Is the High Concentration of Ascorbic Acid in the Eye an Adaptation to Intense Solar Irradiation?

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Ascorbic acid is known to exist in high concentration in the aqueous humor of the eye in many species. It has been observed that diurnal mammals have a very high concentration in aqueous humor whereas nocturnal mammals do not. It has been hypothesized that ascorbic acid protects the eye from the harmful effects of sunlight. We have discovered that of two closely related species of spiny mice, the diurnal species (*Acomys russatus*) has a concentration in aqueous humor that is 35 times higher than that of the nocturnal species (*Acomys cahirinus*). Studies of these two species may be fruitful to extend what is known about adaptation of the eye to protect itself from intense solar radiation. Invest Ophthalmol Vis Sci 30:2265–2267, 1989

Birch and Dann¹ found ascorbic acid in high concentration in tissues other than the adrenal, including the eye. Subsequent workers have shown that ascorbic acid is found in aqueous humor in concentrations 25 times that in plasma in other species, including humans.²–⁷ Linner found that the ciliary body of rabbit cleared its plasma of ascorbic acid and pumped it into the posterior chamber along with newly formed aqueous humor.⁸ This efficient process is carried out by a sodium, ascorbate cotransporter in the ciliary body.⁹

Friedenwald believed that ascorbic acid played an important role in the formation of aqueous humor.¹⁰ Many other functions in the eye have been ascribed to this vitamin, including its role in a redox system,¹¹ in catecholamine synthesis¹² and as an inhibitor of polymorphonuclear leucocyte activity.¹² Ringvold¹³ proposed that ascorbic acid protects the eye from the effects of ultraviolet radiation. Varma¹⁴ reasoned that it protects the crystalline lens from photoperoxidation and helps to prevent cataracts.

Reiss¹⁵ suggested that if ascorbic acid protects the eye from intense solar radiation, it should be observed in higher concentration in species that are

Fig. 1. *Acomys cahirinus.*
chronically exposed to sunlight as compared to species that are not. He analyzed aqueous humor and compared diurnal mammals to nocturnal mammals. Diurnal mammals, such as the human, antelope, tree shrew and rhesus monkey, have aqueous concentrations of ascorbic acid 20 to 40 times higher than plasma. Conversely, nocturnal species such as the slow loris, fruit bats, cats and owl monkeys have a concentration similar to plasma. Reiss's observations support the idea that concentrated ascorbic acid is advantageous to the eye of diurnal mammals, but other explanations are also credible. If two closely related species could be found which forage at opposite phases of the solar cycle, Reiss's hypothesis could be given an additional test. This communication describes a preliminary study of two species of spiny mice (genus *Acomys*) that meet this criterion.

*Acomys cahirinus* lives in the deserts of the Middle East and exhibits nocturnal foraging habits (Fig. 1). The closely related *Acomys russatus* is similarly distributed but sleeps at night and forages in the day (Fig. 2). Visual comparison of the two species permits one to observe a number of adaptations of *A. russatus* to a diurnal existence. This species has smaller, furrier ears, smaller eyes and heavy melanin pigment on exposed skin.

**Materials and Methods.** We acquired a dozen members of both *Acomys cahirinus* and *Acomys russatus* species from Dr. H. Mendelssohn of Tel Aviv University and adapted them for several months to a controlled environment. The mice were kept in a 12/12 hr day/night cycle (light on at 6:00 AM, light off at 6:00 PM). Both species received food containing no ascorbic acid (Lab Chow 5001, Purina Mills, Richmond, IN) and water ad libitum. Samples of aqueous humor were taken from each species and analyzed for ascorbic acid by high pressure liquid chromatography.

The aqueous samples were collected in tiny glass pipets, drawn to a sharp point from 1 mm capillary tubes. After a short induction with ether, intramuscular xylazine (0.5–2.5 mg/kg) and ketamine (10–50 mg/kg) were given. Topical anesthesia with proparacaine was also given. The eye was dried with a cotton-tipped applicator, and the sharp pipet pressed against the cornea and rotated to facilitate penetration of the cornea. The sample would enter the pipet by capillary action augmented by gentle pressure on the globe. Samples of 5–15 μl could be obtained, with

### Table 1. Ascorbic acid content in aqueous humor, mg/dl

<table>
<thead>
<tr>
<th></th>
<th><em>A. cahirinus</em></th>
<th><em>A. russatus</em></th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>Six pooled samples from 12 animals</td>
<td>Three pooled samples from 12 animals</td>
</tr>
<tr>
<td>Mean</td>
<td>0.65 mg/dl</td>
<td>23.1 mg/dl</td>
</tr>
<tr>
<td>SD</td>
<td>0.005 mg/dl</td>
<td>3.4 mg/dl</td>
</tr>
<tr>
<td>Diff.</td>
<td>$P &lt; 0.001$ (student t-test)</td>
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larger samples from A. cahirinus than from A. russels. Because of the small volume of the aqueous humor, samples were pooled as outlined in Table 1.

The samples were frozen and kept at −70°C until analyzed. Analysis was accomplished with an HPLC method of Ellefson and Ford.* Analysis of the unknown samples was performed alongside a series of standards from 0.6 mg/dl to 40 mg/dl. All standards were within 10% of the expected value. The volume of the pooled samples was increased with metaphosphoric acid, 10 μl of sample to 100–200 μl of acid.

The investigations involving animals conformed to the ARVO Resolution on the Use of Animals in Research.

**Results.** The ascorbic acid concentration in the six pooled samples of A. cahirinus was 0.65 ± 0.005 mg/dl (mean ± SD). The ascorbic acid concentration in the three pooled samples of A. russels was 23.1 ± 3.4 mg/dl. As shown in the table the difference between species was significant (P < 0.001).

**Discussion.** The 35-fold difference in ascorbic acid concentration in these two closely related species of spiny mice is consistent with Reiss's hypothesis and the idea that a high concentration of ascorbic acid is an adaptation, similar to pigmentation of the skin, that permits the eye to withstand intense solar radiation. Anyone interested in this adaptation may find these two species of the genus Acomys to be useful models for study.

**Key words:** aqueous humor, ascorbic acid, spiny mice

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*Unpublished method.*

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References