Understanding Accommodation

A computer-animated model illustrates the underlying mechanism of accommodation.

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Standing on the shoulders of giants and benefitting from advanced imaging studies conducted during the past decade, we are now at the brink of understanding the mechanism of accommodation and presbyopia. With this new understanding, we will ultimately succeed in developing better treatments for presbyopia—considered by many to be the holy grail.

Models are of central importance in science. Imagine understanding genetics without the double-helix model of DNA. Model-based cognitive reasoning refers to an inference method used in expert systems based on a model of the physical world. Through building a computer-animated model of accommodation, we can visualize multiple elements moving in synchrony, and with model-based reasoning we can advance our understanding of the underlying mechanisms. Certainly, seeing is believing—and understanding.

There are countless pieces to the puzzle of accommodation, with thousands of scientific studies and theories generated by leading scientists of the 19th and 20th centuries. Hermann von Helmholtz’s lenticular theory of accommodation has been largely confirmed, but the role of the extralenticular components in accommodation is still controversial. As of 2014, the movements of the ciliary body are well documented, and its role as the engine of accommodation is recognized. The distribution of forces via the zonular elements, on the other hand, has not been well understood; however, the anatomy of the zonular architecture has been defined by landmark studies on the movements and elements of the vitreous zonule and hyaloid membrane published in 2010 and 2013, respectively.

A team of European investigators (Elke Lutjen-Drecoll, MD, and colleagues at the Institute of Anatomy in Erlangen, Germany) and American investigators (Mary Ann Croft, MS; Paul Kaufman, MD; and colleagues at the National Primate Lab and University of Wisconsin in Madison) have used electron microscopy and video ultrasound biomicroscopy (UBM) and endoscopy to define the complex, separate elements of the zonules and document the interconnected movements of the extralenticular tissues. Their monumental work has made it possible to build a model and to understand and demonstrate the mechanism of accommodation.

MODELS OF ACCOMMODATION

Based on this new knowledge of the anatomy of the zonular architecture and aided by video UBM imaging of accommodation, I produced my first model of accommodation in collaboration with a computer animator in 2011.

For a video demonstration of this model, visit eyetube.net/?v=ugoba.

The concept of reciprocal zonular action was developed via model-based reasoning as follows:

“During ciliary body contraction, the anterior zonules lose tension while the posterior zonules stretch. During ciliary body relaxation, the posterior zonules lose tension as the lens flattens and is pulled back by the increasing tension of the anterior zonules.”

A second version of the model, the Computer-Animated Model of Accommodation and Presbyopia, version 2.0 (CAMA 2.0; Figure 1) will soon be presented,
incorporating up-to-date knowledge of the anatomy along with the latest biometry. CAMA 2.0 is based on anatomy and biometry in accommodation and disaccommodation. It represents a biometrically accurate (structures within 200 μm accuracy) model of a 25-year-old eye with 8.00 D of accommodation. This model is based on anatomy, biometry, endoscopy, and video UBM; it is not based on theory, and the findings are derived from model-based cognitive reasoning.

A video arrangement of CAMA 2.0 preview slides can be viewed at eyetube.net/?v=ekopu. In preview slide 1, the composite model is presented (Figure 2). The changes in shape and position of all anatomic elements are shown, demonstrating how the structures interconnect and function as a unit. It is helpful to isolate the extralenticular elements, as shown in preview slide 2 (Figure 3). The anterior zonules (zonules of Zinn) are shown in blue. There are three elements of vitreous zonules: (1) the anterior vitreous zonule, shown in yellow; (2) the intermediate vitreous zonule, shown in red; and (3) the posterior vitreous zonule—the interconnecting network of fibers at the vitreous base—shown in off-white.

Additionally, there is a pars plana zonule, shown in green, and the newly described posterior insertion zone to lens equator (PIZ-LE) zonule, shown in purple. Also notice the white line representing the anterior hyaloid membrane and the Weiger ligament, a cradle-shaped attachment of the posterior lens capsule and anterior hyaloid membrane, shown in grey.

The current classification of zonules into anterior or posterior and lenticular, vitreous, or pars plana is confusing. After an analysis of the model, a new classification of...

**TAKE-HOME MESSAGE**

- Through a computer-animated model of accommodation, multiple elements can be visualized moving in synchrony, and model-based reasoning can advance the understanding of the underlying mechanisms.
- The monumental work of European and American researchers has made it possible to build a model and to understand and demonstrate the mechanism of accommodation.
- Using CAMA 2.0, a new classification of zonular architecture can be proposed based on structure and function.
zonular architecture can be proposed based on structure and function. Preview slide 3 (Figure 4) demonstrates the first group of zonules as the anterior zonules, whose function is to release tension on the lens during accommodation, allowing the intrinsic elasticity of the lens to round-up the lens, contributing to the increase in lens thickness and steepening of the anterior and posterior capsules. In disaccommodation, the anterior zonule increases tension and flattens the lens.

The second group of zonules is the crossing zonules shown in preview slide 4 (Figure 5). Here, the anterior vitreous zonule (yellow) is shown inserting into the Weiger ligament, and the PIZ-LE zonule (purple) is shown anchoring the lens equator to the posterior insertion zone. The crossing zonules and Weiger ligament cradle, shape, and stabilize the posterior lens and vitreous. Like a downhill skier who must keep focusing while travelling at 60 mph over bumpy terrain, there must be something to prevent the lens from rattling around in the eye. Based on the model, the crossing fibers combined with Weiger ligament keep the lens in place while allowing the anterior and posterior zonules to provide reciprocal accommodation and disaccommodation of the lens.

The third functional group is the posterior zonules shown in preview slide 5 (Figure 6). These include the intermediate vitreous zonule (red), the posterior vitreous zonule (off-white), and the pars plana zonule (green). These are reciprocal tension fibers that follow ciliary muscle movement and are anchored in the elastic choroid.

Accommodation does not stop at the ora serrata. Movement of the ora has been demonstrated by transillumination, UBM, and endoscopy, and we are just beginning to appreciate the implications. Preview slide 6 (Figure 7) demonstrates the elastic foundation in the choroid, where energy for disaccommodation is stored.

**CONCLUSION**

There is more—much more—but it is time to say adieu, for now. Thank you for allowing me to share my work with you. As a clinical ophthalmologist, I am humbled by the opportunity to make a contribution to understanding accommodation.

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