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Contributions of pterin and carotenoid pigments to dewlap coloration in two anole species

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Abstract

Animals can acquire bright coloration using a variety of pigmentary and microstructural mechanisms. Reptiles and amphibians are known to use two types of pigments—pterins and carotenoids—to generate their spectrum of colorful red, orange, and yellow hues. Because both pigment classes can confer all of these hues, the relative importance of pterins versus carotenoids in creating these different colors is not always apparent. We studied the carotenoid and pterin content of red and yellow dewlap regions in two neotropical anole species—the brown anole (*Norops sagrei*) and the ground anole (*N. humilis*). Pterins (likely drosopterins) and carotenoids (likely xanthophylls) were present in all tissues from all individuals. Pterins were more enriched in the lateral (red) region, and carotenoids more enriched in the midline (yellow) region in *N. humilis*, but pterins and carotenoids were found in similar concentrations among lateral and midline regions in *N. sagrei*. These patterns indicate that both carotenoid and pterin pigments are responsible for producing color in the dichromatic dewlaps of these two species, and that in these two species the two pigments interact differently to produce the observed colors.

Keywords: Anole; Carotenoids; Dewlaps; Lizards; *Norops*; Pigments; Pterins

1. Introduction

A conspicuously colored integument is common among reptiles (Bagnara and Hadley, 1973). Especially in lizards, colors are used as sexual or social signals and may honestly reveal aspects of an individual's quality as a rival or mate (e.g. Cooper and Greenberg, 1992; Kwiatkowski and Sullivan, 2002; Stuart-Fox et al., 2003). Work on other animals, such as birds (reviewed in Hill and McGraw, 2006), has shown that, to better understand how and why these colors have evolved as signals, it is important to determine their molecular basis. This is because different types of color-producing mechanisms (e.g. pigments, microstructures) involve different physiological challenges (McGraw, 2005).

Among the more elaborate color traits in reptiles that carry potential information as social signals are the dewlaps of male lizards. These dewlaps are most commonly red, orange, or yellow in color and have been previously shown to be derived from two types of pigments: pterins (Ortiz et al., 1962) and carotenoids (Macedonia et al., 2000). Pterin pigments are nitrogen-rich, UV-fluorescent compounds that animals synthesize from basic purine (e.g. guanine) precursors (McGraw, 2006). In contrast, carotenoids are lipid-soluble accessory photosynthetic pigments in plants that animals must acquire from the diet (Goodwin, 1984). In fact, both types of pigments can generate this range of red–yellow hues in dewlaps, so one cannot determine which pigment types are responsible for color without biochemical tests.

Prior studies of *Anolis* spp. have shown that yellow-colored dewlaps contained only carotenoids, but that species with orange or red throat colors used pterins (three drosopterins known as drosopterin, isodrosopterin, and neodrosopterin) in their throat fans (Ortiz, 1962; Ortiz et al., 1962; Ortiz and Williams-Ashman, 1963; Ortiz and Maldonado, 1966; Macedonia et al., 2000). However, little work has been done on pigment profiles within individual species when multiple color types are displayed in a dewlap. Many male lizards will combine patches

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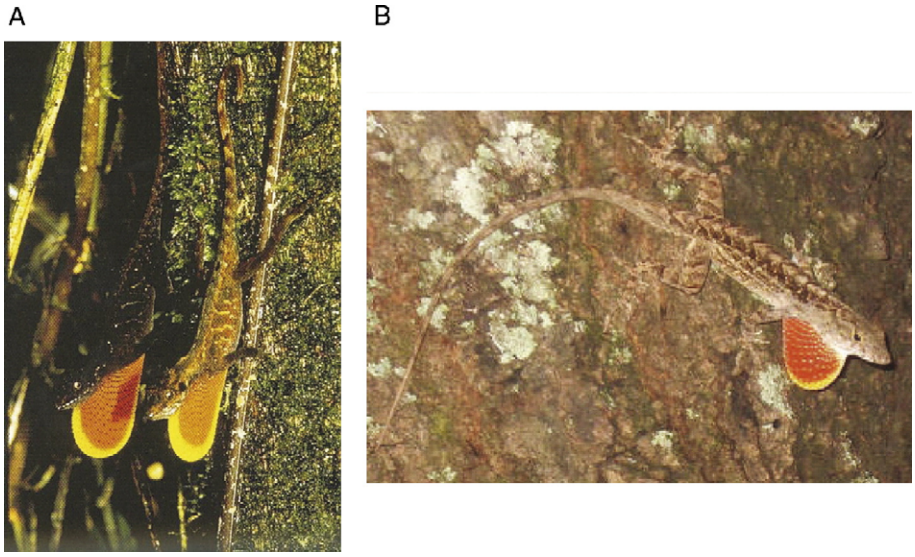

Fig. 1. A. Left: Two male Costa Rican Ground Anoles, *N. humilis*. These lizards display in light gaps of lowland tropical forests of Central America. Copyright Christian d'Orgeix, 2005. Used by permission. B. Right: Male Florida Brown Anole, *N. sagrei*. This lizard displays in full shade of disturbed environments and hardwood-hammock forests throughout Florida and Cuba. Copyright Ann Paterson, 2005. Used by permission.

or borders of yellow with red in their dewlap, and in these cases it is possible that animals use different colored pigments from the same class (pterin or carotenoid) to create the different colors, or that, as has been shown interspecifically, the different colors are in fact due to the different pigment classes.

To investigate how color is produced in different regions of the dewlap, we analyzed and compared concentrations of carotenoids and pterins between central and outer regions in two species of anoles that generally have red (in the lateral regions) and yellow (in the mid-line region) colors (see Fig. 1A and B). *Norops sagrei*, the brown anole, is an invasive species historically found in Cuba, but now found commonly throughout Florida. It is a denizen of disturbed habitats, as well as hardwood-hammock forests throughout much of the state. *N. sagrei* displays in partial shade of an elevated perch, or in forest gaps surrounded by areas of 'long wavelength' light. In contrast, *Norops humilis*, the ground anole, is a common native of lowland rainforests throughout Costa Rica and Panama. It is a cryptic dweller of primary and secondary forests, but readily exhibits courtship and territorial displays from the deeply shaded forest floor (Guyer and Donnelly, 2005).

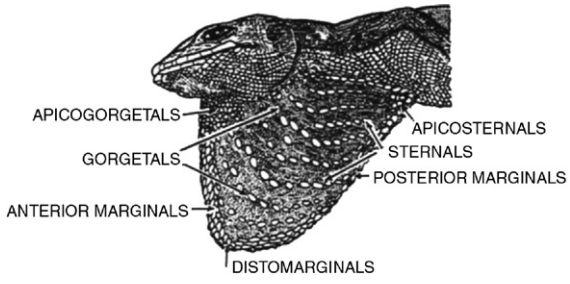

Fig. 2. Adult male *Norops* with dewlap spread, showing location of dewlap scales with terminology proposed by Fitch and Hillis, 1984. We use lateral region to refer to area including gorgetal scales, and midline region to refer to the marginal (anterior, disto-, and posterior) region. See text for rationale.

2. Materials and methods

Lizards used in this study were obtained in two different ways. Male brown anoles (*N. sagrei*) were purchased from a pet store (Glades Herp, Bushnell, FL,USA), where employees capture the lizards locally. They were shipped to one of us (JES) and sacrificed two days later. Male ground anoles (*N. humilis*) were collected at La Selva Biological Station in Costa Rica, transported live to the United States (exportation permit # 003-2005-OFAU), and sacrificed the following day.

Dewlap tissue was removed from lizards as described by Macedonia et al. (2000). Five adult males of each species were fully anaesthetized with chloroform. When animals were completely unconscious, and respiration rates slowed, the spinal cord of each lizard was cut at the base of the neck with surgical scissors. The dewlap skin was excised from the body, and the hyoid cartilage underlying the skin was removed with forceps.

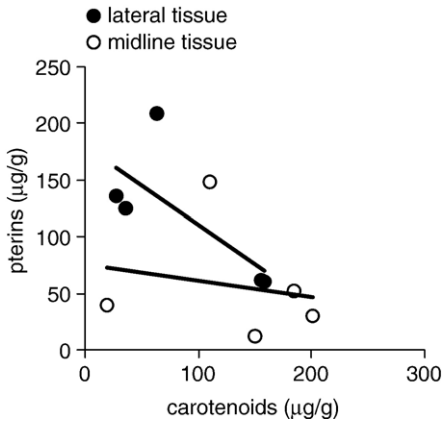

Fig. 3. Regression of pterin concentrations vs. carotenoid concentrations (both expressed in units of micrograms per gram of tissue) in dewlaps of 5 *N. sagrei*. Lateral tissue, $r^2=0.536$, $df=1$, $P=0.16$. Midline tissue $r^2=0.030$, $df=4$, $P=0.78$.