



INTRODUCING OPTICS CONCEPTS TO STUDENTS THROUGH THE *OX EYE EXPERIMENT*

Marcela L. Redígolo – redigolo@univap.br
Leandro P. Alves – leandro@univap.br
Egberto Munin – munin@univap.br

IP&D – Univap
Av. Shishima Hifumi, 2911, Urbanova
São José dos Campos, SP, 12244-000

Abstract: *The basic principles of the Scientific Methodology are not explored during the basic physics subjects in many Engineering courses. Substituted by antagonistic methods instead of scientific ones these classes are presented in a dogmatic and finished way, without space for reflection, analysis, experimentation, proposition and other components intrinsic to Science. The objective of this project is to bring interactive practical activities into classes showing how it is possible to work the concepts and the scientific fundamentals out. During this physics discipline the students are required to learn about Optics, including topics such as reflection, refraction, use of lenses, image formation, image distortions, and human vision and disorders. In this work we present how the teacher can explore all these topics and yet introduce the scientific methodology for the students during the practice, using one single experiment that consists of the opening of an ox eye by the students to study its components (SABA, 1999). A discussion of Science History also can be promoted.*

Keywords: *Interactive activities; Optics; Ox eye; Scientific methodology; Science history;*

1. INTRODUCTION

1.1 Science history

The knowledge of researches developed along many centuries can bring a new meaning into the student learning process. If the students learn about the scientific method behind a well established theory, all the mistakes committed and the time and efforts spent on that, their vision of Science as a process and not as a night-to-day discovery can be reviewed.

From the beginning of time humans have tried to explain the complex process of vision. Recorded studies of human vision date back at least to the time of Aristotle. Aristotle was a prominent philosopher, scientist, and scholar who lived in ancient Greece around the 4th century BC. Aristotle's explanation of the process of human vision was that the object being looked at somehow altered the *medium* (now known to be air) between the object itself and the viewer's eye. This alteration of the medium was thought to propagate to the eye, allowing the object to be seen. During the Middle Ages Aristotle's theory was reversed. Instead of postulating that the object itself had innate properties which allowed vision, popular theory of the time suggested that the viewer's eyes sent out emissions to the object and that those emissions enabled vision to occur. These theories may seem illogical today, but the theories

of long ago were not based on today's extensive experimental scientific data. Instead they were based on the conjecture and observation of scholars.

A realistic understanding of the function of the components of the eye began around the 17th century, after the gross anatomy of the eye had been firmly established. Modern theories of vision start with Johannes Kepler who in *Ad Vitellionem paralipomena* (1604) first correctly described the formation of the retinal image in the eye. A few years later Christoph Scheiner (1619) observed the retinal image by scraping away the sclera of the eye of an ox which was placed in a hole in a shutter (reported by Descartes, 1637). However there was a problem - the retinal image was upside down. Descartes correctly postulated that the image was inverted as a result of being focused onto the retina by the eye's lens (VALVERDE *et al*, 1995).

1.2 The human eye

Vision is a complicated process that requires numerous components of the human eye and brain to work together. The brain then processes those impulses and gives information about what we are seeing.

A sketch of the anatomical components of the human eye, as we now know it, is shown in figure 1. The main structures are the iris, lens, pupil, cornea, retina, vitreous humor and optic nerve.

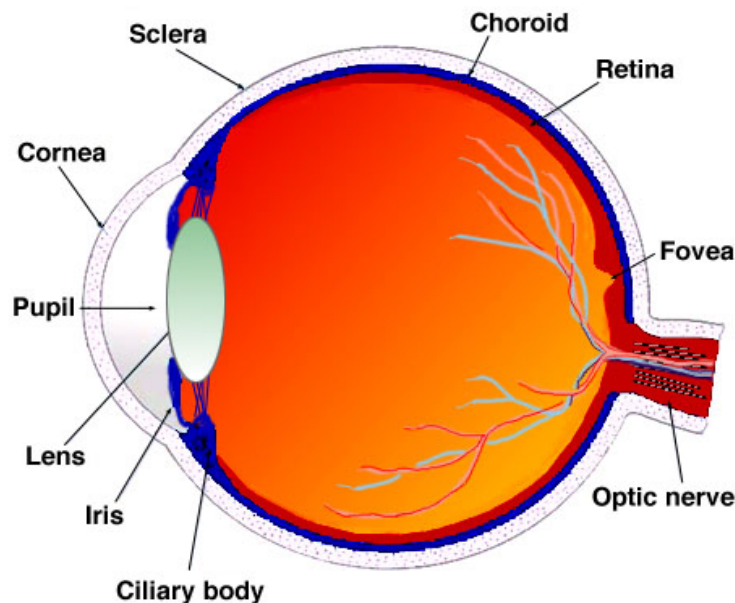


Figure 1: - Sketch of the anatomical components of the human eye.

The most external structure observed is a transparent surface, the cornea, that covers both the pupil and the iris. This is the first and most powerful lens of the optical system of the eye and allows, together with the crystalline lens, the production of a sharp image at the retinal level.

The iris is a colored circular muscle which is pigmented giving us our eye's color and its central aperture is the pupil (see figure 2). The iris controls the size of the pupil so more or less light, depending on the conditions, is allowed to enter the eye. Eye color, or more

correctly, iris color is due to variable amounts of eumelanin (brown/black melanins) and pheomelanin (red/yellow melanins) produced by melanocytes (METZELAAR-BLOK *et al*, 2001).

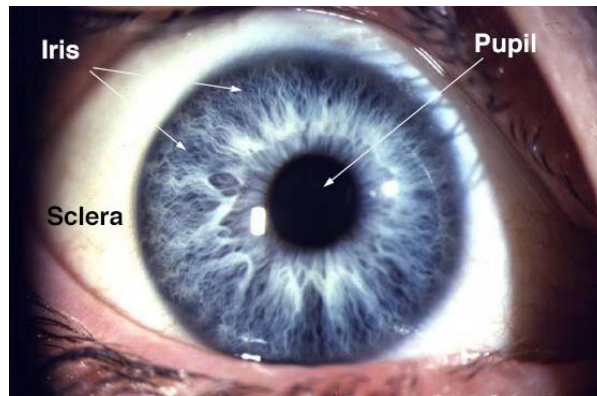


Figure 2: - Picture of a human eye showing the pupil, the sclera and the iris.

The eye's lens which is a transparent body can be found right behind the iris. The lens is suspended by ligaments attached to the anterior portion of the ciliary body. This is a biconvex (convergent) lens with variable curvature. The contraction or relaxation of the ligaments as a consequence of ciliary muscle actions, changes the curvature of the lens in a process called accommodation.

The *white of the eye* is called the sclera, which forms part of the supporting wall of the eyeball. The sclera is continuous with the cornea. Light rays are focussed through the transparent cornea and lens upon the retina. The central point for image focus (the visual axis) in the human retina is the fovea. Here a maximally focussed image initiates resolution of the finest detail that is transmitted to the brain through the optic nerve.

The human eye presents three chambers of fluid: a) the anterior chamber, between the cornea and the iris; b) the posterior chamber, between the iris and the lens; and c) the vitreous chamber, between the lens and the retina. The first two chambers are filled with aqueous humor whereas the vitreous chamber is filled with the vitreous humor, a more viscous and gel-like fluid (VALVERDE *et al*, 1995). The vitreous humor is responsible for 80 % of the process of forming the image upon the retina (SABA, 1999).

2. THE OX EYE DISSECTION PROCESS

The ox eye has many similarities to the human eye (iris, lens, pupil, cornea, retina, vitreous humor, optic disk and optic nerve) and some basic differences as the *tapetum lucidum* (bright carpet) that reflects any light back to the retina. Because the ox has a big eyeball it is easy to handle it to cut and separate the internal structures. Therefore, the basic function of the components of the human eye and how they participate in the vision process can be introduced during this experiment. These details are covered in most high school physics and biology books but the experiment will bring an unique living experience for the students.

The students are required to work in pairs and dissect an ox eye (shown in figure 3). The first step is to remove the excess extraocular tissues (muscles, fat, etc). Some students note how the extraocular muscle tendons blend with the sclera. Using a scalpel to make a small cut in the sclera, they insert their scissors and cut around the equator. The gel-like vitreous humor is then separated from the eye.



Figure 3: - One of the ox eye samples used for the dissection experiment.

At this moment, the teacher can request the students to study the posterior half of the eye, identifying the vitreous humor. After removing it, the retina can be studied. Gently the students can tease the retina and notice that it is attached to the optic nerve head. At this point, a basic difference between human and ox eye can be noticed. The ox eye presents a bright blue-green carpet at the retina region as shown in figure 4. It is the *tapetum lucidum* that reflects any light back to the retina. That is the reason the ox, the cat and other animals can see better in the dark than humans. At the human eye this region is black and absorbs all the light that passes through the retina (CURCIO and HENDRICKSON, 1991).

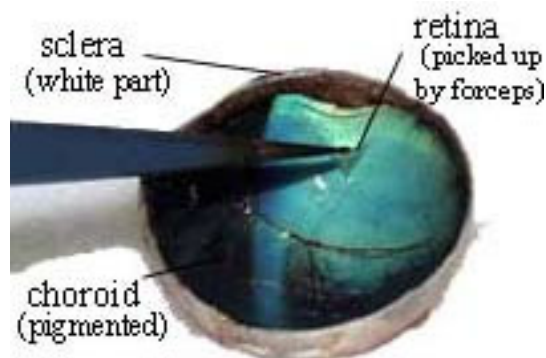


Figure 4: - Picture of a dissected ox eye presenting the blue-green *tapetum lucidum*.

The second part of the experiment consists of studying the anterior segment of the ox eye. First, the students remove the lens, as seen in figure 5. This is a great opportunity to study the image formation and bring some questions into the discussion. The students are requested to place the lens over some text on a page and to note that it is transparent and has different magnifications depending on the pressure it had applied. The ligaments attached to the lens also can be identified in figure 5.

Following the dissection process, the students analyze the pupil (a black-looking aperture that allows light to enter the eye) and the iris. They note the shape and the size of the pupil, the color of the iris and how it is attached to the ciliary body. The ox iris is always brown, that means there is not an ox with blue or green eyes. And besides, the ox pupil is oval and not circular as the human one.



Figure 5: - the ox eye crystalline lens

3. DISCUSSIONS

During the ox eye experiment, many students start to questioning themselves about their knowledge on vision and optics. Questions like:

- Why do we not see the world upside down?
- Since the retinal image is two dimensional, how do we see a three dimensional world?
- How do we work out the real size of objects from their retinal size?

are asked and the teacher can use them to enrich the discussion about image formation, geometrical optics, vision, etc. Also, a number of vision disorders, including both near- and far-sightedness that are a result from an improperly curved cornea, can be introduced to the class.

4. CONCLUSIONS

The aim of this work is to introduce how the teacher can explore topics in geometrical optics, discussing scientific methodology and history, using one single experiment that consists of the dissection of an ox eye by the students to analyze its components.

The project brings this experiment as an interactive practical activity into the class, showing how it is possible to work the concepts and the scientific fundamentals out. The students develop the ability of working in groups and the experiment promotes an increase in their motivation and the development of their criticism.

REFERENCES

CURCIO, C. A. and HENDRICKSON, A. E. **Prog. Ret.**, vol. 10, pp. 89-120, 1991.

METZELAAR-BLOK *et al.* **Invest. Ophthal. Vis. Sci.**, vol. 42, pp. 1951-1954, 2001.

SABA, M and EPIPHANIO, I. **Física na Escola**, vol. 2, n. 2, pp. 16-18, 2001.

VALVERDE, P. *et al.* **Nat. Genet.**, vol. 11, pp. 328-330, 1995.