

Structural Colors in Spiders

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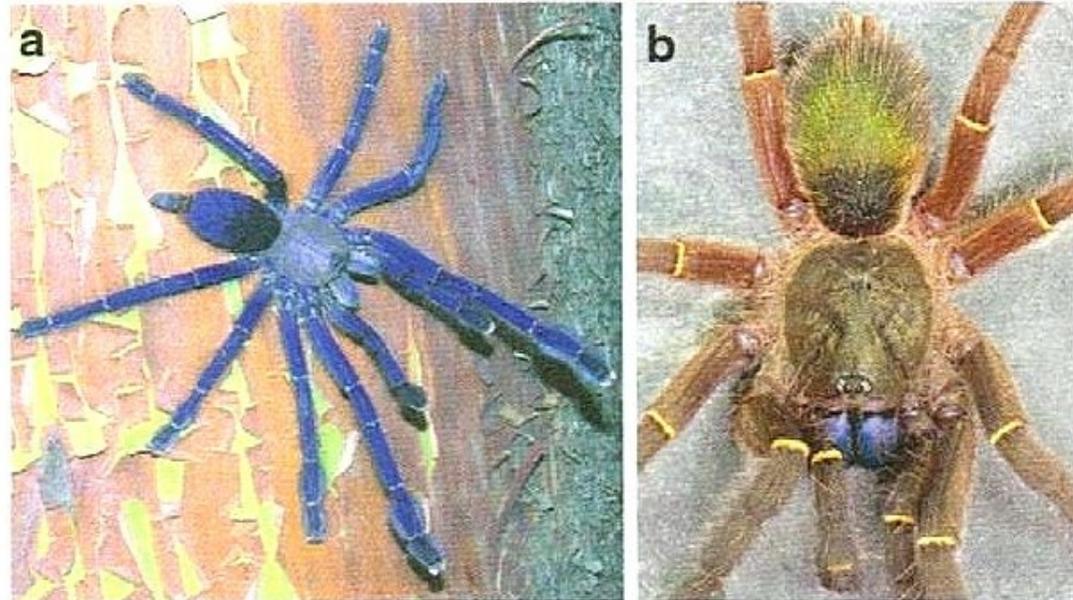
池田博明

24.1. Introduction

- 300年も前にニュートンは色素によるものでない、構造色を知っていた。光学密度の違いによる薄い板の積み重ねが引き起こす色である。
- 著名な構造色は虹色 (iridescence) である。鳥の羽根や昆虫の翅、貝の殻、花弁、鉱物、油球、シャボン玉の例がある。
- クモの研究例は少ない (Foelix et al.2009; Ingram et al.2009, 2011; Parker and Hegedus 2003)。タランチュラとハエトリの二科の構造色に焦点を当ててみる。

24.2. Structural Colors in Hairs of Theraphosid Spiders

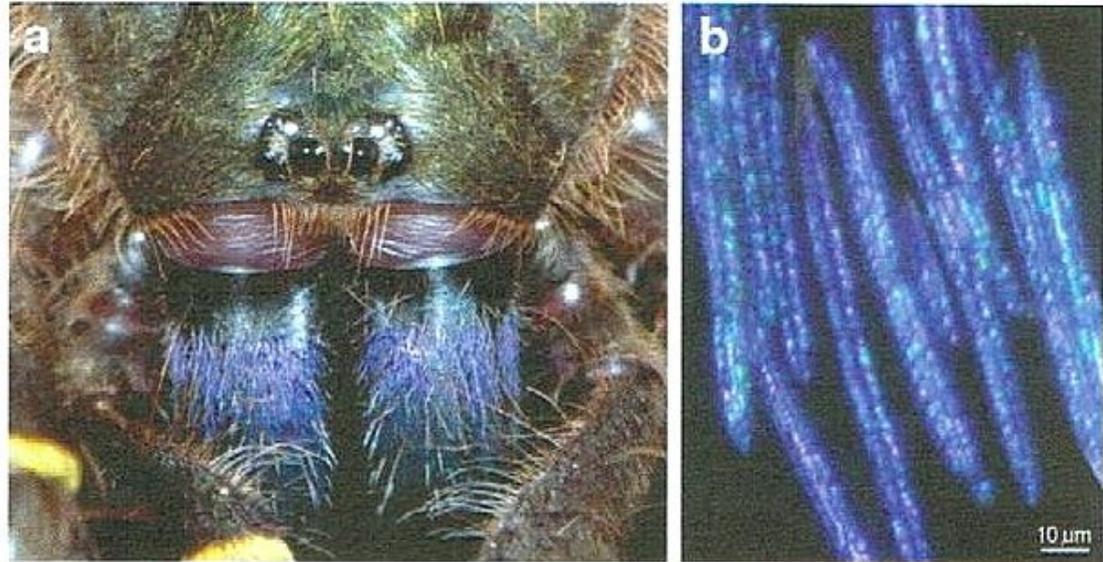
Fig. 24.1 Colorful theraphosids. (a) A deep-blue *Cyriopagopus* resting on a tree trunk (Photo: Rick West). (b) A juvenile *Epebopus cyanognathus* with the typical blue chelicerae, a green-golden opisthosoma, and yellow fringes on the distal femora (Photo: Bastian Rast)



タランチュラの飼育者はその輝かしい色に注目していた。
そのうちの2種がよく研究されている。

24.2.1. *Ephebopus cyanognathus*

Fig. 24.2 Blue hairs on the chelicerae of *E. cyanognathus*. (a) The blue color resides entirely in the hairs, not in the cuticle. (b) Epi-illumination with a weak LED light source yields deep-blue and purple color hues (from Foelix et al. 2009)



[Blue fang tarantula] in Brazil, Guyana and Suriname
弱いLED光を当てると表面の光沢が深青色と紫色を帯びる

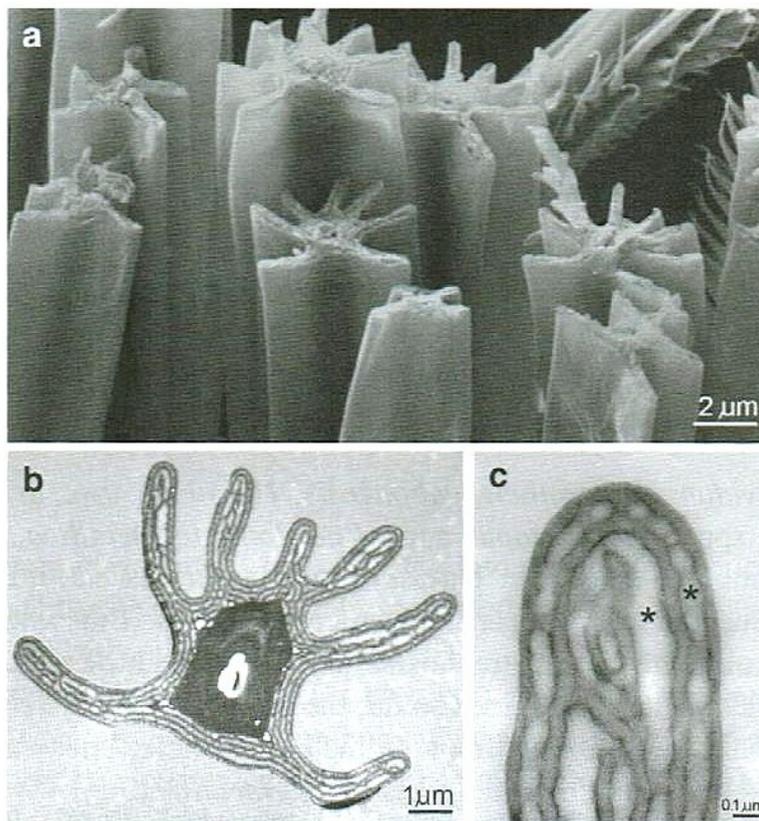


Fig. 24.3 Fine structure of the blue cheliceral hairs in *E. cyanognathus* (Theraphosidae). (a) Hair shafts, clipped with a razor blade, exhibit a typical cogwheel shape in cross section. The lamellar structure of the hair wall is barely visible in this scanning electron micrograph. (b) Cross section of a blue hair as seen in a thin section in the transmission electron microscope. Only the center of the hair shaft consists of solid cuticle, whereas the lateral fins are distinctly layered. (c) High magnification of a lateral fin showing several cuticular lamellae of 50–70-nm thickness, alternating with equally narrow air spaces (*asterisk*) (from Foelix et al. 2009)

青色毛のSEM画像

その毛の断面

クチクラの層状構造(その反射光特性は次のグラフで示す)

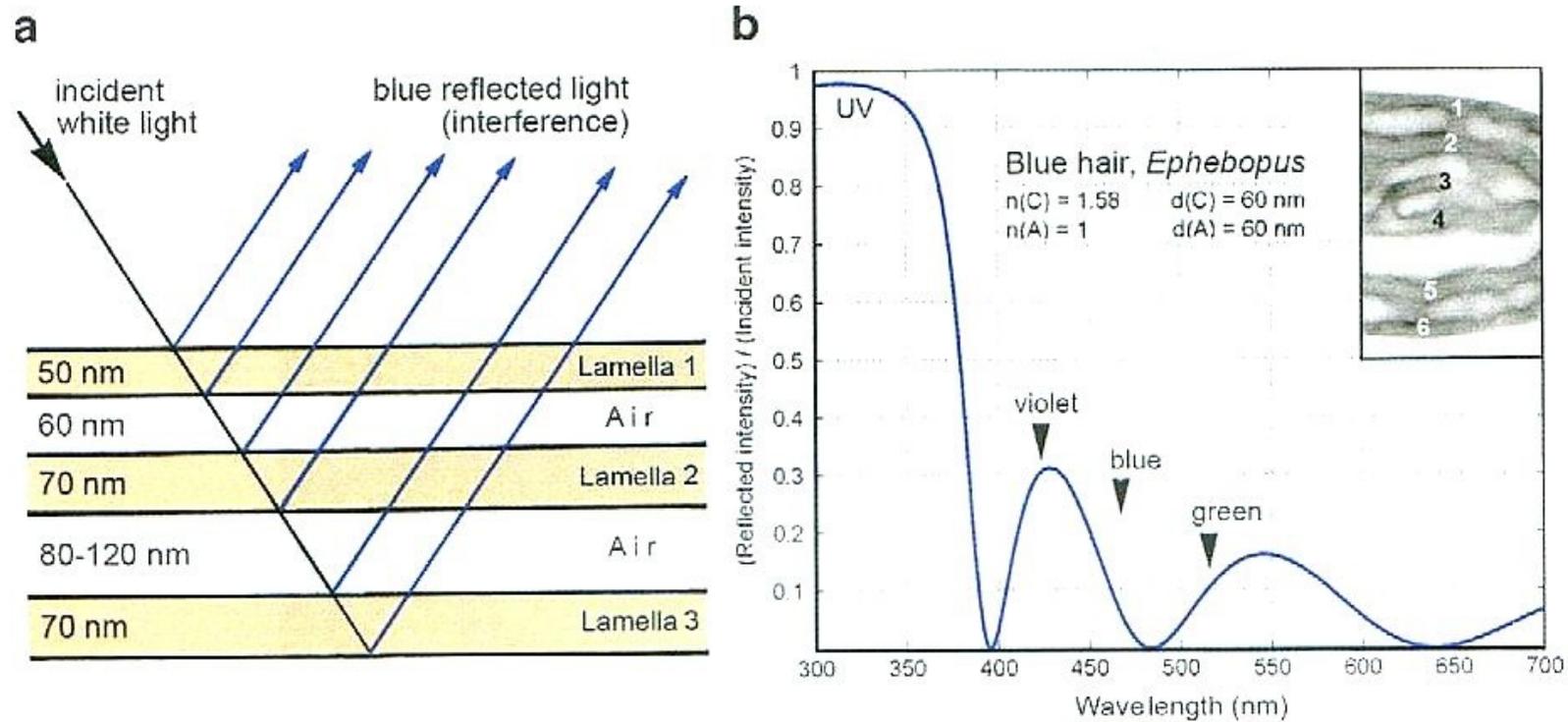


Fig. 24.4 Blue iridescent colors in theraphosid hairs. **(a)** Diagram showing the reflection of incoming *white light* at the border lines of cuticular lamellae and air spaces. Measurements were taken from cheliceral hairs in *E. cyanognathus* (Fig.24.3c). **(b)** Theoretical spectral reflectance of six cuticular lamellae of high refractive index $n(C) = 1.58$ separated by five gaps of low refractive index $n(A) = 1$, based on measurements taken from the *inset* picture. Note that the largest peaks lie in the UV, *violet* and *blue* part of the spectrum, and a smaller one in the *green* (courtesy of Rolf Thieleczek)

24.2.2. Poecilotheria metallica

- Gooty Sapphire Ornamental Tree Spider
- 「Gooty Sapphire」 from India
- 全脚・触肢・上顎に「青色」(虹色)と「黄色」(色合いを変える)の毛をもつ
- 24.2.2.1. Blue Hairs
- 24.2.2.2. Yellow Hairs

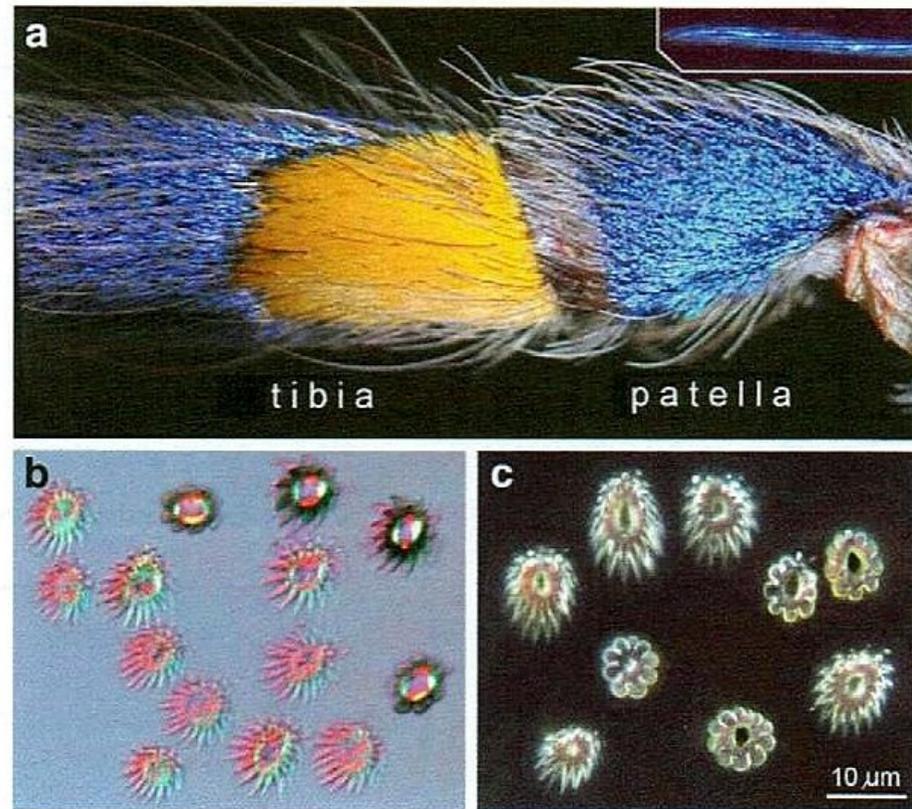
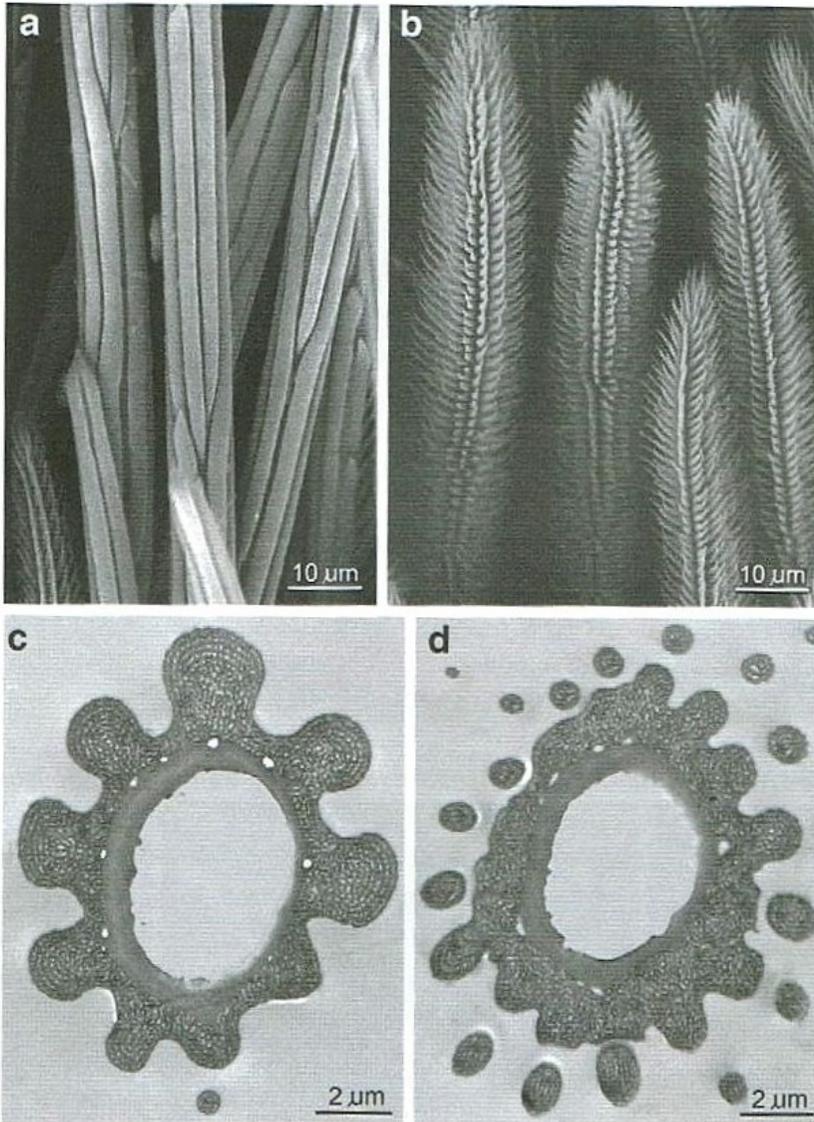


Fig. 24.5 Blue and yellow hairs of the theraphosid *P. metallica*. (a) Note the difference of the blue color hues on tibia and patella, depending on the angle of the reflected light. *Inset*: higher magnification of a blue hair showing longitudinal ridges along the hair shaft. (b) Cross sections of ten spiny (yellow) hairs, which appear pinkish under polarized light; four darker (blue) hairs are seen in the upper right. (c) Cross sections of nine blue hairs under dark-field illumination. The hair shafts bear spines toward the hair base, but are smooth with longitudinal ridges in the distal part



(a)(c) Blue Hairs

(b)(d) Yellow Hairs

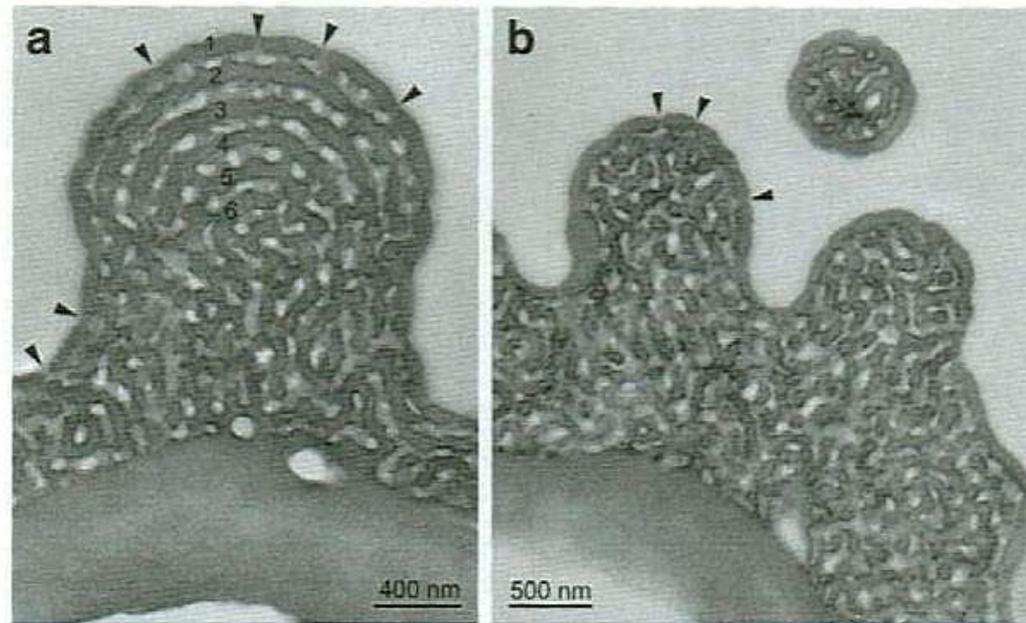


Fig. 24.7 Cross sections of a blue hair (a) and a yellow hair (b) in *P. metallica* (Theraphosidae) at high magnification. (a) Only the innermost part of the hair shaft is solid; the outer cuticle consists of six regular lamellae (1–6), alternating with light air spaces. They connect through pores (arrowheads) to the outside. (b) An irregular cuticular meshwork occupies the peripheral part of yellow hair shafts. Note the pores (arrowheads) on the surface

24.3 Structural Colors in Scales of Jumping Spiders (Salticidae)

- Scales are defined as **flattened hairs** (setae) that have a **pedicel** bent near the socket, so that **scale** lies close and parallel to the surface cuticle (Hill 1979; Townsend and Felgenhauer 1998). Although **the size and shape of scales vary** a great deal among the 5,000 species of salticids, they may be roughly grouped into three types: **lanceolate, spatulate and lamelliform** (Roth 1993)

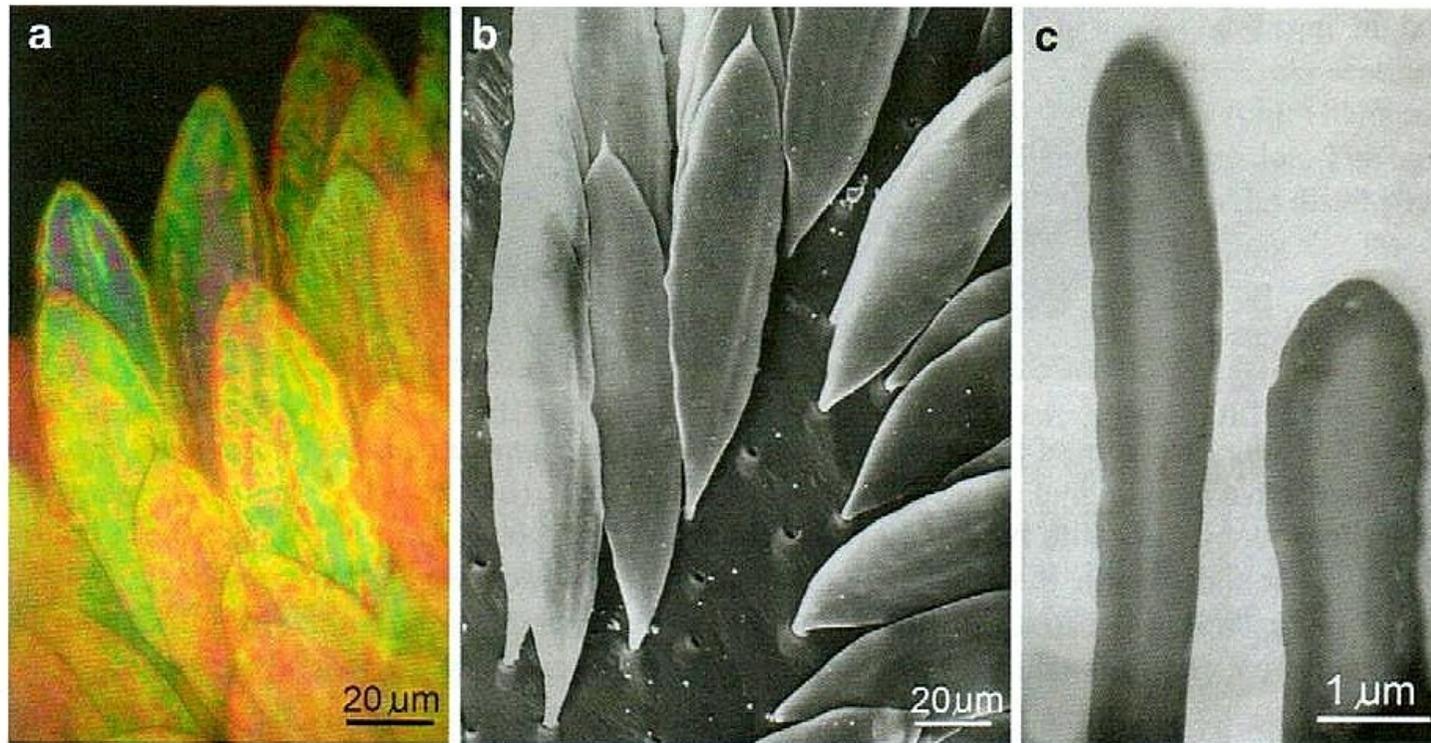
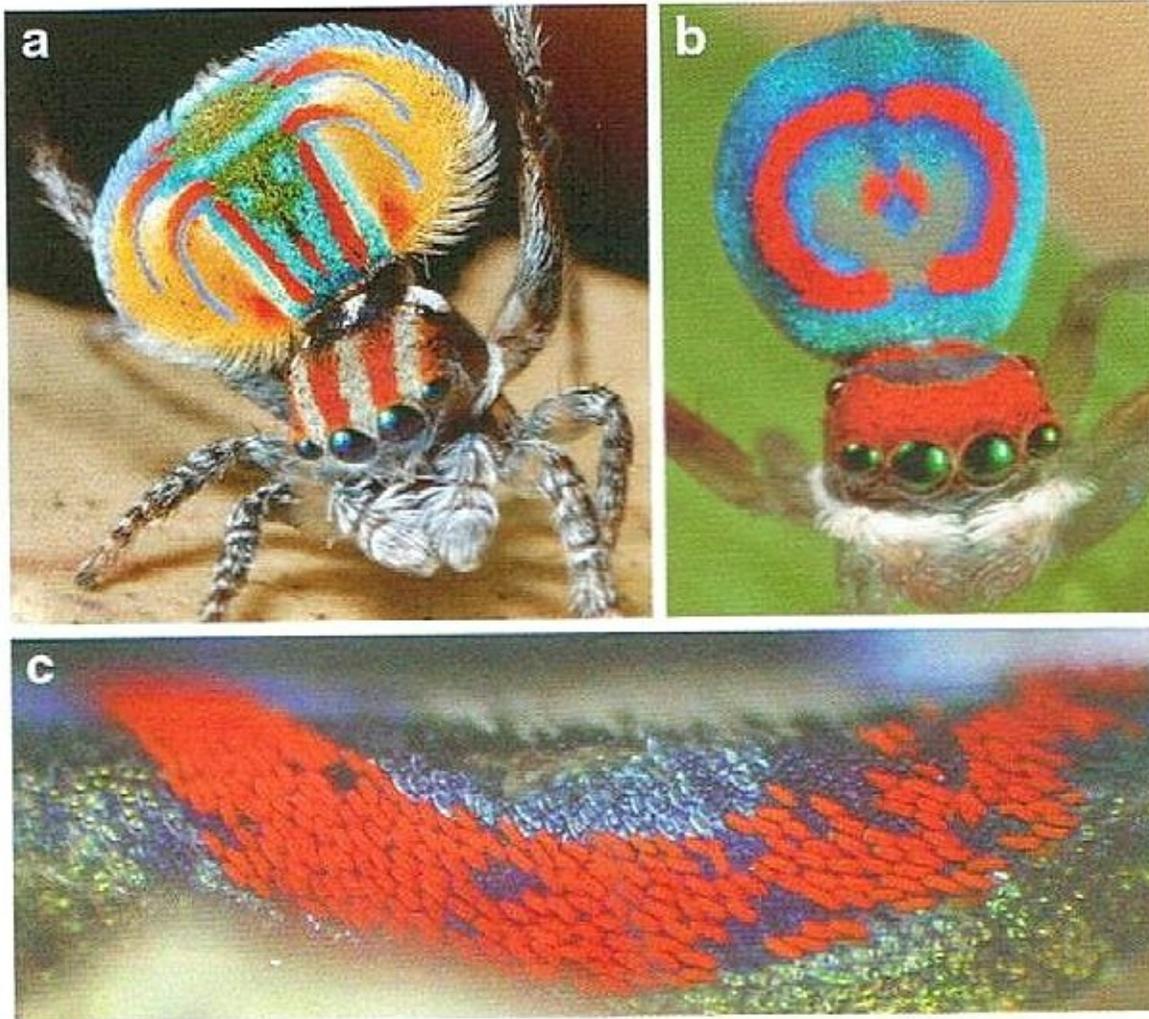


Fig. 24.8 Golden iridescent scales in the salticid *Habronattus hallani*. (a) The femora are densely covered by overlapping, golden scales (Photo: Lisa Taylor). (b) These scales appear very smooth, with hardly any surface structure. (c) This is confirmed in thin sections; the wall thickness of a scale is only 0.2–0.3 μm



(a) *Maratus volans* (b) *Maratus splendidus*
(c) Detail from the lateral opisthosoma of *M. splendidus* showing a band of red brush hairs, flanked on both sides by blue or green scales.

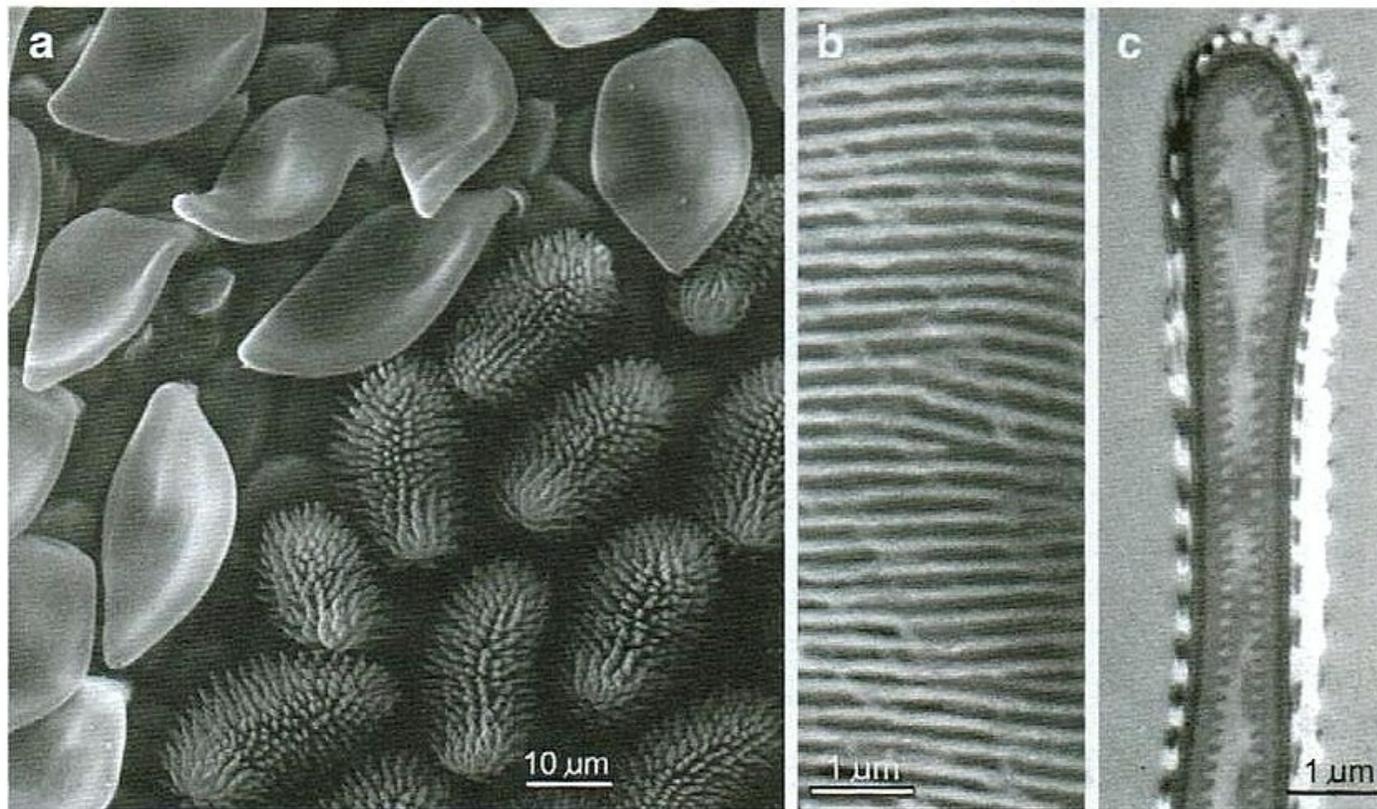
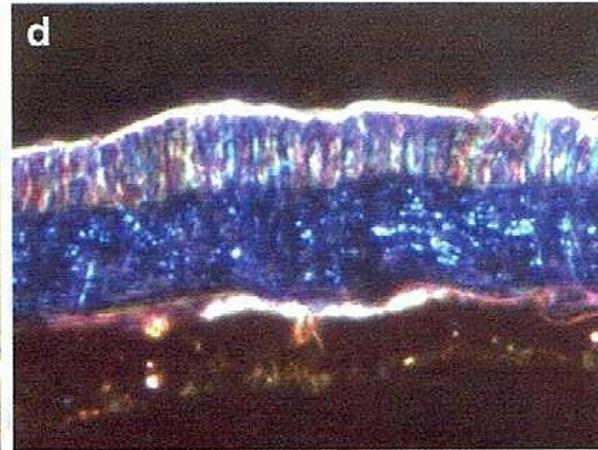
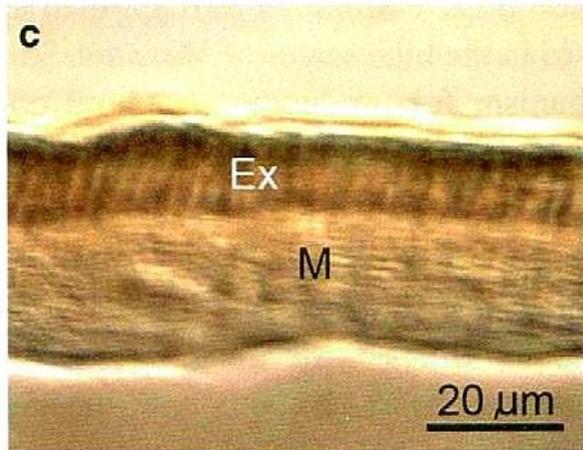
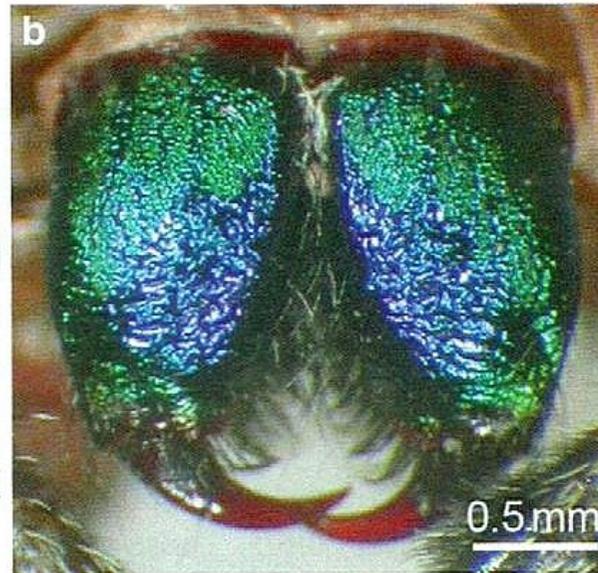


Fig. 24.10 Fine structure of blue scales on the opisthosoma of *M. splendens* (Salticidae). (a) Leaflike (blue) scales are seen on the upper left and (red) hairs on the lower right. (b) High magnification of a blue scale showing fine ridges on the surface. (c) Thin sections reveal a narrow scale wall with surface ridges and a cuticular meshwork inside (*M. volans*)

24.4 Iridescence in the Integument

- 上顎に派手な色彩をもつハエトリが多いが、この構造色は毛によるものというよりはクチクラの表面構造によるものである。
- *Phidippus regius* の深緑色の上顎(a)やその幼体の上顎の色(緑色から青色や紫色に変化する)(b), 外皮表面が二層構造になっている(c)無染色, (d)メチレンブルー染色。



24.5 Structural and Functional Considerations

- 24.5.1 Structural Variation
- タランチュラでは特殊化したhairが構造色をもたらしていた。これらのhairは内部にナノメーターレベルの層状構造を持っていた。フツウクモ類ではhairではなく、scaleの型が構造色をもたらしていた。表面での回折もあった。表面回折はパーカーの光スイッチ説によるとカンブリア紀から既にあったそうだが、クモでは研究されていない。

24.5.2 Behavioral Significance

- クモの構造色の行動的な意義はなんだろうか
- 昼行性のハエトリに見られることから，オス間威嚇誇示行動での役割が考えられる。体色の重要性は証拠もある。
- 幼体と成体で面と向かった餌やヒトに顎等をチラつかす行動は，オス間誇示でも見られた
- 解釈が困難なのはタランチュラは夜行性だということである。



Fig. 24.12 Three sequential images of a subadult female *Phidippus pulcherrimus* (Salticidae), flashing its iridescent blue-green chelicerae at the photographer at a rate of 2–4/s. This palp flicking also occurs when stalking certain kinds of prey

24.6 Conclusions