

INTRODUCTION

The first indications of neutralization of the optical power of corneal curvature by means of the immersion of the eye in a liquid can be found in the writings and sketches of *Leonardo da Vinci*. This author is sometimes credited, because of this, with the discovery of the principle of contact lenses, or even of their actual invention.

Certain drawings showing immersion of the face or the orbital region within hemispheric structures, glass cups filled with water, could even make you believe, if you append appropriate legends, that *Leonardo da Vinci* was aware of, or understood, neutralization of the optical power of the cornea in a liquid. These sketches, diagrams, drawings and texts are found in Manuscripts D and K of Paris, and in the Codex atlanticus of Milan.

By means of a painstaking and careful interpretation of the work of *Leonardo da Vinci*, I will attempt to discover if the neutralization of the corneal dioptic power, in the strict sense, has in fact been described, researched, or utilized and if *Leonardo* had taken cognizance of its significance and interest.

I propose, as a **first step**, to reproduce the texts and the illustrations concerned and to provide from these the most objective possible translation and analysis, taking into account the difficulties of *Leonardo's* prose, by placing them in the context of the manuscripts from which they are taken and from the work of *Leonardo*. In this way, we will view:

- Folios 3 verso and 7 verso of Manuscript D;
- Folios 118 verso and 119 verso of Manuscript K;
- Folio 222 recto/a of the Codex atlanticus.

As a **second step**, I will place the optics, the anatomy, and the ocular physiology in the context of the knowledge of his time. That will take us towards a succinct historical retrospective of the transition from the heritage of Greece to the medieval authors.

Finally, I will challenge these observations using the criteria of the corneal curvature's optical neutralization and the properties of contact lenses. I will investigate these texts and drawings in order to determine if they provide arguments in favor of an earlier description of one or more principles of corneal dioptic power neutralization or contact systems, as certain authors have suggested.

1 – SOURCE DOCUMENTS

The three texts usually quoted in connection with corneal optical neutralization or contact lenses are extracted from:

- Manuscript D, in particular from folios 3 verso and 7 verso;
- Manuscript K, in folio 118 verso;
- Codex atlanticus, in folio 222 recto.

1.1 – MANUSCRIPT D FROM INSTITUT DE FRANCE

The Original of Manuscript D

The original of Manuscript D is said to be preserved in the *Bibliothèque Mazarine* of the *Institut de France*, (23, Quai Conti, Paris). In fact, the manuscript has been placed, for security reasons, in the safes of the *Banque de France*. Researchers are directed either to photographic copies, or to the facsimiles of *Corbeau and Toni* (1964). The latter are in color and of very high quality. They are the ones that I have used.

This Manuscript is handwritten by the author, to judge from its left-handed mirror writing. It is a fascicule of five double pages sheets, which, folded in two, comprises ten folios in 220 x 180 mm format. This is enclosed in four protective folios made from two folded sheets. (1)

The Pagination of Manuscript D

The pagination is in normal, non-mirror handwriting and in progressive order from 1 to 10 in the right superior corner of the front of each of the folios. *Ravaisson-Mollien* (1883) attributed this to the master's hand, but this has been contested (*Corbeau* 1964, *Strong* 1967). The order of the pagination does not in fact correspond to the continuity of sequences linking corresponding arguments, or to that of the watermarks of the paper of the folios. According to these authors, *Leonardo* would not have used a pre-cut work book, but rather large complete sheets of a format double the size of those used today and after folding them in four, he would have used the surfaces thus obtained for writing on. The person carrying out the pagination would have later cut the sheets horizontally, and then would have marked the half folios. These mix-ups of the original pagination by the compiler are not without consequence for our understanding and interpretation of the text and I will take account of that aspect in my analysis.

The Subject Matter of Manuscript D

Manuscript D reveals the ideas of *Leonardo* on the anatomy of the eye in relation to the formation of images and visual perception. Thus, it concerns a specialized treatise, or, more probably part of a specialized treatise. Using a schematized diagram of an artificial eye, he converts the visual organ into a mechanical structure which allows the observation of the progress of the rays from the cornea as far as the optic nerve, while taking into

1. The writing was done on two large-sized sheets that were cut down and paginated later without taking their original arrangement into consideration.

1.1.1 – FOLIO 3 VERSO OF MANUSCRIPT D

A - THE STRUCTURE OF FOLIO 3 VERSO

(Figures 1 – 1 & 1 - 2)

Folio 3 verso of Manuscript D carries the general title “*Occhio umano*” (*On human eye*). It is divided vertically into two sections:

1. The first is the principle section and occupies two thirds of the width and comprises two paragraphs of superposed text, separated by a diagram and legends;
2. The second is in the margin of the foregoing and takes in, from the top downwards, a schematic diagram of the artificial eye and three schematic eye diagrams accompanied by their legends.

The **upper** part of the texts takes the form of sub-titles:

“How to perform an experiment to demonstrate how the visual virtue employs the instrument of the eye.”

“Del fare sperientia come la virtu visiuu adOpera lo sstrumcto dell occhio”

It describes the artificial eye experiment and its interpretation. Two drawings are found in the margin, the first of an artificial eye, and the second of a schematic eye.

The **lower** part of the texts also takes the form of sub-titles:

“How the specie give themselves to the visual virtue with two cross-overs by necessity.”

“Come le spetie si dāno alla uirtu visiuu con due intersegationi P necessita”

It is less homogeneous than the preceding, because the text is interspersed between the three schematic diagrams and their legends.

B - THE SEQUENCES OF FOLIO 3 VERSO

Folio 3 verso can be divided into localized sequences, as follows:

1. As a function of their revealed position in centimeters with reference to the upper margin of the folio, (the total height of the folios is 22 cm),
2. As a function of their position:
 - In the ‘*textual*’ part (sequences T1 to T9);
 - In the ‘*marginal*’ part (sequences M1 to M6).

I propose to describe them, after division and numbering, from above down, as follows:

- 1. The general title** (from 0 to 1 cm) **T 1**
- 2. An homogeneous text** (from 1 to 11.50 cm), comprising the following elements:
 - a sub-title (from 1 to 2 cm) **T 2**
 - a first sequence of text (from 2 to 7cm) **T 3**
 - a sketch of an artificial eye, situated in the margin (from 2 to 7 cm) **M 1**
 - a note in the margin, beside the previous sketch (from 5.5 to 7 cm) **M 2**
 - a second textual sequence (from 5.50 to 11.50cm) **T 4**

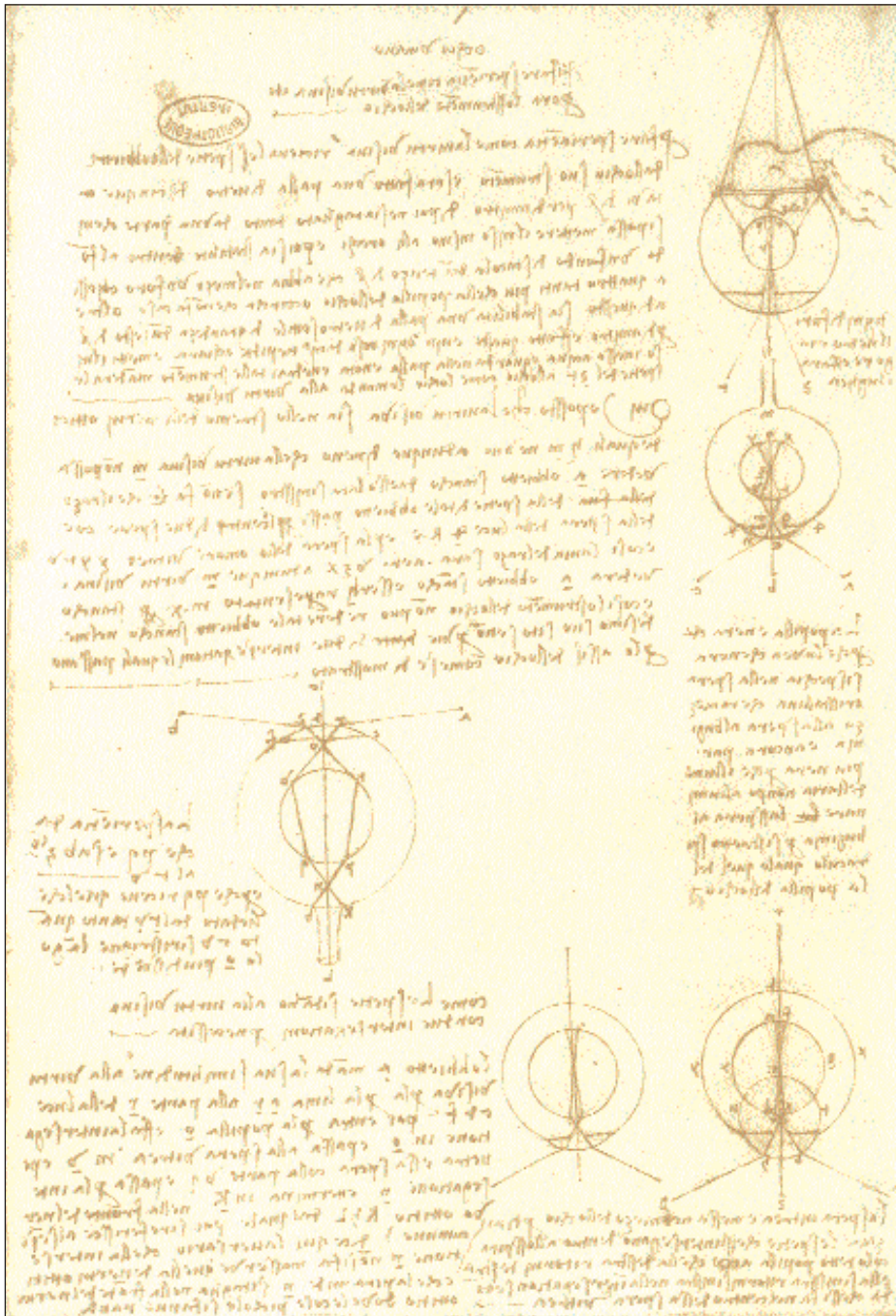


Figure 1 - 1

Leonardo da Vinci, Manuscript D, folio 3 verso.
(original dimensions: 220 x 180 mm).

The mirror writing is typical of Leonardo's writings. To read this requires reversal of the mirror writing. The text contains neither periods nor commas to mark and separate the beginning from the end of sentences. For the present analysis, the document is catalogued in two parts:

- 1.) **on the left**, a main section (the sequences of texts T 1 to T 9), comprising one title, one sub-title, and two parts separated by a central drawing and its legends;
- 2.) **on the right**, a margin (the sequences M 1 to M 6), consisting of the schematic diagram of an artificial eye and three eye-sketches with their legends.

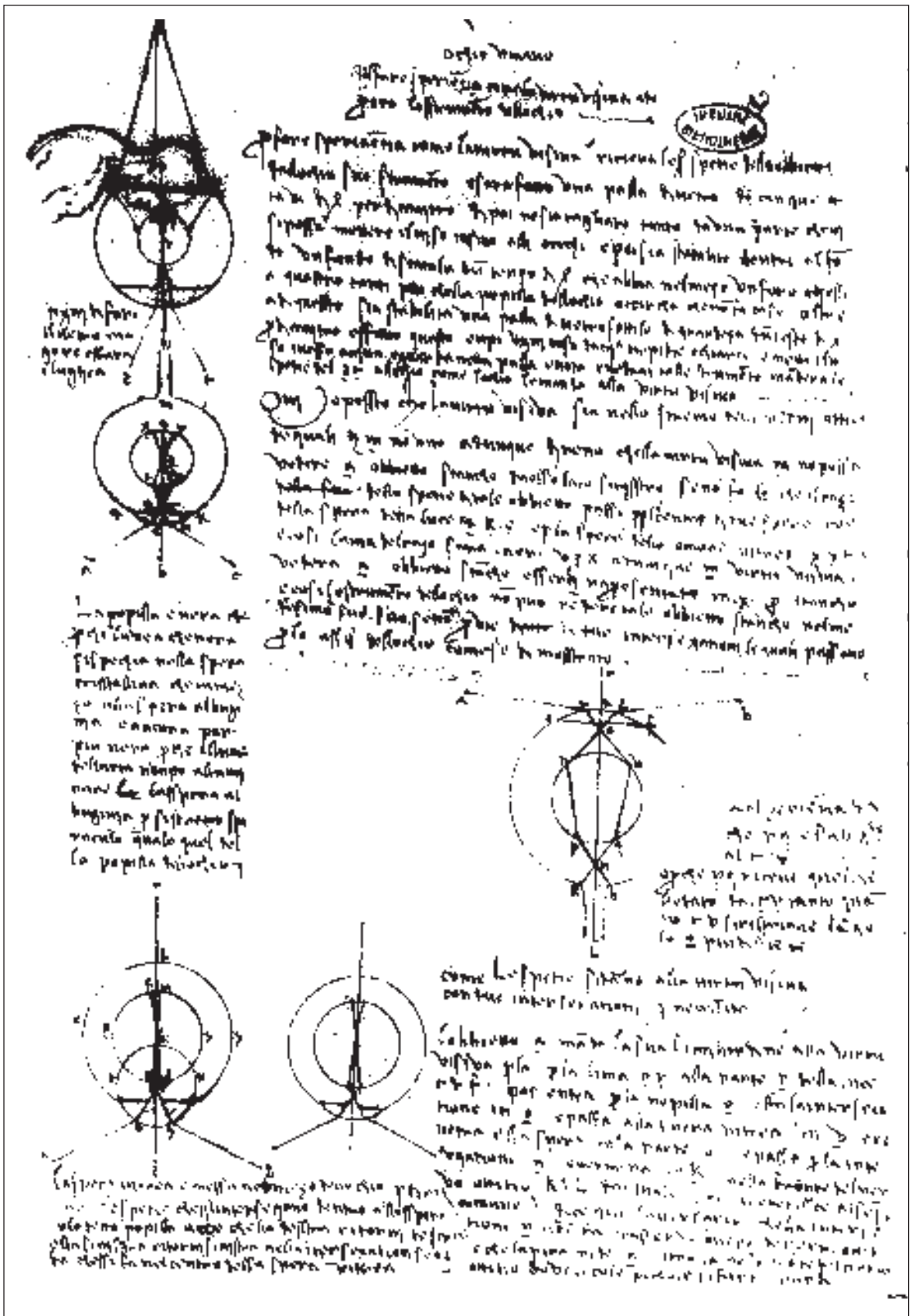


Figure 1 - 2

Leonardo da Vinci, Manuscript D, folio 3 verso.

The mirror writing is reversed, in order to facilitate deciphering the text.

- a sketch of the schematic eye, situated in the margin (from 7 to 10.50cm) **M 3**
- 3. A central part** (from 11.50 to 16.50 cm) formed from the following elements:
- a text in the margin (from 10.50 to 16.50 cm) **M 4**
 - a drawing of the schematic eye, in central position (from 11.50 to 16.50 cm) **T 5**
 - a first lateral text in the central drawing (from 13.5 to 15 cm) **T 6**
 - a second lateral text in the central drawing (from 15 to 16.5 cm) **T 7**
- 4. A lower part** (from 16.5 to 22 cm) with:
- a sub-title (from 16.5 to 17.5 cm) **T 8**
 - a text (from 17.5 to 22 cm) **T 9**
 - two diagrams of the schematic eye in the margin (from 16.5 to 20 cm) **M 5**
 - a text in the margin under the diagram (from 20 to 22 cm) **M 6**

TITLE (T1) (from 1 cm to 2 cm)
(Figure 1-3)

“On human eye”

“Ochio umano”

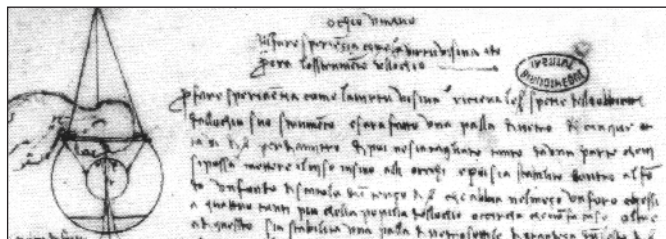


Figure 1 - 3

Leonardo da Vinci, Manuscript D, folio 3 verso. (T 1 & T 2).

This same title, of “*occhio umano*”, is found at the top of folios 3 recto and 8 recto, which leads me to suppose that the writing of these occurred at the same approximate date. For Corbeau (1964) and for Strong (1967), Leonardo would have started with folio 3 verso and continued with folio 8 recto, and then finished with folio 3 recto. The folio 3 verso itself refers to the experiment of the instrument of the eye, that was announced in folio 2 recto and would have been written following this last reference.

SUB-TITLE (T2) (from 1 cm to 2 cm)
(Tableau 1 – 1)

“How to perform an experiment demonstrating how the visual virtue employs the instrument of the eye”.

“Del fare spericizia come la virtu visiuu adopera lo sstrumcto dell ochio”

Leonardo announces that he will explain the formation of the *visual virtue* inside the eye that he likens to an optical instrument. The reference to the *visual virtue* constitutes a vestige of the theory of extramission that is a product of the Greco-Roman concept of the sense of vision, which results from an active force coming from the eye of the observer. The

concept of the eye behaving, as an active element in the process of vision was further expanded in certain quarters at the end of the 15th century. *Leonardo* will abandon the theory of extramission of visual virtue in his later manuscripts of the last period; only to bring it up again in his discussions contained Manuscript D. (*Figure 1 – 3*)

In the context of folio 3 verso, as announced in this sub-title, *Leonardo* no longer gives the *Galenic* meaning of extramission to the *visual virtue*, but considers it as a sensation or perception of vision destined to be transmitted to cerebral structures.

In referring to “*the instrument of the eye*” (“*le sstrumento dell ochio*”), *Leonardo* is innovating, as he attributes the role of an optical instrument to the eye, in the interior of which, the images of the objects (*the species*) are transformed into a visual sensation, the *virtu visiuva* (*visual virtue*).

First Part of the upper Text (T 3) (from 2 cm to 7 cm)

(*Figure 1-4*)

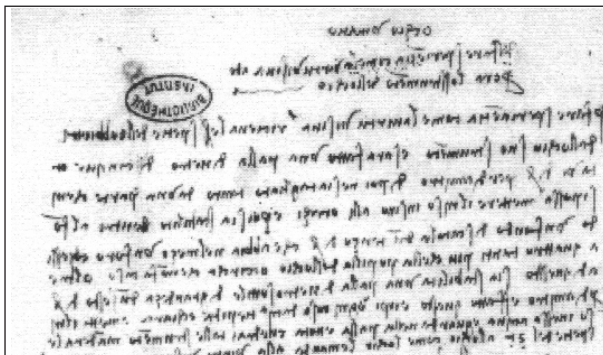


Figure 1 - 4

Leonardo da Vinci, Manuscript D, folio 3 verso. (T 3).

First part of the upper paragraph (T 3).

In this passage, *Leonardo* explains the construction of the artificial eye, reproduced in the margin, where a human head is immersed in such a way that the human eye is situated in the area of the optic nerve of the artificial eye.

species of .s t. to the eye, just as the eye sends them to the visual virtue”.

“In order to perform an experiment that demonstrates how the visual virtue receives the specie of the objects by the eye, its instrument, make a globe of glass of 5/8th of a braccia (3) in diameter, and then cut off a part of sufficient size in order to put the face in it down to the ears. Then fix (4) at the bottom of it a bottom of a box, a third of a braccia in size, in the middle of which will be pierced a hole, four times larger than the pupil of the eye or thereabouts (5), it matters little. In addition, fix a sphere of fine glass (6), of a diameter of a sixth of a braccia in width. That done, fill the whole (7) with tepid (8) and clear water and put the face in this water, look into the sphere and observe how such an instrument dispatches the

“*P fare speringtia come la uirtu visiuva ricieua le spetie delli obbietti dall ochio suo strumçto e sara fatto vna palla ð uetro ð cinque ottavi ð â per ðamjtro ð poi ne sia tagliato tanto da vna parte che uj si possa mettere*

3. “braccia”, measure corresponding in principle to the length of two arms well extended (about 1,60 meter). The braccio of Leonardo corresponds more closely to an ‘ell’ (about 0,60 to 0,70 meter). See note 53.

4. “stabilito, stabilita”, ‘fix’, ‘fix by a suspension’ (according to Corbeau, 1964).

5. “o circha”, word deleted by Corbeau (1964).

6. “uetro sottile”, subtle glass, which is of fine quality and thin, according to the current meaning. But under the circumstances, pure or fine glass would seem to be the more acceptable term, because the context appears to be linked more to the quality of the material of the sphere than to its thickness. In folio 7 verso, the sphere of the crystalline lens is compared to a crystal ball. An empty sphere with thin wall filled with air would not have produced the effect of density attributed to the vitreous humor and the crystalline lens.

7. “ognj cosa”, ‘everything’, (according to Corbeau, 1964).

8. “acq terpida”, ‘lukewarm water’, which is allegedly lighter than cold water: the refraction produced by the interface between the lukewarm water and the glass would cause the rays of light to deviate towards the normal.