Today’s Outline

1. Functions of Colorful Plumage

Why do birds have colorful plumage?

2. Types of Plumage Coloration

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1. Signaling Condition to Potential Mates

Females prefer more colorful males - Plumage color can indicate male’s condition, access to resources, or parental contribution

Colorful Plumage as Visual Signals

Colorful and patterned plumage can communicate information to:

1. Potential Mates
2. Rivals
3. Predators

Predation Selects for Cryptic Coloration

• Male pied flycatcher plumage varies from conspicuous (black & white) to dull (brown)

• More conspicuous males suffered higher predation

Figure 1. Disappearance of feeding pied flycatchers to predators of different plumage colors. Values above 1:3 or 2:1 or 3:1 or 4:1 or 5:1 and so on, Sample sizes 5,-200, and so on. Sample sizes are indicated above bars.

(Slagvold et al. 1990)
2. Signaling Status to Rivals

• Colorful plumage can signal dominance status among conspecifics

• Dominant male chickadees have darker black plumage (Mennill et al. 2003)

3. Signaling Danger/ Unpalatability to Predators

Aposematic Coloration

• New Guinean passerines: Pitohui (5 species) and Ifrita kiwaldi

• Feathers contain homobatrachotoxin, a potent neurotoxin

• Beetles are source of neurotoxin

Colorful Plumage and Flush-Pursuit Hunting

Behavioral Modification of the “Dirty” Rock Ptarmigan:

- male plumage functions to reduce predation risk (cryptic) and attract mates (conspicuous)

Conflicting Plumage Needs

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How do birds achieve color?

Coloration is the result of pigments and structural properties in the feather BARBULES

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Pigment Coloration

- Melanins, carotenoids, porphyrins, psittacofulvins
- Molecules that absorb and reflect different wavelengths of light deposited into the feather barbules during growth

Melanins: blacks, browns, reds, & grays

- Melanosomes (specialized organelles) found inside melanocytes (specialized dendritic cells) that perform melanogenesis (creation of melanin pigment)

Melanins: blacks, browns, reds, & grays

- Melanins: blacks, browns, reds, & grays
- Synthesized endogenously in specialized cells called melanocytes

Melanins: blacks, browns, reds, & grays

- Tyrosine endogenous amino acid
- Tyrosinase enzyme that catalyzes these reactions
- Melanogenesis: occurs in epidermis of birds and mammals

Genetic Determination of Melanin Coloration

- Point mutation (glutamate → lysine) in MC1R linked to plumage polymorphism in the bananaquit, Coereba flaveola
- Mutation present in all melanic birds, absent in yellow birds
- Mutation activates MC1R in absence of α-MSH hormone

MC1R: transmembrane receptor
α-melanocyte-stimulating hormone (α-MSH): binds to MC1R and activates tyrosinase
Agouti protein: binds to MC1R, can inhibit melanogenesis or signal switch from eumelanogenesis to pheomelanogenesis

Thorson et al. 2001
Evolution of melanosomes leads to broader ranges of color and higher rates of speciation (Maia et al. 2013).

Ancestral state: solid, rod-like melanosomes.

**Carotenoids: Yellows, Oranges, and Reds**

- Diet-dependent: cannot be synthesized endogenously in vertebrates

- > 1000 types of carotenoids!
- Carotenoid hue depends on structure & concentration
- Animals can metabolically convert carotenoids

**What determines carotenoid composition?**
• Where else are carotenoids deposited??

• Carotenoids not necessarily deposited and/or converted to be used in feathers

• Role as antioxidants and immune system booster

• Deposited prominently in liver, fat tissue, and in eggs

Genetic Mechanisms in Carotenoid Metabolism

Specificity in Carotenoid Uptake

• Fed carotenoid-deprived diets for 6 months

• Then supplemented diet with β-carotene

• Liver: B-carotene, echinenone, canthaxanthin

• Blood: echinenone, canthaxanthin

• Feces: B-carotene

• Selective absorption of carotenoids into bloodstream for deposition into feathers

(Pox et al. 1969)

Carotenoid coloration can vary across years

- Color depends on pairing status in previous breeding season

Porphyrrins

• Found in owls, bustards, turacos

• Often found in down feathers and breaks down in light

Porphyrrins

• Turacoverdin- only true green pigment in birds

• Turacin- red pigment

• Copper based pigment (need to acquire copper from diet to synthesize)
Psittacofulvins
Pigments only found in parrots (Order Psittaciformes)
- Absorb light at shorter wavelengths than carotenoids
- Polyene chain, also lipid soluble
- Source of these pigments unknown

Psittacofulvins selectively deposited in plumage over carotenoids in parrots
- Parrots circulate carotenoids in bloodstream, but deposit psittacofulvins in plumage

Structural Color: Scattering Light
- Light refracts when it travels through substances with different refractive indices (eg. air and keratin)
- Color of light that is scattered depends on structure and arrangement of pigment molecules and air bubbles in keratin

Structural Color: Incoherent Scattering
- Structural white in the Rock Ptarmigan (Lagopus mutus)
- Feathers reflect ~50% of visible light (compared to ~15% in others)
- Large, randomly distributed air vacuoles in barbules, no pigments
- Snow reflects ~80% of visible light (Dyck 1979)

Structural Color: Coherent Scattering
- Specific arrangement of air bubbles and melanin molecules in keratin reinforces certain wavelengths
- Blues and iridescent feathers
- Color depends on viewing angle
Structural Color: Coherent Scattering

- Blue Structural
- Produced in ramus of feather - not barbules!
- Melanin quasi-ordered

Coherent Scattering - Iridescence

- Melanin molecules highly ordered
- Any wavelength of light possible (not just blue)

Major Types of Structural Colors

- Hummingbirds gorgets

Combining Structural and Pigmentation Color

- Eg. Most green color (not in Turacos!) comes from structural blue + pigmented yellow
- Structural color can enhance pigmented color

Physics of Light and Color: Sensitivity to ultraviolet wavelengths

UV reflectance is ubiquitous in feathers

(Eaton & Lanyon 2003)
UV-reflecting feathers in the blue tit

Visible light: Mating success reduced

UV light: Visible light + sunscreen

UV light: UV light + sunscreen