the ocular globe is approximately spherical, with a diameter averaging 24.5 mm. The cornea is a transparent tissue inserted into the sclera at the limbus, the anterior chamber is behind the cornea. The iris is the anterior extension of the ciliary body, it presents as a flat surface with a centrally situated round aperture, the pupil. The iris lies in contiguity with the anterior surface of the lens, dividing the anterior chamber from the posterior chamber, each of which contains aqueous humor. The lens is a biconvex, avascular, colorless and almost completely transparent structure about 4 mm thick and 9 mm in diameter. The lens is suspended behind the iris by the zonules, which connect it

with the ciliary body. Anterior to the lens is the aqueous humor and posterior to the lens is the vitreous. The "vitreous body" which occupies approximately four fifths of the cavity of the eyeball, behind the lens. The vitreous body is formed of gelatinous material, known as the vitreous humor. Typically, the vitreous humor of a normal human eye contains approximately 99% water along with 1% macromolecules including: collagen, hyaluronic acid, soluble glycoproteins, sugars and other low molecular weight metabolites.

**[0004]** The retina is essentially a layer of nervous tissue formed on the inner posterior surface of the eyeball. The retina is surrounded by a layer of cells known as the choroid layer. The retina may be divided into a) an optic portion which participates in the visual mechanism and b) a non-optic portion which does not participate in the visual mechanism. The optic portion of the retina contains the rods and cones, which are the effectual organs of vision. A number of arteries and veins enter the retina at its center, and splay outwardly to provide blood circulation to the retina. The posterior portion of the vitreous body is in direct contact with the retina. Networks of fibrillar strands extend from the retina and permeate or insert into the vitreous body so as to attach the vitreous body to the retina.

**[0005]** The optic nerve provides communication between the retina and the brain. The optic nerve is primarily composed of axons from the retinal ganglion cells along with glial support cells and other tissue. The optic nerve begins at the optic nerve head or disc and passes through the sclera in the area of the lamina cribrosa. The optic nerve then passes through the orbit and optic canal to the optic chiasm. Posterior to the lamina cribrosa, the optic nerve is surrounded by a three-layered meningeal sheath similar to the central nervous system which consists of a dura mater (optic nerve sheath), arachnoid mater, and pia mater. The subarachnoid space surrounding the optic nerve is in direct communication with the subarachnoid space of the central nervous

system.

**[0006]** The term "glaucoma" encompasses a group of diseases that cause progressive damage to the optic nerve and resultant optical field defects, vision loss and, in some cases, blindness. Glaucoma is typically, but not always, accompanied by abnormally high intraocular pressure. There are three basic types of glaucoma--primary, secondary and congenital. The primary type of glaucoma is most common. Cases of primary glaucoma are classified as either open angle or closed angle. Secondary glaucoma occurs as a complication of a variety of other conditions, such as injury, inflammation, vascular disease and diabetes. Congenital glaucoma is elevated eye pressure present at birth due to a developmental defect in the eye's drainage mechanism.

**[0007]** As well as being an important marker of the presence and advancement of glaucoma, the structure of the optic nerve head may play a role in the pathogenesis of glaucoma. Two main theories exist for the mechanism of optic nerve damage in glaucoma. One theory, known as the mechanical IOP related theory, suggests that the pressure head acts directly on the lamina cribosa. The lamina cribosa is not well supported superiorly and inferiorly at the disk and, as a result, initial damage occurs superiorly and inferiorly to produce the characteristic arcuate defects. Variations in the ganglion cell support at the disk may explain the variations between IOP susceptibilities of individuals with similar IOP's. The second theory, known as the vascular mechanism of damage theory, suggests that changes occur within the microcirculation of the disk capillaries and such microvascular changes are responsible for glaucomatous changes.

**[0008]** Irrespective of the type of glaucoma a patient suffers from, controlling IOP through the use of drugs and/or surgery is a mainstay of treatment. It is generally acknowledged that lowering intraocular pressure in glaucoma patients can prevent or lessen the irreversible glaucoma-

associated destruction of optic nerve fibers and the resultant irreversible vision loss.

**[0009]** Presently the use of topically applied glaucoma medications consisting of mainly beta blockers, prostaglandin analogues, alpha-2 agonists, and carbonic anhydrase inhibitors are short acting, prone to deleterious side effects, prone to compliance issues, and must be used for life. Also, at present, the use of argon laser trabeculoplasty as a means for treating glaucoma is limited in clinical response, lasts only approximately 1-2 years, and is limited by the number of applications per eye. Also, at present, the performance of trabeculectomy procedures with or without antimetabolites allows for the external drainage of aqueous humor from the eye. However, trabeculectomy procedures can be technically difficult, fraught with early hypotony, late failure, and high rate of endophthalmitis leading to permanent loss of the eye.

**[0010]** Another surgical approach to the treatment of glaucoma involves the implantation of a shunt to drain aqueous humor from the anterior chamber of the eye. Examples of glaucoma shunts of the prior art include those described in the following United States Patents: No. 5,626,558 entitled "Adjustable Flow Rate Glaucoma Shunt and Method of Using Same;" No. 6,007,510 entitled "Implantable Devices and Methods for Controlling the Flow of Fluids Within the Body;" No. 6,007,511 entitled "Shunt Valve and Therapeutic Delivery System for Treatment of Glaucoma and Methods and Apparatus for its Installation;" No. 6,142,969 entitled "Sutureless Implantable Device and Method for Treatment of Glaucoma" and No. 6,626,858 entitled "Shunt Device and Method for Treating Glaucoma." The entire disclosure of each of these United States patents is expressly incorporated herein by reference.

**[0011]** Thus, there remains a need in the art for the development of new methods and apparatus for lowering IOP and/or for draining fluid from the posterior chamber of the eye for treatment of glaucoma or other disease

states.

### Summary of the Invention

**[0012]** The present invention provides devices and methods for draining fluid from the posterior chamber of the eye into the optic nerve and/or the subarachnoid space. The posterior chamber of the eye is in direct fluidic communication with the anterior chamber of the eye. Thus, the methods and devices of the present invention may be used to treat diseases that are characterized by excess production and/or impaired drainage of aqueous humor (e.g., glaucoma) as well as other vitreoretinal disease states (e.g., for clearance of vitreous hemorrhage).

**[0013]** In accordance with the invention, there is provided a method for draining fluid from the posterior chamber of the eye by creating a passageway between the posterior chamber of the eye and either i) a location within the optic nerve or ii) a location within the subarachnoid space. Contiguous communication between the anterior chamber, posterior chamber and subarachnoid space may be achieved by additionally performing either a) complete or partial surgical removal of the vitreous humor (e.g., a vitrectomy) or b) liquefaction of all or a portion of the vitreous humor (e.g., pharmacologic vitreolysis by intravitreal administration of urea; a urea derivative; a compound having a urea group; hyaluronidase or any other enzyme or agent that causes vitreal liquefaction). The passageway by which the fluid drains from the posterior chamber into the subarachnoid space may simply comprise a hole or puncture made in the lamina cribosa or other suitable location. Alternatively, the passageway may comprise a tubular shunt device that is implanted so as to drain fluid from the posterior chamber into the optic nerve or into the subarachnoid space. Fluid which first drains into the optic nerve will diffuse into the subarachnoid space where it becomes mixed with CSF. Fluid which drains directly into the subarachnoid space will mix with CSF within the subarachnoid space. In applications of the

method wherein a shunt device is employed, the shunt device may alternatively extend between the anterior chamber and subarachnoid space such that it bypasses the posterior chamber or vitreous cavity (i.e., the shunt device may extend through a subconjunctival or subscleral tunnel), furthermore the shunting device may also incorporate a system of communication between the anterior chamber and subarachnoid space that bypasses the vitreous humor by passing directly through it (e.g., a tube that extends through the vitreous body).

**[0014]** Further in accordance with the invention, there is provided a shunt device for draining fluid from the posterior chamber of the eye into the optic nerve or subarachnoid space. Such shunt device comprises a tube having a proximal end, a distal end and a lumen extending longitudinally therethrough, a substantially tissue penetrating tip on the distal end of the tube, a plurality of openings formed at or near the distal end of the tube to allow fluid to drain out of the lumen of the tube and at least one tissue engaging member configured to allow the shunt device to be advanced, tip member first, into tissue but to engage said tissue in such a manner as to subsequently deter retraction of the shunt out of the tissue. Optionally, the shunt device may additionally include a pressure control and/or one-way valve to control the magnitude of the pressure head required to cause fluid to drain from the eye through the shunt device and/or to prevent unwanted backflow of fluid into the eye through the shunt device. Also, optionally, the shunt device may comprise a shielding member, such as a semi-permeable membrane, to prevent or deter clogging of the shunt device by foreign matter and or tissue in-growth.

**[0015]** Still further in accordance with the present invention, there is provided a system that comprises a shunt device of the above-described character in combination with an introducer that is insertable into the eye and useable to implant the shunt device at its desired implantation position within or adjacent to the optic nerve. Such introducer may comprise a tubular cannula through which the shunt device may be passed and/or an

elongate member which may be used to drive or advance the shunt device to its intended location. In some embodiments, the elongate member may be used without the tubular cannula. In other applications, the shunt device will be initially loaded into the lumen of the tubular cannula and the elongate member (e.g., a solid or tubular pusher rod) may be used to push the shunt device out of the distal end of the cannula and to its intended site of implantation.

**[0016]** Still further in accordance with the invention, there are provided methods and devices for delivering therapeutic substances (e.g., drugs, biologics, etc.) into the eye. An implant which contains the substance is implanted in the optic nerve and a therapeutic amount of the substance subsequently elutes from the implant.

**[0017]** Further aspects and elements of the present invention will become apparent to those of skill in the relevant art upon reading and considering the following detailed description and the accompanying drawings to which it refers.

### **Brief Description of the Drawings**

**[0018]** Figure 1 is a longitudinal sectional view of one embodiment of an ocular shunt implantation system of the present invention.

**[0019]** Figure 1A is a perspective view of the cannula component of the ocular shunt implantation assembly of Figure 1.

**[0020]** Figure 1B is a perspective view of the shunt component of the ocular shunt implantation assembly of Figure 1.

**[0021]** Figure 1B' is a partial cut-away/sectional view of a shunt device of the present invention incorporating an optional one-way valve to deter backflow and optional shielding member (e.g., a semi-permeable membrane) to deter clogging of the shunt due to debris or cellular tissue

ingrowth.

**[0022]** Figure 1C a perspective view of the pusher component of the shunt implantation assembly of Figure 1.

**[0023]** Figure 2A is a cross-sectional view of a human eye into which an ocular shunt implantation system of the present invention has been inserted and positioned for advancement/implantation of the shunt.

**[0024]** Figure 2B is a cross-sectional view of a human eye into which an ocular shunt of the present invention has been implanted to shunt fluid from the posterior chamber of the eye into the body of the optic nerve.

**[0025]** Figure 2C is a cross-sectional view of a human eye into which an ocular shunt of the present invention has been implanted to shunt fluid from the posterior chamber of the eye into the area outside of the optic nerve.

### Detailed Description

**[0026]** The following detailed description and the accompanying drawings are provided for the purpose of describing certain non-limiting examples or embodiments of the invention only. This detailed description is not intended to describe all possible examples and embodiments of the invention and, thus, shall not limit the scope of the claimed invention in any way.

**[0027]** Figures 1-1C show one embodiment of a system 10 for implantation of a shunt device 12 in accordance with the present invention. This system 10 generally comprises the shunt device 12, a cannula 14, and a pusher 16. As shown in Figure 1, the shunt device 12 is initially positioned within the lumen 18 of the cannula 14 and the pusher 16 is positioned in the lumen 18 of the cannula 14 behind the shunt device 12 such that the pusher 16 may be used to push the shunt device 12 out of

the distal end DE of the of the cannula 14. One way of performing this shunt-expulsion procedure is shown in Figure 2A and is explained in detail herebelow.

**[0028]** The particular embodiment of the shunt 12 shown in Figure 1B comprises a tube 22 having a lumen 24 extending longitudinally therethrough. A tip member 26 is positioned on the distal end of the tube 22. The tip member 26 of this embodiment is generally conical in shape, but it will be understood that the tip member may be beveled, tapered, trocar tipped or of any other shape that will allow it to advance through tissue as explained herebelow. Apertures 28 are formed in the side wall of the tip member 26 to allow fluid to drain out of the lumen 24 of the tube 22. Optional tissue engaging members 30, such as barbs, hooks, undercuts, adhesive regions, tissue in-growth receiving areas, etc., may be formed on the shunt 12 to deter unwanted movement or retraction of the shunt 12 after it has been advanced to its intended implantation position. Also, optionally, a flange (e.g., any laterally extending member or area or increased diameter) may be formed on the proximal end of the tube 22 to engage the lamina cribosa or other tissue in a manner that deters advancement of the tube beyond its intended position. The shunt device 12 may have a diameter or cross-dimension at its widest point of about 1 micron to about 2000 and preferably of about 50 microns to about 400 microns.

**[0029]** Figure 1B' shows an alternative embodiment of the shunt device 12a which has the same construction as the shunt device 12 shown in Figure 1B but additionally includes an optional one way valve 23 and an optional shielding member 29 which covers the apertures 28 to prevent or deter the entry of foreign matter or tissue ingrowth through apertures 28. The one way valve 23 serves to allow fluid flow in the distal direction (Arrow DD) while preventing or substantially deterring backflow in the proximal direction (Arrow PD). The one way valve may be a duckbill type valve comprising a plurality of flexible leaflets 25, as shown, or may

comprise any other suitable type of check valve or one-way valve, such as a ball type check valve, a flapper, or any of the valves typically used as hemostatic valves on small medical catheters of a size similar to this shunt device 12a. Also, this one-way valve 23 may be constructed to open only when the pressure of fluid within the lumen 24 proximal to the valve 23 exceeds a predetermined maximum, thereby providing for control of the intraocular pressure and preventing the drainage of too much fluid from the eye as may result in hypotony or other untoward sequale.

**[0030]** The cannula 14 may comprise a tube having a generally cylindrical wall 14, a lumen 18 extending longitudinally therethrough between an open proximal end PE and an open distal end DE.

**[0031]** The pusher 16 may comprise a solid or tubular elongate member 34 having a proximal end PE and a distal end DE. Optionally, a handle 38 may be positioned on the proximal end of the elongate member 34. Also, optionally, the elongate member 34 may have an outer diameter that is sized to be received within the lumen 24 of the shunt device 12 and the distal end DE of the elongate member 34 may be tapered, as shown in Figure 1C, to seat within the tapered tip member 26 of the shunt device 12.

**[0032]** Some or all of the components of the system 10 may be formed of silicon, polyethylene, polypropylene, polycarbonate, stainless steel or other biologically compatible materials. In the particular embodiment shown in the figures, the shunt device 12 or 12a may be substantially formed of silicon material. The shunt device 12 or 12a may also involve an active pumping system or may incorporate a wick like system to move fluid in the required direction.

**[0033]** Figure 2A-2C show the system of Figures 1-1C in its currently intended mode of operation. Prior to implantation of the shunt device 12 or 12a, a vitrectomy device may be inserted into the posterior chamber PC

and a vitrectomy performed to remove at least a portion of the vitreous body from the posterior chamber PC. Alternatively, all or a portion of the vitreous body may be liquefied. Such vitreal liquefaction may be accomplished by intravitreal administration (e.g., intravitreal injection) of one or more agents that cause liquefaction of the vitreous humor. Examples of such agents include but are not limited to; urea, urea derivatives, compounds having urea groups, hyaluronidase and other enzymes or other substances that cause vitreal liquefaction. Descriptions of these and other substances that cause vitreal liquefaction, as well as dosage information and associated methods for administration, are found in United States Patent Nos. 5,292,509 (Hagman); 6,551,590 (Karageozian et al.); 6,610,292 (Karageozian et al.) and 6,462,071 (Karageozian et al., the entireties of which are expressly incorporated herein by reference.

[0034] As shown in Figure 2A, a small opening such as a needle puncture is made in the pars plana PP and the system 10 of the present invention is inserted through that opening and through a region of the posterior chamber PC from which the vitreous body has been removed (e.g., by vitrectomy) or in which the vitreous body has been liquefied (e.g., by intravitreal injection of a vitreous liquefying agent as described above). The system 10 is advanced to position where the distal end DE of the cannula 14 is positioned immediately anterior to the lamina cribosa. The pusher 16 is then advanced in the distal direction (Arrow DD) while the cannula 14 is held stationary, thereby pushing the shunt device 12 or 12a out of the distal end DE of the cannula 14 and causing the distal tip member 26 of the shunt device 12 or 12a to penetrate through the lamina cribosa and optic nerve ON tissue. The pusher 16 is advanced until resistance is felt due to the impingement of the flange member 32 of the shunt device 12 or 12a with the optic nerve head. At this point, the shunt member 12 or 12a has been advanced to its intended implantation site and the pusher 16 and cannula 14 may be removed from the eye, leaving the shunt device 12 or

12a in place. Depending on the angle at which the shunt device 12 or 12a is advanced, its outflow apertures 28 may be positioned at a subdural location within the body of the optic nerve ON (as shown in Figure 2B) or within the subarachnoid space adjacent to the optic nerve ON (as shown in Figure 2C). In instances where the outflow apertures 28 are positioned within the body of the optic nerve ON (as shown in Figure 2B), fluid that drains out of the outflow apertures 28 will subsequently diffuse and/or be transported through the optic nerve and into the subarachnoid space where it will mix with cerebrospinal fluid. In instances where the outflow apertures are located within the subarachnoid space, fluid that flows out of the outflow apertures 28 will mix with cerebrospinal fluid that resides within the subarachnoid space. In either case, the typical backpressure of fluid adjacent to the outflow apertures 28 will be low enough to facilitate drainage of excess fluid from the eye and in the distal direction (arrow DD) through the shunt device 12 or 12a.

### OPTIC NERVE DRUG DELIVERY SYSTEM

**[0035]** The shunt device 12, 12a may, in some embodiments, additionally function as a substance delivery device for sustained delivery of a therapeutic substance directly to the optic nerve.

**[0036]** Macular edema is the accumulation of fluid and small molecules in the retinal tissues. As this fluid accumulates in the outer plexiform and the inner nuclear layers of the retina, it results in macular thickening which may be accompanied by deposits of lipoprotein. Chronic macular edema can result in loss of sight if it becomes severe or affects the center of the macula.

**[0037]** Various agents have been proposed for treatment of macular edema. Several agents have been developed that specifically target a particular inflammatory cytokine. Existing monoclonal antibodies have activity against TNF- $\alpha$ , IL-2 and VEGF. Of these, the anti-VEGF agents

have been the most extensively studied. Several animal and clinical studies have shown that anti-VEGF agents can decrease vascular permeability and inhibit angiogenesis. Several studies are under way to determine the clinical utility of intravitreal injections of these agents in the treatment of diabetic macular edema. Early results from clinical trials with ranibizumab (Lucentis, Genentech), bevacizumab (Avastin, Genentech) and pegaptanib sodium (Macugen, (OSI) Eyetech) appear favorable.

**[0038]** Corticosteroids act on a broad range of processes that are known to contribute to the pathophysiology of macular edema. For example, corticosteroids are known to inhibit prostaglandin and leukotriene synthesis and to interfere with the actions and/or production of ICAM-1, IL-6, VEGF- $\alpha$  and stromal-derived factor 1 (SDF 1). Corticosteroids may also increase the expression of genes that code for "tight junction proteins" which may also be helpful in treating macular edema. Repeated intravitreal injection of 25 mg of the corticosteroid triamcinolone acetonide has been reported to increase in visual acuity in patients with exudative age-related macular degeneration, with the peak in visual acuity and intraocular pressure elevation occurring about 2 to 5 months after each injection. Jonas, J., et al., *Intravitreal Reinjection of Triamcinolone for Exudative Age-Related Macular Degeneration*; Archives of Ophthalmology, Vol. 122, No. 22, pp 218-222 (2004). Additionally, the I-vation TA Sustained Drug Delivery System (Surmodics, Eden Prairie, MN) is a helical metal implant coated with a commercially available drug delivery polymer that contains triamcinolone acetonide the (Bravo<sup>TM</sup> Drug Delivery Polymer, Surmodics, Eden Prairie, MN). Also, polysaccharide and other drug delivery coatings that may be useable for delivery of corticosteroids such as triamcinolone acetonide are described in United States Patent Application Publication No. 2005/0255142, which is expressly incorporated herein by reference.

**[0039]** The shunt 12, 12a of the present invention may be coated with a drug delivery coating, such as those mentioned above, containing a

suitable amount of a therapeutic substance (e.g., from about 1 to about 100 mg triamcinolone acetonide) which is effective to treat macular degeneration or other disorders and inflammation of the optic nerve, retina or macula.

**[0040]** The hydrophilic or hydrophobic drug substances (e.g., agents for wet macular degeneration, agents for prevention of macular edema, anti-proliferative substances, agents for prevention of dry macular degeneration) may be combined with a coating that is applied to the surface of the shunt 12, 12a or could be applied as a gel like material to the shunt device 12, 12a which would contain polymeric materials that will help the time release of the drugs over an extended period of time. In some embodiments intended for drug delivery only, the device 12, 12a may be devoid of a lumen and will not necessarily perform a shunting function.

**[0041]** The device 12, 12a containing the therapeutic substance may be implanted in the optic nerve as described above without the need to perform a vitrectomy. Implantation may be performed by delivering the device 12, 12a through a small caliber (27 Gauge, 25 Gauge, or 23 Gauge) needle inserted through the intact vitreous. This variant of the procedure will be recommended when highly diffusible drugs are employed and the drug needs to get to the delivery site very fast. Also another variant that could be performed if vitrectomy is not realized is the administration of a substance that can produce vitreous liquefaction or vitreous detachment previous the insertion of the device 12, 12a (24 to 48 hrs). Theoretically if there is not vitreous attached to the optic nerve possibilities of scarring tissue could be prevented mainly in those cases in which implants will not release anti-proliferative substances.

**[0042]** When used for delivery of a therapeutic substance (e.g., from about 1 to about 100 mg triamcinolone acetonide) the device 12, 12a may be implanted either at the periphery of the optic nerve or in the center of the optic nerve. Insertion at the periphery will avoid damage of nerve fiber

layer but could reach at the same time the lamina cribrosa. Insertion in the center of the optic nerve will imply penetration of the lamina cribrosa which will help to anchor the device 12, 12a. Based on topographic features, one suitable area for insertion, either in the periphery of the optic nerve or in the center of the optic nerve, is the nasal area. Insertion of the device 12, 12a at the nasal area will prevent damage of ganglion cell axons belonging to the macula area.

**[0043]** When used for delivery of a therapeutic substance, the length of the device 12, 12a may vary depending on the elution and diffusion characteristics of the drug. Low diffusion drugs that need to reach the optic nerve may best be delivered using a long (e.g., more than 3mm in length) device 12, 12a. High diffusion drugs that are intended to reach macula and other parts of the retina may be delivered by a shorter device 12, 12a (e.g., one that is less than 3 mm in length). A luminal or canulated embodiment of the device 12, 12a may allow drug delivery as well as drainage of aqueous humor and will typically be 3mm or more in length.

**[0044]** The shape of the device 12, 12a may vary and it may have be solid or canulated (i.e., having a lumen). Either solid or canulated will have the ability to harbor one or more compartments for drugs, gels, polymers, and or substances that will be released. Materials that will be used as a therapeutic substances may be also incorporated on the walls of the device 12, 12a as a coating or paint which by the time will be released slowly. Canulated embodiments of the device 12, 12a may have the ability to work also as a draining system for aqueous humor; aqueous humor may be drained through the optic nerve. This drainage may be achieved either through the sub-arachnoidal space or the intra-orbital space. Intraocular pressure is higher than the pressure in the SNC that gradient will allow fluid (aqueous humor) to drain in the sub-arachnoidal space or at the optic nerve. The canulated device 12, 12a also can drain aqueous humor to the orbit. A small caliber device will prevent high rate of drainage preventing hypotony. Drugs belonging to the device 12, 12a will

prevent formation and deposition of tissue inside the lumen of the canula. The device 12, 12a may have a head and tail. The head will be used to manipulate the device 12, 12a and will remain visible on the surface of the optic nerve after insertion, the tail will be buried in the stroma of the nerve, will penetrate lamina cribrosa and can have different shapes to be anchored in either tissue or lamina cribrosa: arrow like, harpoon like, etc.

**[0045]** Biodegradable and non biodegradable embodiments of the substance delivering device 12, 12a may be used. Biodegradable embodiments will release therapeutic substances as long as they remain in the optic nerve and will not require manual removal. Non-biodegradable embodiments may be formed of biocompatible metallic or non metallic materials such as polymers, plastics or silicone and may or may not be removed after all of the therapeutic substance has eluted from the device.

**[0046]** The foregoing description is directed to certain embodiments and examples of the invention only and does not necessarily include or expressly mention each and every possible embodiment or example of the invention that is within the scope of the following claims.

**CLAIMS**

What is claimed is:

1. A method for delivering a therapeutic substance into the eye of a human or animal subject, said method comprising the steps of:
  - A) providing an implant that contains a quantity of the substance; and
  - B) inserting the implant into the optic nerve such that a therapeutic amount of the substance will elute from the implant.
  
2. A method according to Claim 1 wherein the implant has a lumen and additionally functions as a tubular shunt such that fluid from the interior of the eye will enter one end of the shunt and said fluid will exit the other end of the shunt either i) at a location within the optic nerve or ii) at a location within the subarachnoid space.
  
3. A method according to Claim 2 wherein the implant comprises a tube having a proximal end, a distal end and least one tissue engaging member formed on the implant to deter unwanted movement of the implant after it has been implanted.
  
4. A method according to Claim 3 wherein the at least one tissue engaging member comprises a barb or barb like structure that allows the shunt to be advanced through tissue in a distal direction but engages the tissue in a manner that deters subsequent retraction of the shunt in a proximal direction.
  
5. A method according to Claim 2 wherein the implant comprises a

tube having a proximal end, a distal end and a flange member formed on the proximal end thereof.

6. A method according to Claim 2 wherein the implant comprises a tube having a valve associated therewith, said valve being operative to perform at least one valving function selected from the group consisting of a) allowing fluid to flow out of the eye but deterring fluid from backflowing into the eye and b) allowing fluid to flow out of the eye only when the fluid pressure exceeds a predetermined maximum pressure.

7. A method according to Claim 2 wherein the implant comprises a tube having a proximal end, a distal end and at least one shielding member associated therewith to deter foreign matter or cells from clogging the tube.

8. A method according to Claim 7 wherein the shielding member comprises a semi-permeable membrane constructed and positioned such that fluid flowing out of the distal end of the tube will diffuse outwardly through the membrane but foreign matter and cells will not diffuse inwardly through the membrane and into the distal end of the tube.

9. A method according to Claim 1 wherein the implant is devoid of a lumen.

10. A method according to claim 1 wherein the therapeutic substance comprises a corticosteroid.

11. A method according to Claim 1 wherein the implant contains from about 1 to about 100 mg triamcinolone acetonide.

12. A method according to Claim 1 wherein the method is carried out to treat macular degeneration.

13. A method according to Claim 1 wherein step B is performed without a vitrectomy.

14. A method according to Claim 13 wherein step B is performed by delivering the implant through a needle that is inserted into the optic nerve through the intact vitreous.

15. A device for delivering a substance to the eye of a human or animal subject, said apparatus comprising:

an implant that is insertable into the optic and from which a diagnostic or therapeutic amount of the substance will elute.

16. A device according to claim 15 wherein the device further comprises a lumen for draining fluid from the posterior chamber of the eye into the optic nerve or subarachnoid space.

17. A device according to claim 16 wherein the implant comprises:  
a tube having a proximal end, a distal end and a lumen extending longitudinally therethrough;  
a substantially conical tip member on the distal end of the tube;  
a plurality of openings formed in the substantially conical tip

member to allow fluid to drain out of the lumen of the tube; and

at least one tissue engaging member configured to allow the shunt to be advanced, tip member first, into tissue but to engage said tissue in such a manner as to subsequently deter retraction of the shunt out of the tissue;

wherein at least a portion of the device contains the substance that elutes.

18. A device according to Claim 17 further comprising a one way valve that allows fluid to flow in only one direction through the lumen of the tube.

19. A device according to Claim 17 further comprising a shielding member which deters foreign matter or cells from clogging the tube.

20. A device according to Claim 19 wherein the shielding member comprises a semi-permeable membrane constructed and positioned such that fluid flowing out of the openings formed in the tip member will diffuse outwardly through the membrane but foreign matter and cells will not diffuse inwardly through the membrane and into the lumen of the tube.

21. A device according to Claim 17 further comprising a flange member on the proximal end of the tube.

22. A device according to Claim 17 wherein the device is at least partially formed of material selected from the group consisting of:

silicon;

polyethylene;  
polypropylene;  
polycarbonate;  
stainless steel; and  
other biologically compatible materials.

23. A device according to Claim 17 wherein the tube is configured to extend through the vitreous body, thereby providing for drainage of aqueous humor through the vitreous body and into either the optic nerve or the subarachnoid space.

24. A device according to Claim 17 wherein the tube is configured to extend through a subconjunctival or subscleral tunnel, thereby bypassing the posterior chamber and vitreous cavity.

25. A device according to any of claims 15-24 wherein the substance comprises a corticosteroid.

26. A device according to Claim 25 wherein the device contains from about 1 to about 100 mg of triamcinolone acetonide.

27. A system comprising a device according to any of claims 15-27 in combination with a cannula, said device being initially positioned within the cannula and subsequently advanceable out of the cannula.

28. A system according to Claim 27 further comprising a pusher that

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is insertable into the cannula to push the shunt device out of the cannula.

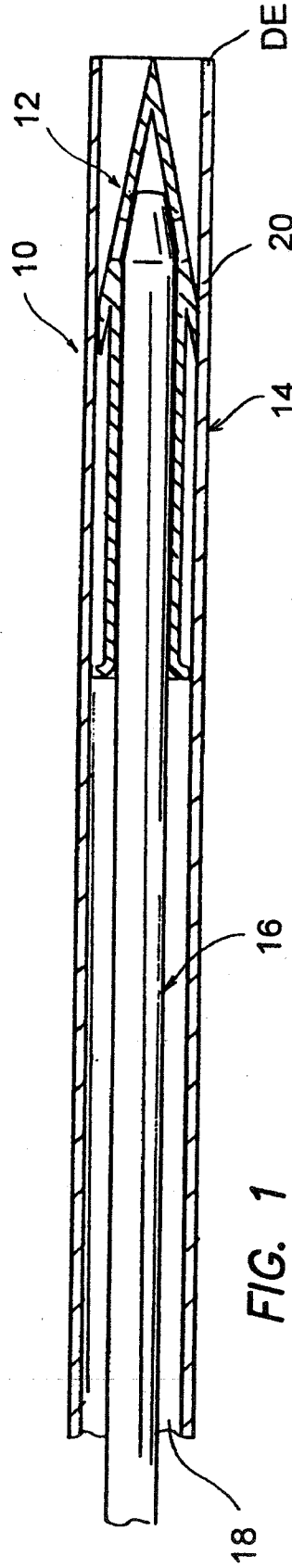


FIG. 1

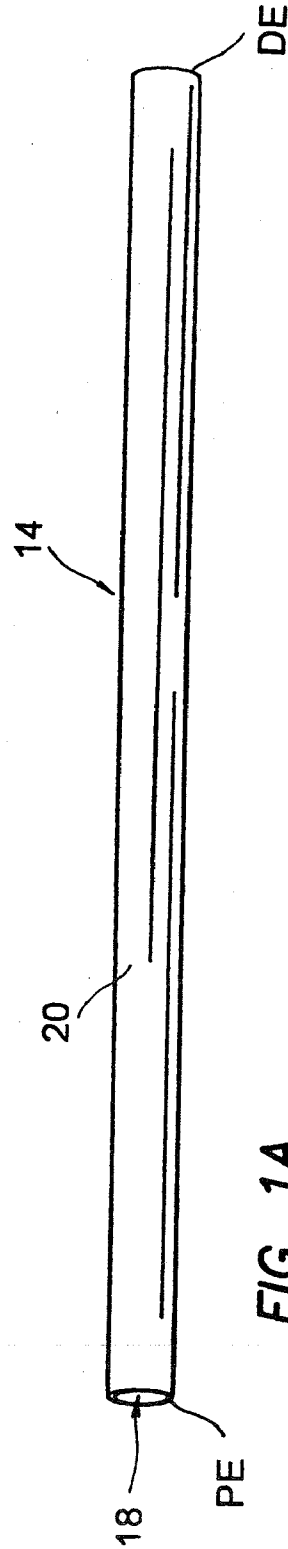


FIG. 1A

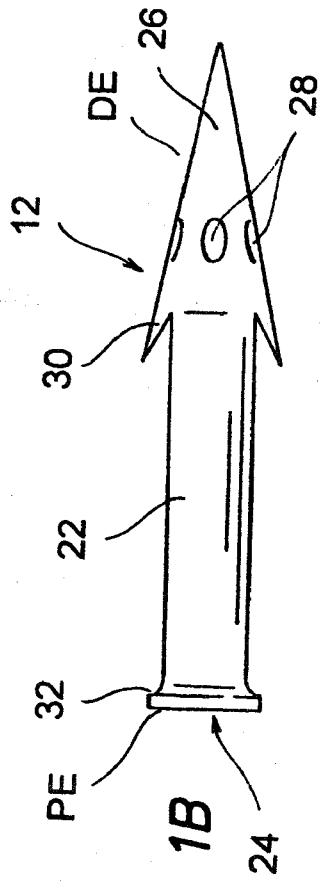
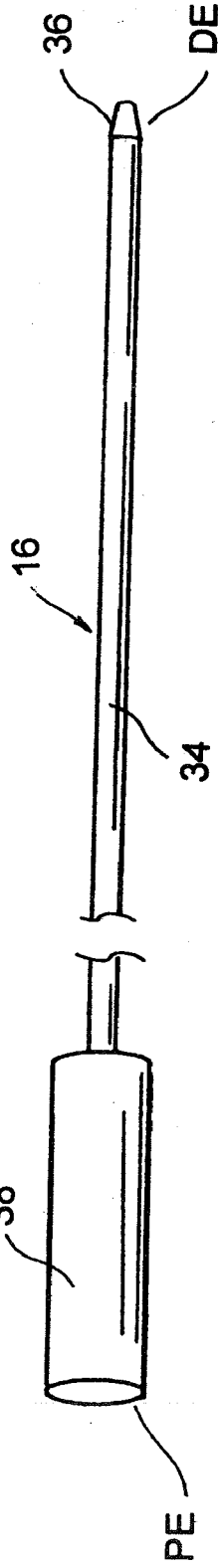


FIG. 1B

FIG. 1C



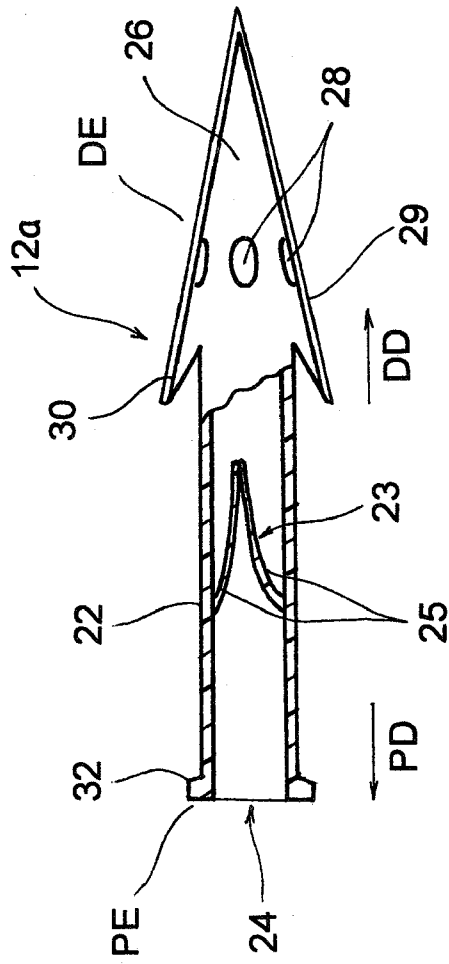


FIG. 1B'

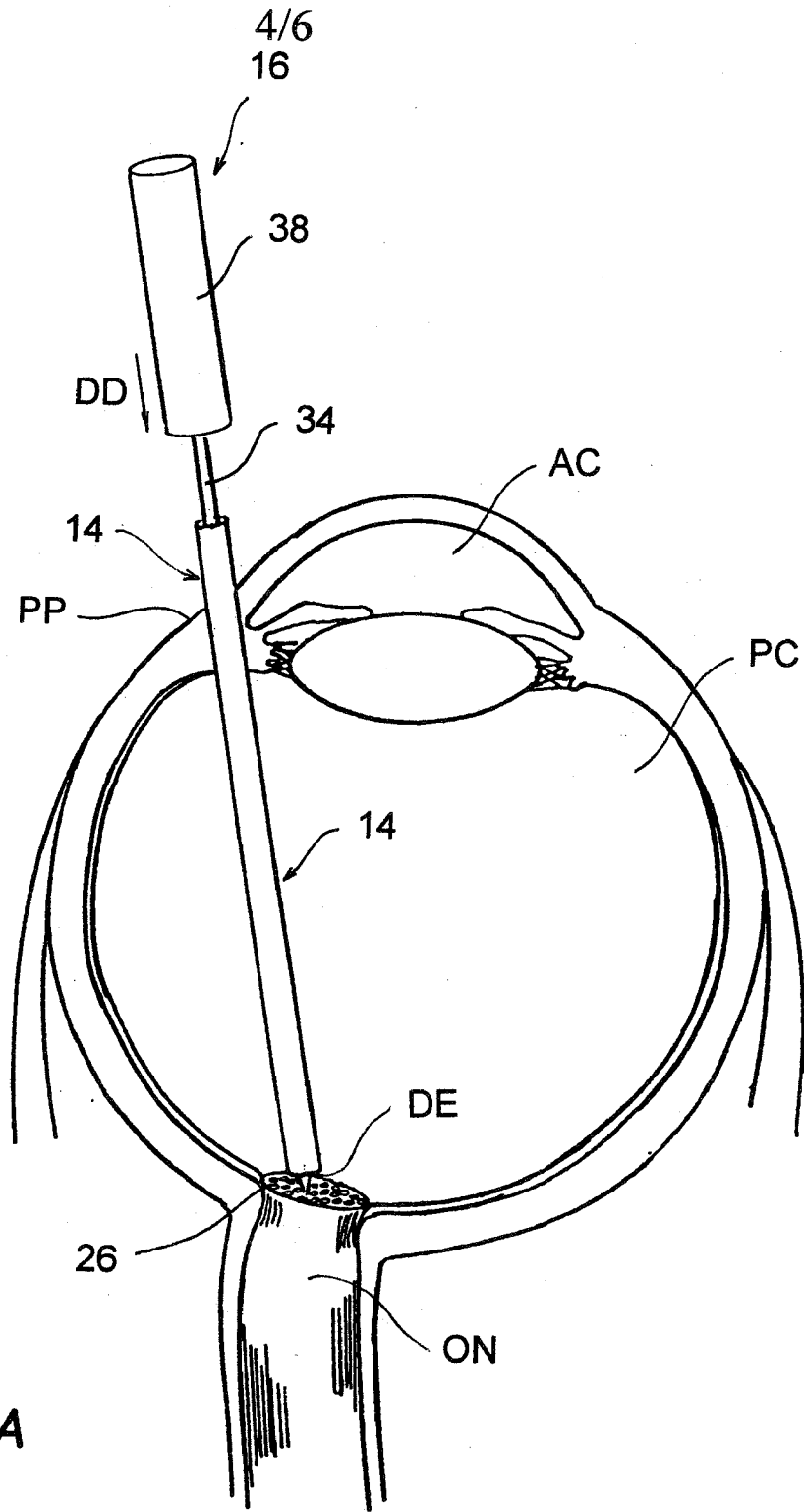


FIG. 2A

FIG. 2B

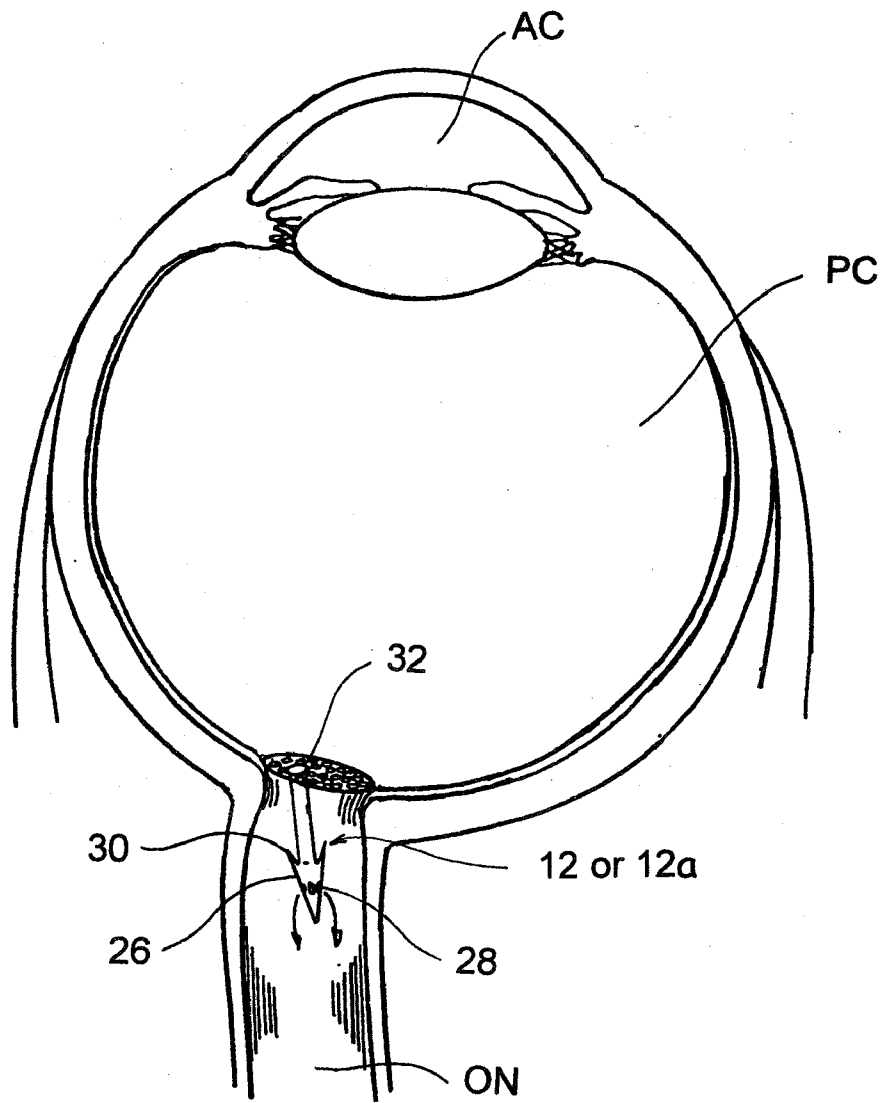
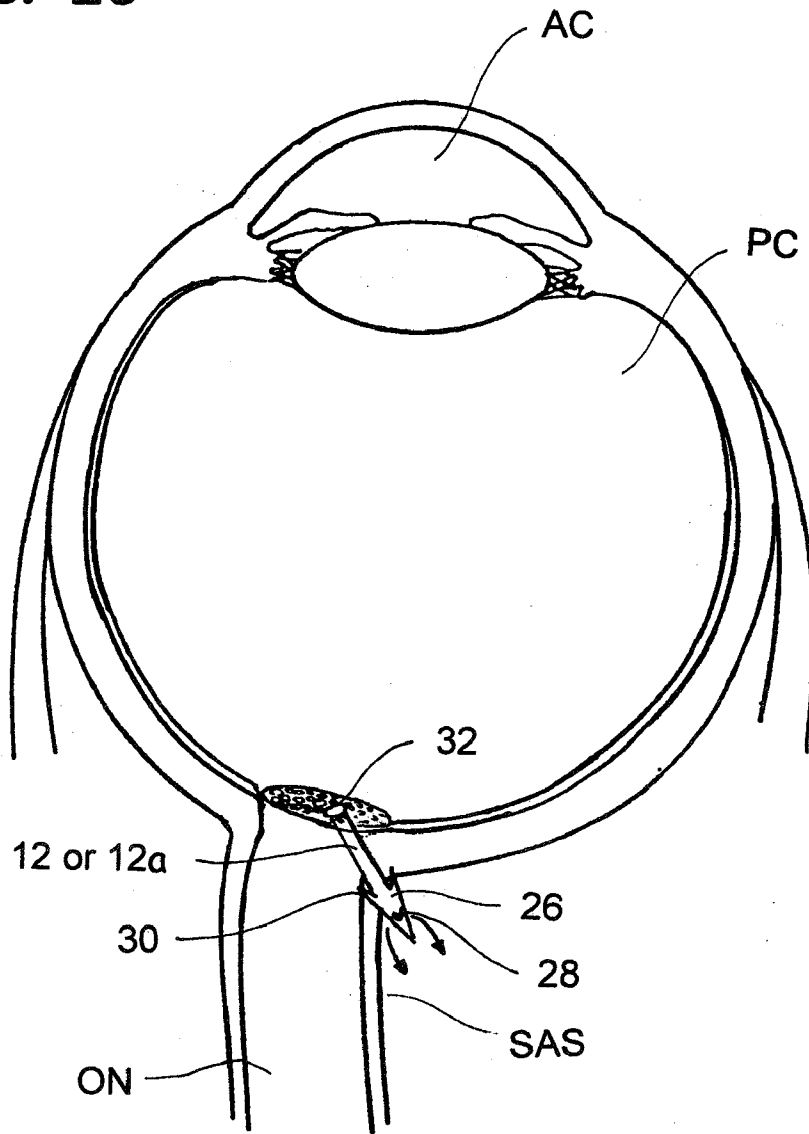


FIG. 2C



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2009/039647

| A. CLASSIFICATION OF SUBJECT MATTER<br>IPC(8) - A61M 5/00 (2009.01)<br>USPC - 604/8<br>According to International Patent Classification (IPC) or to both national classification and IPC   |   |   |
|--|---|---|
| B. FIELDS SEARCHED<br>Minimum documentation searched (classification system followed by classification symbols)<br>IPC(8) - A61M 5/00 (2009.01)<br>USPC - 424/422, 427; 604/8, 19, 21, 48<br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>PatBase, Google Scholar  |   |   |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT   |   |   |
| Category*  | Citation of document, with indication, where appropriate, of the relevant passages      | Relevant to claim No.   |
| Y  | US 2004/0254517 A1 (QUIROZ-MERCADO et al) 16 December 2004 (16.12.2004) entire document | 1-26  |
| Y  | US 2006/0257451 A1 (VARNER et al) 16 November 2006 (16.11.2006) entire document         | 1-26  |
| Y  | US 5,772,671 A (HARMON) 30 June 1998 (30.06.1998) entire document                       | 13, 14  |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C.  |   |   |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"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<br>"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<br>"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<br>"&" document member of the same patent family |   |   |
| Date of the actual completion of the international search<br>26 June 2009  |   | Date of mailing of the international search report<br><b>09 JUL 2009</b>                            |
| Name and mailing address of the ISA/US<br>Mail Stop PCT, Attn: ISA/US, Commissioner for Patents<br>P.O. Box 1450, Alexandria, Virginia 22313-1450<br>Facsimile No. 571-273-3201  |   | Authorized officer:<br>Blaine R. Copenheaver<br>PCT Helpdesk: 571-272-4300<br>PCT OSP: 571-272-7774 |

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2009/039647

**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.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
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:
  
3.  Claims Nos.: 27-28  
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 additional 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 additional fees, this Authority did not invite payment of additional fees.
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.