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UV absorption by gerrid cuticles[1]

Abstract—*Halobates* is exposed to continuous insolation at the sea surface throughout its life. Although the UV-absorbance spectrum of its dorsal cuticle (260–450 nm) is similar to those of related species from inshore and freshwater habitats where shelter from sunlight is available, the UV absorbance of the cuticle in a direction perpendicular to its outer surface is much higher in *Halobates* than in a mangrove-dwelling *Rheumatobates* or a stream-dwelling *Gerris*.

The ocean-skater *Halobates*—a genus of wingless insects akin to the more familiar pond-striders—lives on the open sea surface between latitudes 50°N to 40°S, often thousands of kilometers from the nearest shade, and is subjected to continuous insolation every day of its life (Cheng 1973*a*). How does it avoid damaging effects of sunlight, particularly those in the ultraviolet range?

Underlying the long body hairs of *Halobates* is a layer of microtrichia with bent and swollen ends, which probably functions as a plastron (Cheng 1973*b*; Andersen and Polhemus 1976). This undercoating may also serve to scatter much of the incident light, making the insects look silvery in sunlight or by artificial light at night. Light, including UV, which penetrates beyond this barrier and reaches the surface of the insect is then either reflected or absorbed.

In certain insects some of the energy of the incident UV light may be re-emitted as fluorescence; this has not been observed in *Halobates*. Although UV reflectance may contribute to the interference colors of some butterfly wings (Ghiradella et al. 1972; Ghiradella 1974), it has not been considered as a means of avoiding potentially damaging effects of these wavelengths. The biological role in insect cuticles of certain amino acids such as tryptophan and tyrosine, which can absorb light in the UV range, or of melanins, which absorb in the visible range as well, has apparently not been investigated either (Neville 1975).

We report here on the absorbency of *Halobates* cuticle and that of comparable gerrids from brackish and freshwater habitats and discuss the potential role of the cuticle as a biological shield against UV damage. Since light of wavelengths <260 nm is absorbed by even very thin layers (0.1 mm) of colorless chitin (Merker 1929), we concentrated attention on light in the near-ultraviolet and violet-blue ranges. We thank R. E. Reichle for cutting the thin sections of the cuticles; S. Caveney, O. Holm-Hansen, R. A. Lewin, A. C. Neville, and J. E. Tyler for helpful comments and discussions; W. Heiligenberg for help with the translation of Merker's paper; and the Mid-Pacific Marine Laboratory for providing transport, accommodation, and research facilities at Enewetak Atoll.

Specimens of *Halobates sericeus* Eschscholtz were collected from the central north Pacific Ocean gyre (31°N, 155°W) in February 1973. *Rheumatobates aestuarius* Polhemus was collected from mangrove lagoons in the Baja California region (24°N, 110°W) in April 1973, and *Gerris remigis* Say from Sunfish Creek near Waterloo, Ontario (43°N, 80°W), in May 1969. Intensities of solar radiation in these areas at midday during the months when the specimens were collected were roughly comparable.

We cut 1-μm sections of the dorsal thoracic cuticles perpendicular to the outer surface of each of the gerrids and examined them with a Leitz UV microscope, under monochromatic UV light attained by using a linear mirror monochromator and quartz reflection optics. The thin sections were mounted on quartz slides with quartz cover slips and examined with an immersion objective in a glycerine/water mixture (n_D = 1.440). Absorbance at a

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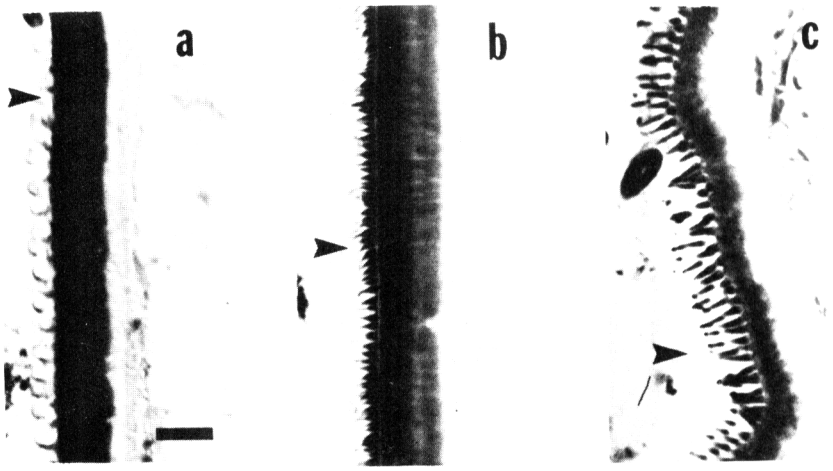

Fig. 1. UV photomicrograph taken at 280 nm of thin sections of dorsal thoracic cuticles of a) *Halobates*, b) *Rheumatobates*, and c) *Gerris*. (All sections orientated in same way; arrow points to outer surface of cuticle; scale bar = 5 μm.)

given wavelength was measured with a photomultiplier tube directly above the objective, the output signal being detected on a Leeds and Northrup DC amplifier. The absorbance, A_s, was calculated as follows:

$$A_s = -\log_{10}\frac{I}{I_0}, \qquad (1)$$

where I and I_0 were the intensities of light of a given wavelength transmitted by the cuticle and by a blank area. The absorbance was measured at selected wavelengths between 260 and 450 nm. Photomicrographs were taken at 280 nm with a Leica MD camera and Kodak high-contrast copy film. Details on the preparation of sample, microscopy, photography, and analyses of photographic negatives were essentially the same as those given by Scott et al. (1969).

Since insects of the same species collected at different localities or at different times of the year were remarkably similar in color patterning, and we did not detect any morphological differences in their cuticles under the light microscope, we considered it sufficient to examine sections of only one or two specimens of each species.

The UV-absorbing layer appears as a dark band in the photomicrographs (Fig. 1). This layer is about 4 μm thick in *Halobates*, about 3 μm thick in *Rheumatobates*, and only about 1 μm thick in *Gerris*. The UV absorption spectra measured through the dark layer of each cuticle are shown in Fig. 2. The absorbance in *Halobates* is much higher than in the two other gerrids. At 280 nm it is about twice that of *Rheumatobates* and five times that of *Gerris* (Table 1). The shape of the spectrum is similar for all three insects, suggesting that the absorbing material is similar in chemical composition but differs only in concentration.

The absorbance, A_c, of the UV-absorbing layer in a direction perpendicular to the outer surface of the cuticle can be calculated from the Beer-Lambert law in the form

$$A_c = A_s \times \frac{\text{thickness of absorbing layer in cuticle}}{\text{thickness of section}}. \qquad (2)$$

The percent transmittance, T_c, of incident light by the cuticle is then given by

$$T_c = \frac{100}{\text{antilog } A_c}. \qquad (3)$$

The values thus obtained for T_c (Table 1) indicate that at a wavelength of 280 nm only 0.0002% of the radiation is transmit-

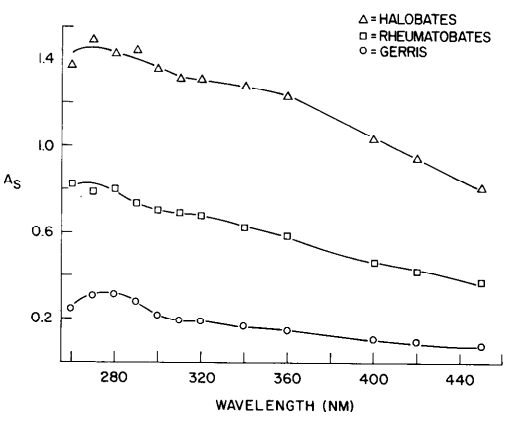

Fig. 2. Absorption spectra of dark layers of dorsal thoracic cuticles.

ted through the cuticle of *Halobates*. The cuticle of *Rheumatobates* will let through 0.4%, while the *Gerris* cuticle will absorb only half of the radiation. These differences correlate well with the different habitats of the three insects. In their natural environments neither *Gerris* nor *Rheumatobates* normally strays far from the shade of mangrove plants or other riverbank vegetation, and they normally do not venture out in the open during noon hours. *Halobates*, however, has nowhere to hide.

We made a comparative study of UV tolerance of *Halobates* collected at Eneweta k Atoll in September 1975 and laboratory-reared flightless *Drosophila*. A UV "sterilamp" was placed about 10 cm above the insects; for controls insects were shielded under aluminum foil. The *Drosophila* died within 30 min, but under similar UV irradiation *Halobates* remained active for at least 24 h (when the experiments were terminated). The UV tolerance of *Halobates*, attributable to the demonstrated high absorption of UV light by the cuticle, is probably an important adaptation for its life at the sea surface.

Table 1. Absorbance of cuticles at 280 nm.

Cuticle	A_s	Thickness of absorbing layer (μm)	A_c	T_c (%)
Halobates	1.4	4	5.6	0.0002
Rheumatobates	0.8	3	2.4	0.4
Gerris	0.3	1	0.3	50

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