Seeing decade by decade

In 1959, I was 11 years old when one of my teachers determined that I needed to be examined by an optometrist who confirmed that I needed eyeglasses. The optometrist found that my eyes were myopic, that is, that I could see clearly close up, but hardly at all at any distance. I was shortly fitted with a wonderful pair of eyeglasses that allowed me to see and read at a distance as well as close-up. If you've seen pictures of U.S. Senator Barry Goldwater in the 1960s, then you know what my first set of eyeglasses was like. My first set of lenses were glass (probably crown glass), and very thick. Not quite as thick as the bottom of coke bottles, but still very thick. The frames were the sturdy, black plastic frames. I cannot tell you how many times the frames broke in those early years, but I had extensive time periods when the frames were held together by some form of tape.

At some point in the 1960s, my glass lenses were replaced with plastic lenses that were advertised as being safer because they were "shatterproof." However, another advantage of plastic lenses over glass is that plastics commonly used for eyeglasses generally have a higher index of refraction than glasses used for eyeglasses, so that lenses with the same optical curvature could be achieved in plastic lenses that were lighter weight than the corresponding glass lenses. Frames also evolved during that time period into lighter weight, but sturdier. In the late 1960s and early 1970s, nothing would work for me but thin wire frames, which I believe were made of a base metal plated with a thin gold coating. I think that this was during the time period that I had shoulder-length hair, a Nehru jacket, and bell-bottom pants. (God, I hope that none of the photographs from that era survive today!) Although I thought at the time that the wire frames looked good, they certainly weren't very practical in terms of durability. Today, there are wire frames made of stainless steel, titanium, and titanium alloys that are somewhat more durable and more flexible.

At some point, eyeglass manufacturers developed lenses in polycarbonate materials that are higher in index of refraction than plastic, so that thinner, more lightweight lenses could be manufactured. Polycarbonate lenses are also more resistant to shatter than the original plastic lens materials. I note that lens manufacturers are careful these days not to claim that materials are "shatterproof," only that they are more shatter-resistant. Today, there are more than a dozen different plastic materials and a half-dozen or so glass materials that are used in lenses for eyeglasses (e.g., see http://en.wikipedia.org/wiki/Corrective_lens).

In my mid-40s, I noticed that it was becoming harder and harder to read at close distances. Sure enough, a visit to my optometrist confirmed presbyopia, the hardening of the lens that occurs with age that increases the difficulty to focus, particularly on objects close to the eyes. At first, I had two pairs of glasses, one for reading and one for normal everyday activities other than reading. After struggling with this for some time, I accepted the notion that I needed bifocals. The original form of bifocals, credited to Benjamin Franklin, had a split glass lens with a bottom part for seeing close (including reading) and a top part for distance vision. My bifocals consist of embedded lenslets for close vision with the major portion of each lens dedicated to distance vision. The embedded lenslets occupy a little more than one-fourth of the area of each lens. Each bifocal lens is manufactured out of one piece of material. For me the transition from distance vision to close-up vision is seamless now, with a large-enough field of view in each case that the glasses do not usually intrude upon the process.

During my 50s, I decided that I wanted to try contact lenses. The idea for a contact lens dates back to Leonardo da Vinci (e.g., see http://en.wikipedia.org/wiki/Contact_lens). I had always resisted their use previously. The early versions of contact lenses were fairly thick and not very flexible. They would also pop out of the eye at awkward moments. I cannot remember how many basketball games that I have seen suspended while the participants crawled around on the floor of the court looking for one of the players' lost contact lenses. However, by the time I got around to it great strides had been made in the materials. In the 1960s, soft lenses made out of hydrogel materials were invented by Czech chemist Otto Wichterle (e.g., see http://en.wikipedia.org/wiki/Contact_lens) and Drahoslav Lím, his assistant. New lens materials were developed that were lightweight and much more flexible.

The first set that I had, though, were

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still somewhat stiff. I remember feeling like someone was trying to poke a stick in my eye as I struggled to get them in. These rigid lens materials were gas permeable, which is important for oxygen transport to the eye. Later, I wore contact lenses that were extended use lenses that were extremely flexible and lightweight. Those were intended to be used for a couple of weeks at a time and then thrown away. Those contact lenses were enabled by the development of lenses from silicone hydrogels that were oxygen permeable. Contact lenses were also developed that had a toroidal figure to compensate for astigmatism, which helped me because I am astigmatic in both eyes. For a while, I also used the monovision approach in which one eye is optimized for distance vision, while the other eye is optimized for near vision. It took a short while to get used to the conflicting signals that my brain was receiving from my different eyes, but it is true that the brain ultimately compensates.

Alas, as I reached my 60s, I developed glaucoma (e.g., see http://en.wikipedia.org/wiki/Glaucoma). There are several types of glaucoma, but mine is apparently of the form which results in an increase in intraocular pressure that can damage or destroy the optic nerve. Fortunately, my optometrist caught it before too much damage had occurred, and I was referred to an ophthalmologist who has worked with me to get my intraocular pressure under control. Unfortunately, this meant that I could no longer wear contact lenses and have had to return to regular eyeglasses.

There have been an amazing number of developments in eyeglass technology over my lifetime, far too many to mention in this short article. I remember both of my parents adopting eyeglasses coated with photochromic materials that were transparent indoors, but darkened in sunlight to limit the amount of light incident on the eye. Most eyeglass lenses have antireflection coatings as well as anti-scratch and scuff-resistant coatings. Many of the materials for regular lenses as well as contact lenses have substantially less transmission in the ultraviolet, which helps protect the eyes against cataracts.

I've seen presentations at MRS Meetings and elsewhere on adaptive lens materials that could change focal length under fluid pressure (e.g., see recent work by D.-Y. Zhang and colleagues, *Appl. Phys. Lett.* **82**; p. 3171, 2003, DOI: 10.1063/1.1573337) or electrical bias (e.g., see recent work on electroactive liquid-crystal lens materials by Nasser Peyghambarian and colleagues, *Appl. Phys. Lett.* **90**, 111105, 2007, DOI: 10.1063/1.2712773). I'm cautiously optimistic that work in these or other areas will yield, within my lifetime, a contact lens of adjustable focal length to serve for distance vision or near vision on command.

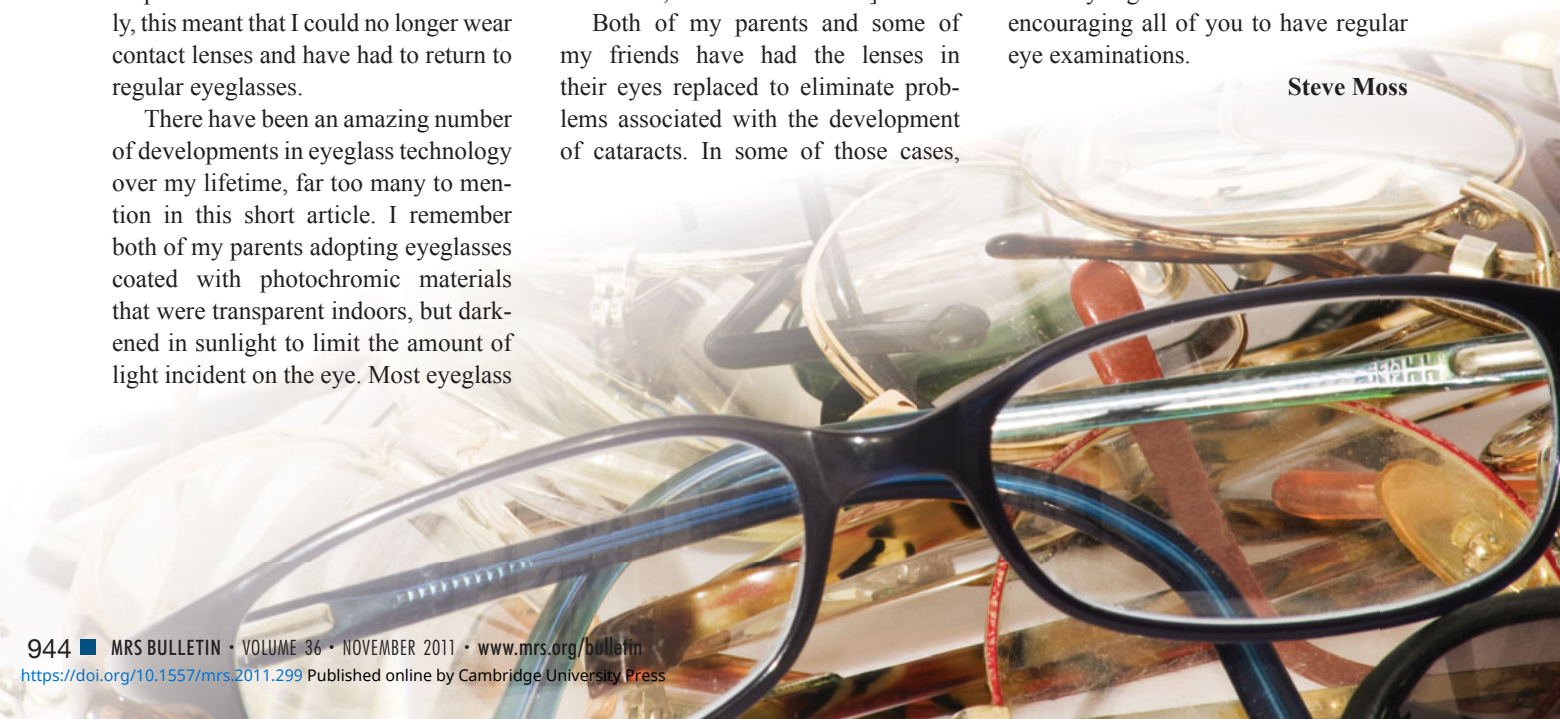
[Note added in proof: Gopal Rao pointed out to me that a company called Superfocus already makes eyeglasses with adjustable lenses (see www.superfocus.com). Each lens consists of a rigid lens and a flexible lens. The flexible lens consists of a membrane and the region between the membrane and the rigid lens contains a clear fluid. The nosepiece of the glasses has a sliding bar that allows the wearer to adjust the position of the fluid altering the shape, and hence the correction, of the flexible lens.]

Both of my parents and some of my friends have had the lenses in their eyes replaced to eliminate problems associated with the development of cataracts. In some of those cases, the eyesight has been nearly perfectly corrected for distance vision. I am assuming that as my eyes age further, this will happen to me and the lenses in my eyes will be replaced. If I am lucky and my distance vision is completely corrected as a result, then I will only need eyeglasses for reading.

I am also cautiously optimistic that research into glaucoma will achieve a cure, or at least better methods to control intraocular pressure. Finally, I am also cautiously optimistic that medical research (perhaps involving the burgeoning biomaterials community) will find a method to restore damaged nerve cells including cells in the optic nerve damaged by glaucoma (maybe through stem cell research).

My eyes now are myopic, astigmatic, and presbyopic—and I have glaucoma. My distance vision without correction is virtually nonexistent. Materials research in the areas of plastics has significantly benefited me by making it possible for my optometrists and ophthalmologists to enhance the quality of my vision. Research in the area of medicine to treat glaucoma has allowed my intraocular pressure to be brought under control. Without the research behind these advances, my eyesight would not be anywhere near as good as it is today. If we maintain our commitment to research in these areas, I believe that future generations will experience much better eyesight. I cannot close without encouraging all of you to have regular eye examinations.

Steve Moss



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