VI is important for the increase in binding affinity to 11-cis-retinal. The high affinity for antagonist 11-cis-retinal would be preferable in order for rhodopsin to act as a photoreceptive protein, because it reduces the possible binding of the agonist all-trans-retinal and reduces spontaneous activation in the dark. This characteristic is emphasized in vertebrate rhodopsin, which has no affinity to agonist all-trans-retinal, resulting in complete reduction of dark noise.

NOVEL MULTIPLE OPSIN GENES FROM BRANCHIOPOD CRUSTACEANS

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Visual pigments are typical photoreceptive molecules in animals, consisting of opsin proteins and chromophores. The spectral property of these molecules is mostly attributed to the primary structure of the opsin proteins. Multiple opsin genes belonging to the different spectral classes have been obtained from many insects, e.g., six genes from *Drosophila melanogaster* in four classes. In crustaceans also, microspectrophotometric and electrophysiological studies have revealed the presence of multiple photoreceptors with different spectral sensitivities in stomatopod and decapod species. Nevertheless only a few opsin genes are obtained until now, e.g., one gene from *Procambarus clarkii* and two from *Hemigrapsus sanguineus*, and these genes would belong to only two spectral classes. To verify genes in multiple spectral classes in crustaceans, RT-PCR and RACE methodologies were carried out in branchiopod crustaceans, *Triops granarius*, *T. longicaudatus* (Notostaca) and *Branchinella kugenumaensis* (Anostraca), and seven types of opsins that would belong to three spectral classes were successfully obtained from each species, containing types different from known ones in crustaceans.

THE ULTRA-VIOLET RECEPTOR IN THE COMPOUND EYE OF FIREFLY, *LUCIOLA CRUCIATA*

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The communication in firefly involves two individuals: females are usually sender and males are both sender and receiver. Female sit on the leaves and males fly to search a female using their flashing pattern. *L.cruciata* emits light in flashes with species-specific temporal patterns to attract mates. Female and male fireflies both had the bioluminescent organs which produce the emitting light peaking around 570 nm. The spectral sensitivity measured by ERG method revealed the peak sensitivity at 570 nm corresponding with the emitting light. In addition with the green light sensitivity, the ultraviolet reception was observed. When the compound eyes were adapted by 380 nm or 600 nm lights, the sensitivities of UV region or green region were diminished, respectively. Those results indicate *L.cruciata* have the UV-photoreceptor cells in addition to the green-photoreceptor cells. In our previous report, the visual pigments of the firefly, *L.cruciata* possess two types of chromophores: retinal and 3-hydroxyretinal. When those visual pigments were adapted by UV or red lights, retinal was affected by the UV light. We will discuss the role of those two photoreceptors.

THE ORIGIN OF THE COLOR OF THE LEAF BEETLE, THE JEWEL BEETLE, AND THE DAMSELFLY AND THEIR INTRASPECIFIC COMMUNICATION

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Insects commonly have cuticles with a blackish color due to high concentrations of melanin or similar pigments, which make them inconspicuous. However, many insect species instead emphasize their appearance, by featuring a brightly colored and/or very shiny cuticle. Extreme examples can be found among some species. In this case biological success is apparently realized by an explicit display, so to signal the presence to a possible sexual partner. The leaf beetle, *Plateumaris sericea*, exhibits strong color polymorphism. The dorsal surface of *P. sericea* has a peak reflectance that varies from ca 450 nm to 750 nm. This extreme variation in peak wavelength directly explained from the differences in the nanostructured multilayers in the cuticle. Another brilliant beetle, the jewel beetle, *Chrysochroa fulguidissima*, has green elytra with dark red-purplish stripes. A third case is the male damselfly, *Calopteryx japonica*, where multilayers in the wing veins act as bluish-green reflectors. The iridescence of those species is also in each case biologically important, because it functions as a discriminatory signal in the intraspecific communication.

STRUCTURE OF THE COMPOUND EYE VISUAL SYSTEM OF THE HUMMINGBIRD HAWKE MOTH, *MACROGLOSSUM PYRRHOSTICATA*

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The insect compound eye is one of the most extensively studied visual systems. They are classed into apposition eyes and superposition eyes. A large part of our knowledge about the insect visual system has come from many neuroanatomical studies on the apposition eyes, whereas our knowledge on the structure of the superposition eye is limited. Although the structure of the eye was reported for several species in nocturnal moths, large variations occurred for their retinal organizations among them. In the present study the visual system of the hummingbird hawkmoth *Macroglossum pyrrhosticta* has been examined in order to increase our knowledge for the structure of the superposition eye. The compound eye consisted of about 8,000 ommatidia. Each ommatidium contained nine retinular cells in a large area of the eye, but that contained eight retinular cells in the dorsal margin of the eye. Retinal organization also differed between the two areas. Observed structures are discussed in relation with the visual behavior of this insect.

STRUCTURE OF THE OPTIC LOBE IN THE LARVA OF THE TIGER BEETLE

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The visual system of the tiger beetle larva shows some characteristic profiles. First, it distinctly controls predatory and escape behaviors. Second, the optic lobe occurs beneath the eyes in the tiger beetle larva, whereas it usually occurs in the protocerebrum in other larval insects. Third, distance sensitive neurons have been already physiologically identified in the optic lobe. A survey of these preceding works suggests that the visual system of this larva must be a rewardful system for neurophysiological approaches on such specific visual functions. Morphological data are also required for such approaches, but there have been a few reports on the structure of the visual system of the tiger beetle larva. The optic lobe consists of lamina and medulla neuropils. Some neural elements were identified in the lamina neuropil. However, our knowledge for a whole feature of the optic neuropils, especially for the medulla neuropil, is still limited. In the present study neural elements have been identified in the optic lobe of the tiger beetle larva. Obtained data are discussed in reference to the specific visual function of this larva.

A PRELIMINARY EXPERIMENT OF COLOR VISION UNDER DIM ILLUMINATION IN THE ORB-WEAVING SPIDERS, *ARGIOPE AMOENA* AND *A. BRUENNICHII*

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The AM eye of the orb-weaving spiders, *Argiope amoena* and *A. bruennichii*, has three types of receptor cells, UV-sensitive cells with maximum sensitivities at about 360 nm, blue-sensitive cells at 480-500 nm, and green-sensitive cells at 540 nm, and the AM eye shows a circadian oscillation of spectral sensitivity (Yamashita and Tateda, 1978). *Argiope amoena* and *A. bruennichii* appear to be active both during the day and night (noct/diurnal spiders); they stay in the hubs of their webs and attack prey animals throughout the day. In the present study, color discrimination of *Argiope* under dim illumination was examined by heat-avoidance learning in association with colored papers. I observed that *Argiope* could discriminate colored papers under dim illumination. It was suggested that *Argiope* may have color vision at night levels of illumination.

CALMODULIN IS REQUIRED TO OPEN cGMP-GATED CHANNEL IN THE SUGAR RECEPTOR CELL IN BLOWFLY, *PHORMIA REGINA*

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We isolated labellar chemosensilla from blowfly, *Phormia regina*, and purified calcium binding proteins from the water soluble fraction. The most abundant calcium-binding protein was calmodulin. To investigate the role of calmodulin in taste transduction, electrophysiological responses were recorded with the calmodulin inhibitor, W-7. When we stimulated the labellar chemosensillum with sucrose plus W-7, an initial short-term impulse generation from the sugar receptor cell was observed but it was followed by a silent period. When the sensillum was stimulated with W-7 plus a membrane permeable cGMP analog, dibtyryl-cGMP or 8-Bromo-cGMP, impulses of the sugar receptor cell were induced but the frequency was decreased. By the sidewall-recording method, we observed that the receptor potential induced by sucrose stimulation was decreased by W-7 in the sugar receptor cell, and corresponded with a disappearance of impulses. These data strongly suggest that the cGMP-gated channel generating receptor potential in the sugar receptor cell requires calmodulin for its gating.

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EXPRESSION OF G-PROTEIN AND NITRIC OXIDE SYNTHASE IN THE LABELLAR CHEMOSENSORY NEURONS OF BLOWFLY

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To investigate molecules involved in signal transduction pathways in chemosensory neurons of the taste organ of blowfly, *Phormia regina*, we performed western-blot and immunocytochemical analyses of the labellum of blowfly, by using antibodies against G protein α-subunits (G αs, G αi, G αo and G αq). In the western blot analysis of the