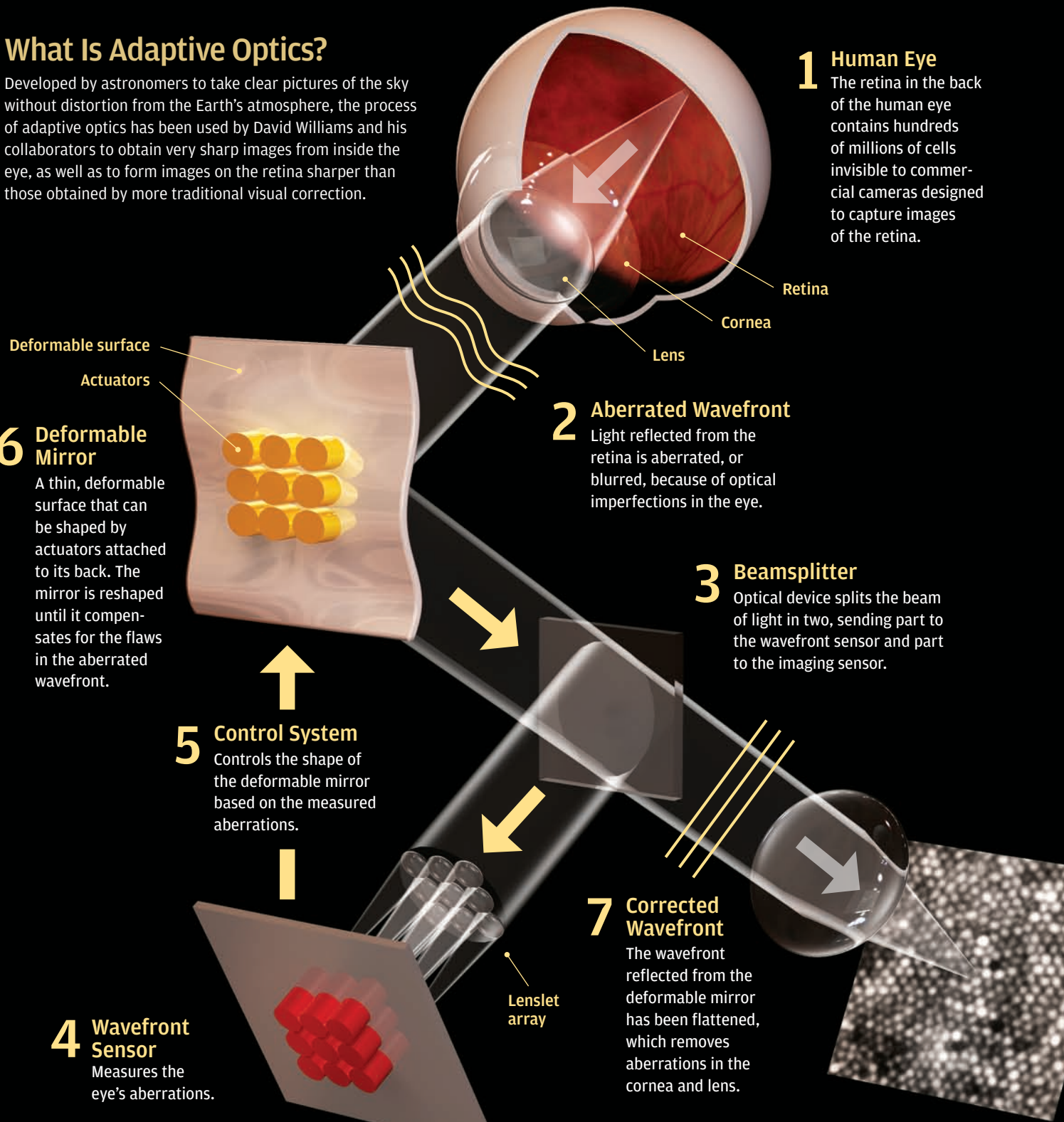
What Is Adaptive Optics?

Developed by astronomers to take clear pictures of the sky without distortion from the Earth's atmosphere, the process of adaptive optics has been used by David Williams and his collaborators to obtain very sharp images from inside the eye, as well as to form images on the retina sharper than those obtained by more traditional visual correction.



1 Human Eye

The retina in the back of the human eye contains hundreds of millions of cells invisible to commercial cameras designed to capture images of the retina.

2 Aberrated Wavefront

Light reflected from the retina is aberrated, or blurred, because of optical imperfections in the eye.

3 Beamsplitter

Optical device splits the beam of light in two, sending part to the wavefront sensor and part to the imaging sensor.

4 Wavefront Sensor

Measures the eye's aberrations.

5 Control System

Controls the shape of the deformable mirror based on the measured aberrations.

6 Deformable Mirror

A thin, deformable surface that can be shaped by actuators attached to its back. The mirror is reshaped until it compensates for the flaws in the aberrated wavefront.

7 Corrected Wavefront

The wavefront reflected from the deformable mirror has been flattened, which removes aberrations in the cornea and lens.

8 Image Sensor

The corrected wavefront is focused here, capturing a high resolution image of the retina.

ILLUSTRATION BY STEVE BOERNER FOR *ROCHESTER REVIEW* (SOURCE: DAVID WILLIAMS, WILLIAM G. ALLYN PROFESSOR OF MEDICAL OPTICS)

Sharpest Pictures Ever of the Retina

The images below show the advantage that adaptive optics retinal imaging offers over standard commercial cameras for imaging the retina.

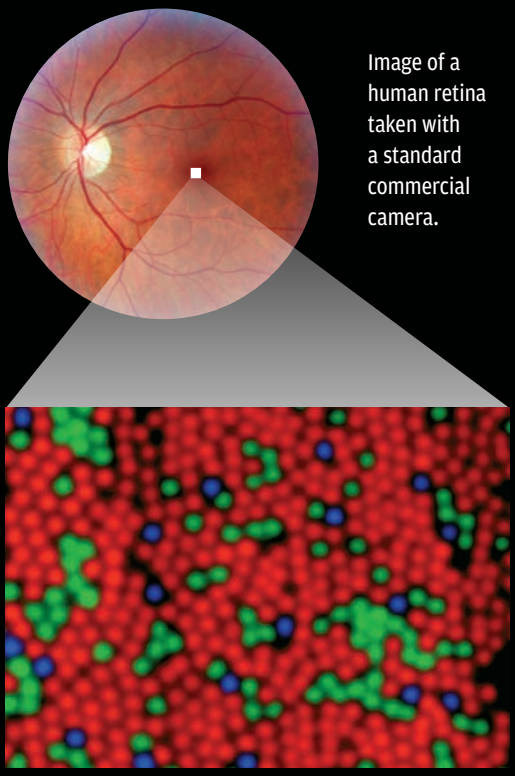
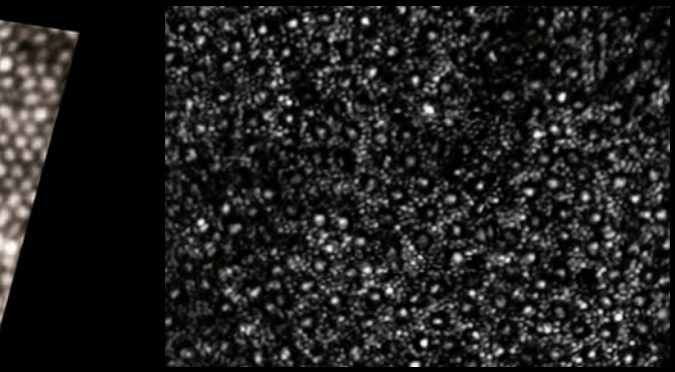


Image of a human retina taken with a standard commercial camera.

Retinal image taken with adaptive optics—the first ever of its kind—showing the three kinds of cones responsible for color vision. Each cone is five microns in diameter, about 1/20th the diameter of a human hair.



The clearest image ever taken of rod photoreceptors in the living human eye. The rods, each just two microns in size, are the smaller spots in the image.

ISTOCKPHOTO (TOP); AUSTIN ROORDA (CENTER); ALF DUBRA (BOTTOM)

VISION SCIENCE

Stars in Your Eyes

One of the world's leading experts on human vision, **David Williams**—the William G. Allyn Professor of Medical Optics—has pioneered new technologies that are improving eyesight for people who are legally blind and those with 20/20 vision alike. And he's done it by applying methods of astronomers to the terrain of the eye.

In September, Williams received the António Champalimaud Vision Award in Lisbon, Portugal, in recognition of his work on adaptive optics. In awarding the prize, the jury said that Williams and his research group have "set the stage for current approaches to vision correction and have opened up new possibilities for imaging retinal structures in the living eye."

With a prize of 1 million euros, the award recognizes contributions to vision research and is the largest in vision science and ophthalmology. Williams receives half the prize, which will support his future research; he shares the award with developers of optical coherence tomography, another method of imaging the retina that has improved the diagnosis and clinical management of retinal disease.

Williams says that "this technology makes it possible for us to image the retina with unsurpassed resolution and moves us further down the path to the understanding of retinal disease."

Adaptive optics was first developed by astronomers so that telescopes could see more clearly through the Earth's atmosphere. The technologies that Williams and his group developed apply these techniques to the eye, making it possible to image individual retinal cells—down to individual photoreceptors in the living human retina—by looking through the pupil. The group developed techniques that not only can modify the light leaving the eye to obtain better pictures of the retina but also can modify the light going into the eye to achieve better vision. The methods that Williams's team developed are used throughout the world in Lasik procedures today.

Williams, whose primary appointment is in the Institute of Optics, is dean for research in Arts, Sciences & Engineering. He joined the faculty in 1981 and is also director of the Center for Visual Science, a research program bringing together 30 faculty members from five departments to understand how we see and the disorders that compromise sight.

David Williams

While Williams has led the way, he notes that the effort was by no means his alone. He calls the discoveries in adaptive optics that the Champalimaud Award honors the "work of many graduate students, postdoctoral fellows, and colleagues over two decades.

"It is great for our whole community that the achievements and potential of adaptive optics for vision are showcased with this award."

—Leonor Sierra

BRANDON VICK