We, OCULAR PROSTHETICS PTY. LIMITED,
of NIGHTINGALE WING, SYDNEY HOSPITAL, MACQUARIE STREET,
SYDNEY, NEW SOUTH WALES, 2000,

hereby apply for the grant of a standard patent for an
invention entitled "OCULAR PROSTHESIS",
which is described in the accompanying provisional
specification.

Our address for service is PAUL F. KILDEA, Patent and
Trade Mark Attorney, 19 LOGAN STREET, NARRABUNDAH,
A.C.T. 2604.

DATED this 11th. day of SEPTEMBER 1989.

OCULAR PROSTHETICS PTY. LIMITED
By Its Patent Attorney

PAUL F. KILDEA.

To: THE COMMISSIONER OF PATENTS
From: PAUL F. KILDEA.
DECLARATION IN SUPPORT OF AN APPLICATION FOR A PATENT

In support of the Application made by
OCULAR PROSTHETICS PTY. LIMITED
for a patent for an invention entitled
OCULAR PROSTHESIS
I, EDIT ELEONORA GILLOTT,
of 804 TRUST BUILDING, 155 KING STREET, SYDNEY,
NEW SOUTH WALES, 2000,
do solemnly and sincerely declare as follows:-

1. I am authorised by OCULAR PROSTHETICS PTY. LIMITED the applicant for the patent to make this declaration on its behalf.

2. CLIFFORD ROY TREFRY
of 804 TRUST BUILDING, 155 KING STREET, SYDNEY,
NEW SOUTH WALES, 2000
is the actual inventor of the invention and the facts upon which the Applicant is entitled to make the application are as follows:
OCULAF PROSTHETICS PTY. LIMITED is the Assignee of THE SAID CLIFFORD ROY TREFRY.

DECLARED at SYDNEY this 14th day of SEPTEMBER 1989.

Signature of Declarant

To: THE COMMISSIONER OF PATENTS
From: PAUL F. KILDEA.
AN ARTIFICIAL EYE

1. An artificial eye comprising a substantially domed anterior external surface having a section thereof corresponding to the cornea of a natural eye, representations of the iris and other parts of a natural eye visible through the corneal section and a display associated with the representation of the iris adapted to be differentially activated by incident light falling on the eye to create an impression that the pupil of the iris dilates or contracts in changing light conditions, characterised in that control apparatus including a photoelectric cell is housed within the eye behind the iris display for differentially activating the display and an optic fibre is connected between a position on the anterior surface of the eye where it is exposed to the incident light falling on the eye to said photoelectric cell for measuring the light being transmitted along the optic fibre.
TO BE COMPLETED BY APPLICANT

Name of Applicant: OCULAR PROSTHETICS PTY. LIMITED

Address of Applicant: NIGHTINGALE WING,
SYDNEY HOSPITAL
MACQUARIE STREET
SYDNEY NEW SOUTH WALES 2000.

Actual Inventor: CLIFFORD ROY TREFRY

Address for Service: PAUL F. KILDEA
PATENT AND TRADE MARK ATTORNEY
19 LOGAN STREET, NARRABUNDAH, ACT 2604.

Complete Specification for the invention entitled: "AN ARTIFICIAL EYE"

The following statement is a full description of this invention, including the best method of performing it known to me:—
The invention relates to an artificial eye, in particular to an ocular prosthesis which is used to replace a natural eye of a living being. The invention also has application to the eyes of a statue, to dolls' eyes, to education models demonstrating the working of an eye, and so forth.

Artificial eyes have been in use for many years. When a natural eye has been removed from the orbit (socket), it has been known to replace the natural eye in the orbit with an ocular prosthesis. An ocular prosthesis has been made from a variety of materials and for many years glass was used. More recently, they have been made from plastics material such as polymethyl methacrylate.

An ocular prosthesis may take any of a variety of shapes. In one common form, it has been made somewhat in the shape of a hemisphere. The anterior part of the prosthesis presents a substantially hemispherical or domed surface which, when the prosthesis is properly positioned in the orbit, rests against the inner lining of the eyelids and usually permits normal opening and closing of the eyelids. That section of the anterior wall of the prosthesis which corresponds to the cornea of a natural eye is transparent and visible through the corneal section are representations of other parts of a natural eye (e.g. lens, iris, pupil, blood vessels, etc.). The representations of the eye parts are visible through open eyelids and are made to look as natural as possible and to match the wearer's remaining natural eye.

The posterior surface of the prosthesis may be somewhat flattened or non-planar and is shaped with the object of mating
with the tissue defining the internal surfaces of the orbit so that the orbital muscles, which were effective to initiate and control movement of the natural eye, would also be effective to give similar movement to the prosthesis. Because prior ocular prostheses were relatively heavy, the orbital muscles generally have not been effective to produce movement of the prosthesis similar to that of the natural eye. To minimise this problem, it is proposed in Patent No.584,704 to make a lighter hollow prosthesis.

Even so, a difficulty still exists with known ocular prostheses because, as represented, the iris is fixed and thus the pupil has not been able to dilate in the same manner as is the case with a natural eye. Therefore, known ocular prostheses present a rather glassy stare and the inability of the pupil to dilate has provided a telltale indication of something artificial.

In an attempt to overcome this shortcoming, it has been proposed to provide an ocular prosthesis with a simulated iris, the apparent movement of which is controlled by the incident light falling on the prosthesis. The pupil was represented in a size appropriate for a bright light environment and was surrounded by a display adapted to be differentially activated by incident light falling on the corneal section of the prosthesis to create the impression that the pupil dilates or contracts in changing light conditions. A photoelectric cell was incorporated within the prosthesis to measure the incident light and control the display.

However, attempts to date have not been satisfactory. According to one proposal, the pupil was represented by a domed
lens window of a photoelectric cell directed toward the front of the prosthesis so as to be directly exposed to environmental light conditions via the transparent corneal portion of the prosthesis. Although effective to measure environmental light conditions, its prominent appearance and colouring betrayed the existence of an artificial eye.

We have previously proposed to mount the photoelectric cell to the rear of the liquid crystal display assembly. A narrow axial bore through the assembly provides a passage for incident light falling on the transparent corneal portion of the prosthesis to pass for registration by the photoelectric cell. Thus, the appearance of the prosthesis was improved and its artificiality was better disguised. However, in certain circumstances, the photoelectric cell caused the reflection of a silver light through the axial bore and this was not acceptable. Moreover, the photoelectric cell did not accurately record the amount of incident light under all conditions.

It is an object of the invention to provide an artificial eye with a pupil which gives the appearance of changing in size in response to changing light conditions but which does not suffer from the disadvantages of those previous proposals.

According to the invention, an artificial eye is formed with a substantially domed anterior external surface having a section thereof corresponding to the cornea of a natural eye, representations of the iris and other parts of a natural eye visible through the corneal section and a display associated with the representation of the iris adapted to be differentially activated by incident light falling on the eye to create an
impression that the pupil of the iris dilates or contracts in changing light conditions, characterised in that control apparatus including a photoelectric cell is housed within the eye behind the iris display for differentially activating the display and an optic fibre is connected between a position on the anterior surface of the eye where it is exposed to the incident light falling on the eye to said photoelectric cell for measuring the light being transmitted along the optic fibre.

The invention will be illustrated by reference to the accompanying drawings which show an ocular prosthesis according to one embodiment of the invention. In the drawings:

Fig.1 illustrates a side sectional view of a prosthesis; and
Fig.2 illustrates a display pattern which may be produced by one display in accordance with the present invention.

In Fig.1 of the drawings, there is illustrated a substantially hollow ocular prosthesis having an anterior wall 1 and a posterior wall 2 with a hollow space 3 therebetween. The anterior wall 1 is shaped to provide a somewhat hemispherical or domed surface which, when the prosthesis is in position in the orbit, rests against the inner lining of the eyelids. The anterior wall 1 has a transparent section 4 which is visible between open eyelids and represents the cornea of a natural eye. All of the apparatus for simulating a dilating pupil is housed between anterior wall 1 and posterior wall 2.

Adjacent corneal portion 4, the internal surfaces of anterior wall 1 are squared to provide flattened portions 5 which form mounting surfaces for iris button 6. On its anterior side, iris
button 6 is provided with a transparent surface on which are formed, as by painting, representations of various parts of a natural eye so as to be visible through the corneal section. At the centre of the representation of the natural eye is an iris with a small black circular area depicting a contracted pupil as the pupil of a natural eye would appear in maximum environmental light conditions. Below the representation of a natural eye, the iris button 6 comprises apparatus for simulating a dilating pupil. This may include a liquid crystal display in the form of one or more rings such as that shown in Fig.2. The iris button and display may be as described in Specification No.PCT/AU85/00237.

Mounted on the rear of iris button 6, and not visible through the corneal section, is microchip 7 and photoelectric cell 8 on which is mounted a battery 10. A tiny fibre optic cord 9 is fixed in a hole in the anterior wall 1 of the prosthesis such as, for example, in that part of the prosthesis which represents the scleral body of the eye, where it is exposed to incident light falling on the prosthesis. The position of the exposed end of fibre optic cord 9 should be such that it remains exposed for all normal positions of the prosthesis in the socket when the eyelids are open. The other end of cord 9 is connected, preferably detachably, to photoelectric cell 8 which measures the light being transmitted along the optic fibre cord 9. Once the light value is measured, the electronic circuit responds and either energises or closes off part of the liquid crystal display in the manner described in the PCT application previously referred to. In this construction, † means to transmit incident light to photoelectric cell 8 does
not interfere with either the appearance or function of iris button 6 and its liquid crystal display and facilitates the arrangement of the small parts which may be assembled as a removable module.

Fig.2 illustrates one form of liquid crystal display pattern on background 19. This pattern has a central area 31 and concentric substantially annular areas 32, 33 and 34. Each of the areas 31, 32, 33 and 34 are separated from an adjacent area by a gap of approximately 3-4 microns. Central area 31 is aligned with the small black circular area representing a contracted pupil in the painted representation of a natural eye. The black painted pupil area is smaller than the area 31 and appears to lie concentrically within that area. Areas 31-34 may be selectively energised.

When the ocular prosthesis is being worn in strong light conditions, there would be no activation of the liquid crystal display and only the painted pupil is visible through the transparent corneal section 4. Diminishing strength of light incident on corneal section 4 is registered by photoelectric cell 8 which sends a signal via microchip 9 to cause activation of the liquid crystal at one or more of the areas 31-34 which appear blackened through the corneal section 4 of the prosthesis. At first, only liquid crystal area 31 is activated and appears blackened. This has the effect of simulating a dilating pupil as the size of the pupil appears to increase from that of the black painted area to that of area 31. As the light deteriorates further, the liquid crystal at area 32 is additionally activated simulating further dilation of the
pupil. This process continues until all of the liquid crystal areas are activated and appear blackened. This process thus gives the impression of a dilating pupil under decreasing light conditions. In increasing light conditions the reverse process gives the impression of a contracting pupil.

Iris button 6, microchip 7, photoelectric cell 8 and battery 10 constitute a module which is sized to pass through access port 11 in the posterior wall 2 of the ocular prosthesis.

Access port 11 is provided with closure member 13 which may be screw-threaded at its rim to mate with a corresponding thread surrounding the access port 11. A tension spring 12 presses against battery 10 and the closure member 13 to secure the module in place. If required, the module can be removed should repairs be necessary.

The hollow space 3 of the prosthesis may contain silica gel to absorb any condensate.

The iris button preferably includes a tiny rheostat which may be adjusted to vary the switching of the liquid crystal display to match the apparent dilation of the prosthesis with the dilation of the wearer's natural eye. Adjustment of the rheostat may be made before the module is assembled in the prosthesis although, preferably, the adjustment means is conveniently located as to be reachable through access port 11.

The invention is not restricted to the embodiment described above and various changes and modifications will be apparent to persons skilled in the art. Thus, the construction and position of the optic fibre cord may be varied to suit require-
ments. For example, the position of the end of the cord in the anterior surface of the prosthesis may be chosen to take account for an eye defect. To give better exposure to incident light, the optic fibre cord may be multi-stranded with the ends of different strands fixed in different holes at different positions in the anterior surface of the prosthesis. Again, the number of rings in the display may be changed; so may be the nature of the display.

In addition, the invention has applications to dolls' eyes to make them more lifelike because of the apparent ability to change the size of the pupil. In this case, adjustments are made to ensure a correlated dilation of both eyes. The invention is also applicable to statues or models of humans or animals, particularly where a precise resemblance to the subject is required. Further, the invention has use as an educational device, both for children and adults, to demonstrate the operation of parts of an eye. Patients with eye problems may be materially assisted by such a demonstration.
The Claims defining the invention are as follows:

1. An artificial eye comprising a substantially domed anterior external surface having a section thereof corresponding to the cornea of a natural eye, representations of the iris and other parts of a natural eye visible through the corneal section and a display associated with the representation of the iris adapted to be differentially activated by incident light falling on the eye to create an impression that the pupil of the iris dilates or contracts in changing light conditions, characterised in that control apparatus including a photoelectric cell is housed within the eye behind the iris display for differentially activating the display and an optic fibre is connected between a position on the anterior surface of the eye where it is exposed to the incident light falling on the eye to said photoelectric cell for measuring the light being transmitted along the optic fibre.

2. An artificial eye as claimed in Claim 1, wherein the display is a liquid crystal display.

3. An artificial eye as claimed in Claim 1 or 2, wherein differential activation of the display forms one or more concentric annular rings surrounding the representation of the pupil.

4. An artificial eye as claimed in Claim 3, wherein, commencing with the smallest ring, one or more rings are activated by diminishing incident light to simulate a dilating pupil.
5. An artificial eye as claimed in any one of the preceding Claims, wherein the eye is substantially hollow.

6. An artificial eye as claimed in Claim 5, wherein the control apparatus is in the form of a module housed within the hollow eye.

7. An artificial eye as claimed in Claim 6, wherein the module is removable from the hollow eye.

8. An artificial eye as claimed in any preceding Claim, wherein the optic fibre cord is multi-stranded with the ends of different strands connected at different positions in the anterior surface of the eye.

9. An artificial eye as claimed in any one of the preceding Claims and including an adjustment means housed within the eye, whereby the apparent dilation of the pupil may be matched with the dilation of the pupil of the other eye.

10. An artificial eye substantially as herein described and illustrated in the accompanying drawings.

DATED this 11th. day of SEPTEMBER 1990.

OCULAR PROSTHETICS PTY. LIMITED

By Its Patent Attorney

PAUL F. KILDEA.