from **nanostructure** to **macroevolution**

*Rafael Maia*

*Columbia University*
diversity across the tree of life
why are some groups more diverse than others?
adaptive radiations
adaptive radiations

- medium tree finch (Camarhynchus pauper)
- small tree finch (Camarhynchus parvulus)
- vegetarian finch (Camarhynchus crassirostris)
- large cactus finch (Geospiza conirostris)
- cactus finch (Geospiza scandens)
- sharp-beaked ground finch (Geospiza difficilis)
- large ground finch (Geospiza magnirostris)
- medium ground finch (Geospiza fortis)
- large tree finch (Camarhynchus psittacula)
- mangrove finch (Camarhynchus heliobates)
- woodpecker finch (Camarhynchus pallidus)
- warbler finch (Certhidea olivacea)
- Cocos Island finch (Pinaroloxias inornata)
- small ground finch (Geospiza fuliginosa)
adaptive radiations: ecological opportunity
adaptive radiations: key innovations

Pharyngeal jaw
not a product of stronger selection but of greater opportunity
Evolution:

Sex & Death
sexual selection & diversification
Can we think about ornamental traits and diversification in the same way?
COLORS
COLORS

are **not created equal**
pigment-based colors

pigment-based colors
pigment-based colors
pigment-based colors

pheomelanin

eumelanin

[Image of birds with annotations showing pheomelanin and eumelanin]
reconstructing dino color

Anchiornis huxleyi
reconstructing dino color

Anchiornis huxleyi
pigment-based colors
pigment-based colors
structural colors
structural colors
structural colors
iridescence in feathers

Figure 4-1
*Ornithology, Third Edition*
© 2007 W. H. Freeman and Company
iridescence in feathers

Figure 4-1
Ornithology, Third Edition
© 2007 W.H. Freeman and Company
Iridescence in feathers

Melanin-containing organelle (melanosome)
form & function: structure determines color
form & function: structure determines color
form & function: structure determines color
form & function: structure determines color
form & function: structure determines color
A new kind of laser captures light just like some colorful bird feathers. The device mimics the nanoscale structure of colorful feathers to make high-intensity laser light with almost any color.
form & function: structure determines color
form & function: structure determines color
form & function: structure determines color
form & function: structure determines color
structural colors
variation through shared mechanisms
How do color-producing mechanisms influence color diversification?
an integrative approach to the study of avian coloration
an integrative approach to the study of avian coloration

Development
an integrative approach to the study of avian coloration

Development

Function
an integrative approach to the study of avian coloration

Development

Function

Evolution
How do color-producing structures become organized?
feather development

Earliest

Later

Barb Ridges

Rachis

Follicle Collar

keratinocyte (barbule)

melanocyte
Blue-black grassquit (*Volatinia jacarina*)
melanin deposition and organization are decoupled
organization likely not cell-mediated
likely related to the amount of melanin and speed of keratinization
organization through self-assembly
organization through self-assembly

DROP DRYING FOOTAGE AT 25X SPEED

University of Pennsylvania, Department of Physics and Astronomy
Bio-Inspired Structural Colors Produced via Self-Assembly of Synthetic Melanin Nanoparticles

Ming Xiao,†,⊥ Yiwen Li,⊥⊥ Michael C. Allen,§ Dimitri D. Deheyn,§ Xiujun Yue,‡ Jiuzhou Zhao,† Nathan C. Gianneschi,*,† Matthew D. Shawkey,*,‡ and Ali Dhinojwala*,†
How does the structural template influence color evolution?
color is a multidimensional trait
Hartlaubius aurata
Cinnyrincinclus leucogaster
Onychognathus tenuirostris
Onychognathus neumanni
Onychognathus morio
Onychognathus albirostris
Onychognathus tristramii
Onychognathus frater
Onychognathus blythii
Onychognathus salvadorii
Onychognathus walleri
Onychognathus fulgidus
Onychognathus nabouroup
Poeoptera lugubris
Poeoptera kenricki
Poeoptera stuhlmanni
Poeoptera femoralis
Poeoptera sharpii
Speculipastor bicolor
Grafisia torquata
Saroglossa spiloptera
Neocichla gutturalis
Lamprotornis shelleyi
Lamprotornis hidebrandti
Lamprotornis chloropterus
Lamprotornis elisabeth
Lamprotornis acuticaudus
Lamprotornis iris
Lamprotornis chalybeaus
Lamprotornis purpureus
Lamprotornis nitens
Lamprotornis chalcurus
Lamprotornis regius
Lamprotornis bicolor
Lamprotornis fischeri
Lamprotornis albicapillus
Lamprotornis superbus
Lamprotornis pulcher
Lamprotornis ornatus
Lamprotornis splendidus
Lamprotornis mevesii
Lamprotornis unicolor
Lamprotornis purpuroptera
Lamprotornis caudatus
Lamprotornis australis
Hylopsar purpureocauda
Notopholia corruscus
reconstructing evolution
reconstructing evolution
Evolutionary stability of optical complexity
how birds see the world

The diagram shows absorbance spectra for different wavelength (nm) ranges, labeled as uv, s, m, and l. The absorbance peaks are indicated at various points along the wavelength axis, which ranges from 300 to 700 nm.
how birds see the world
how birds see the world
747 individuals from 47 species
10-15 body patches
creating an avian color space
creating an avian color space
creating an avian color space
pavo: an R package for the analysis, visualization and organization of spectral data

Rafael Maia, Chad M. Eliason, Pierre-Paul Bitton, Stéphanie M. Doucet, Matthew D. Shawkey

Full publication history
DOI: 10.1111/2041-210X.12069

Application

New Phytologist

Widespread flower color convergence in Solanaceae via alternate biochemical pathways

Julienne Ng, Stacey D. Smith

Full paper

Functional Ecology

The price of looking sexy: visual ecology of a three-level predator–prey system

David Outomuro, Linus Söderquist, Frank Johansson, Anders Ödeen, Karin Nordström

LETTER

Study on spectral parameters and the support vector machine in surface enhanced Raman spectroscopy of serum for the detection of colon cancer

Xiaochu Li, Tianyue Yang, Bao Li, Jun Yao, Youtao Song, Dell Wang and Jianhua Ding

Published 14 October 2015 • © 2015 Astro Ltd

Laser Physics Letters, Volume 12, Number 11

Geoderma

Proximal sensing of Cu in soil and lettuce using portable X-ray fluorescence spectrometry

Daniel Sapriska, Raphael A. Vincenzo Roncal, Luis Roostalá
non-iridescent

PC1

PC2
How fast is evolution?
modeling evolution: Brownian Motion

rate parameter $\sigma^2$
modeling evolution: Brownian Motion

\[ \sigma^2_1 = 0.1 \]
\[ \sigma^2_2 = 1.0 \]

Time

Phenotype

\[ \sigma^2 = 0.1 \]
\[ \sigma^2 = 1.0 \]
rate parameter $\sigma^2$, attraction parameter $\alpha$, optimal trait value $\theta$
modeling evolution: Ornstein-Uhlenbeck
innovations result in
40x faster evolution of color
innovations result in 40x faster evolution of color and faster speciation
Melanosome morphology underlies diversification
YOU LOOK WEIRD.

I LIKE IT.
Proximate and developmental factors are critical to color evolution.
Proximate and developmental factors are critical to color evolution.

Optical innovations: key component of ornamental diversification.
The genomic and molecular basis of phenotypic novelty
The genomic and molecular basis of phenotypic novelty

Linking microevolution and macroevolution of coloration
current & future directions

The genomic and molecular basis of phenotypic novelty

Linking microevolution and macroevolution of coloration

The role of color innovations in avian diversification
Tiffany Bozic, “Oil Slick”

Dustin Rubenstein
Luke Harmon
Matthew Shawkey
Chad Eliason
Regina Macedo