Carotenoids and the Eye

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The *macula lutea* ("yellow spot" in Latin) of the human eye is the center of the human retina responsible for our ability to perform high visual acuity tasks such as reading, driving, and recognizing faces (Figures 1 & 2).

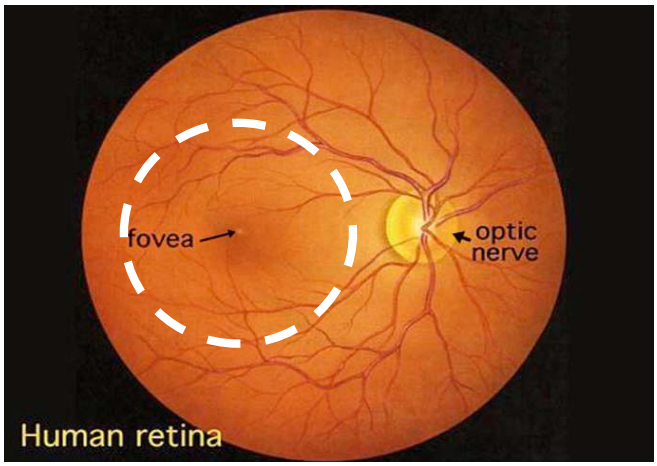

Figure 1:
The macula is a 5 millimeter diameter region of the retina denoted by the dashed white circle). It is centered on the fovea. Image courtesy of Webvision (http://webvision.med.utah.edu/).

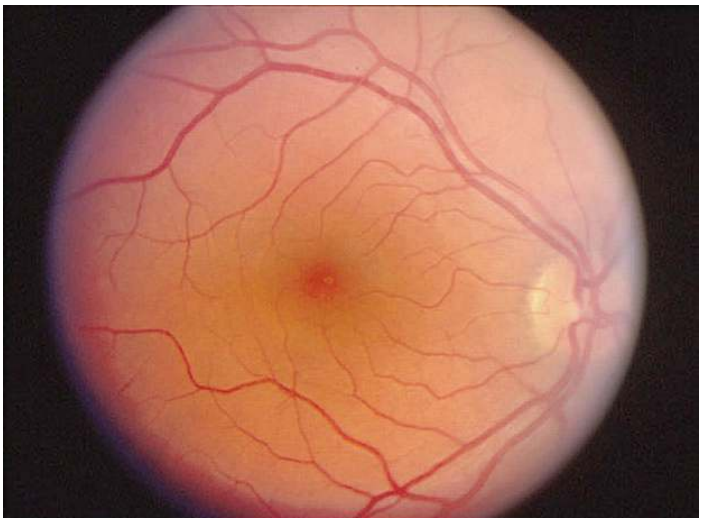

Figure 2:
The yellow macular pigment is most highly concentrated in a 500 micron region centered on the fovea. It spreads diffusely at much lower concentrations for several more millimeters. Image is courtesy of Webvision (http://webvision.med.utah.edu/).

The center of this cone-rich region of the primate retina known as the fovea is specifically enhanced with just two of the many carotenoids consumed in our diets—lutein and zeaxanthin (Figure 3).

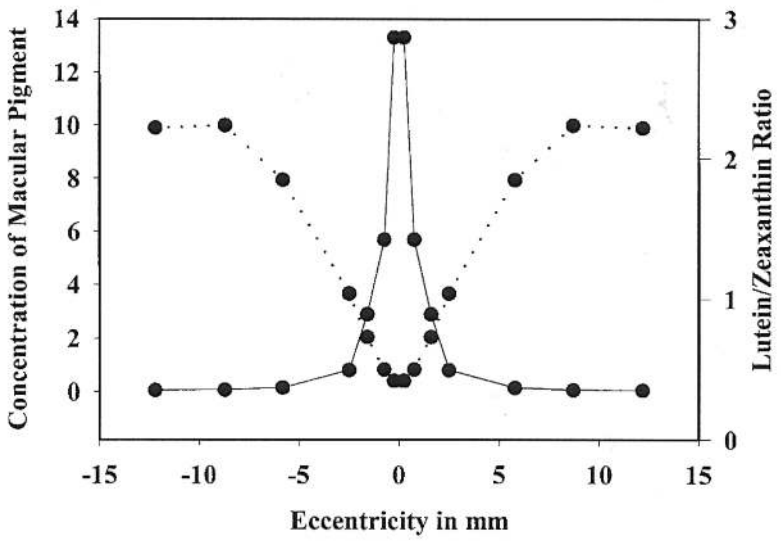

Figure 3:
Distribution of lutein and zeaxanthin in the macula of the human eye. Image courtesy of John T. Landrum, PhD.

These xanthophyll carotenoids commonly found in dark green leafy vegetables and orange and yellow fruits and vegetables are deposited in the fovea at extraordinarily high concentrations (~1 mM) through mechanisms involving specific transport and binding proteins (Figure 4).

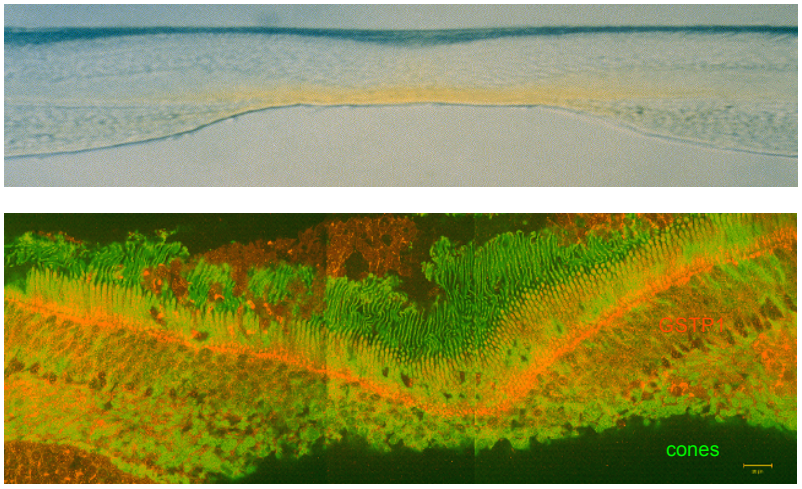

Figure 4:
The upper image is a cross-section of a primate foveal pit (vitreous side down) showing the location of the yellow macular pigment. The lower image shows the distribution of the zeaxanthin-binding protein GSTP1 as an orange band in a primate foveal pit. Upper image is courtesy of D. Max Snodderly, PhD. Lower image is courtesy of Jeanne M. Frederick, PhD.

Lutein, zeaxanthin, and their metabolites collectively constitute the macular pigment which is thought to protect the photoreceptor cells of the macula from light-induced oxidative damage and to promote visual performance through reduction of glare and chromatic aberration.

Age-related macular degeneration (AMD) is the leading cause of irreversible visual loss in the elderly in the developed world. This common disorder that affects millions of people worldwide is a complex disease originating from a variety of risk factors including increasing age, heredity, pigmentation, smoking, light exposure, and diet. AMD has two major forms that cause loss of central vision. The dry form begins with small yellow deposits of oxidized proteins and lipids beneath the retina known as drusen (Figure 5) which over many years can evolve to geographic atrophy (Figure 6), a condition in which many of the cells of the macula die leaving behind a sharply outlined area of nonfunctioning retina. In some cases, early dry AMD with drusen can transform to the wet form in which abnormal blood vessels invade the retina and underlying tissues causing permanent damage to the macula in a matter of weeks (Figure 7).

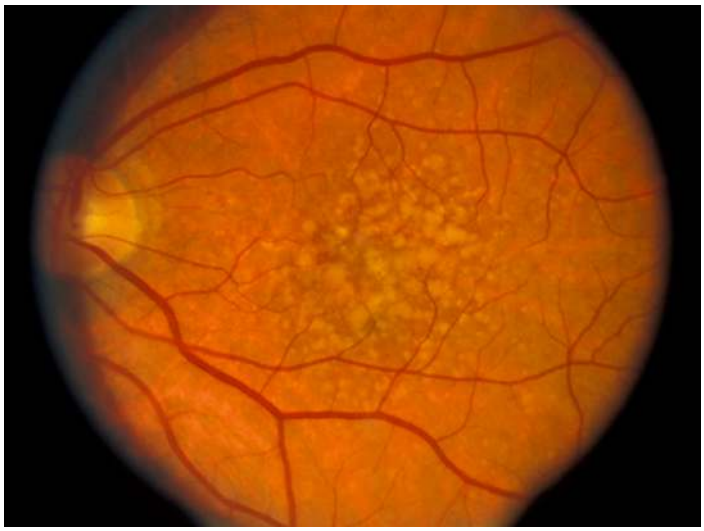

Figure 5:
Intermediate stage dry AMD showing extensive large soft drusen in the macula. Image from the Moran Eye Center photographic archives.

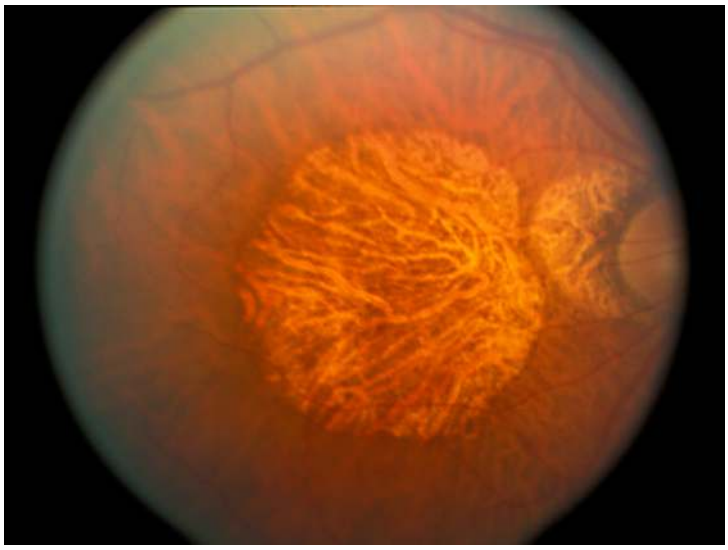

Figure 6:
Advanced stage dry AMD showing geographic atrophy of the macula. Image from the Moran Eye Center photographic archives.

Figure 7:

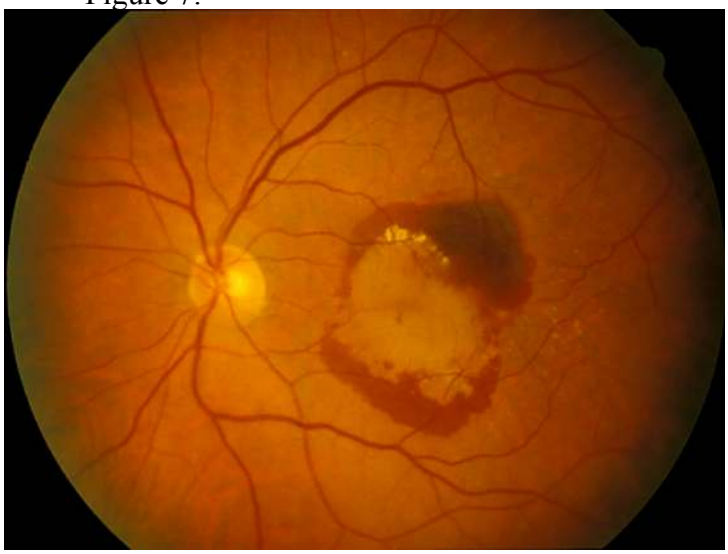

Figure 7:
Advanced stage wet AMD showing a choroidal neovascular membrane surrounded by blood. Image from the Moran Eye Center photographic archives.

In the past decade, treatment of advanced AMD has improved, but it is still of paramount importance to try to prevent or at least delay its onset. Increasing epidemiological evidence indicates that individuals with high dietary intakes of lutein and zeaxanthin have significantly lower risks of visual loss from AMD. These carotenoid-rich diets raise blood levels which in turn raise long-term macular pigment levels in most

individuals. Since dietary habits are difficult to change in the elderly, many eye doctors recommend daily lutein and/or zeaxanthin supplements to their patients at risk for visual loss from AMD. The National Eye Institute is currently evaluating a supplement formulation containing 10 mg of lutein and 2 mg of zeaxanthin in the Age-Related Eye Disease Study 2 (AREDS2), a five-year, randomized, placebo-controlled study involving over 4000 patients with high-risk intermediate AMD (AREDS2: http://www.areds2.org).