

Lecture Notes: Feathers

Class Business

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Reading for this lecture

Required. Gill: Chapter 4.

Optional. Procter & Lynch: Pages 81-115.

1. Evolutionary origins

A) WHEN DID FEATHERS FIRST ARISE?

- i) Today, feathers are found only on birds. Recently discovered fossils show that some dinosaurs also had feathers (birds are presumed to have evolved from these dinosaurs).
- ii) Determining origins is difficult because feathers rarely fossilize.
- iii) But, *Archaeopteryx* clearly had well-formed feathers, suggesting that the first feathers appeared well before 135 million years ago.

B) FEATHERS ARE UNIQUE STRUCTURES:

- i) Two main hypotheses for why feathers developed.
- ii) **Hypothesis 1 – Flight:** elongation (and perhaps fraying) of protofeathers thought to help with gliding; eventually further modification allowed the many forms of flight we see today.
- iii) **Hypothesis 2 – Thermoregulation:** increasing feather size and complexity at the edges both helped ancestral birds to maintain their body temperature.
- iv) It is uncertain which of these hypotheses is correct. Note that this debate relates to the origins of flight (see next lecture) and to which group of reptiles the birds arose from (see last lecture). However, the appearance of feathers in the fossil record long before flight could have been possible indicates that feathers did not (initially) evolve “for” flight; there is no reason that both functions could not have contributed to the evolution of complex feathers

2. Feather structures

A) KERATIN

- i) Feathers are made of a unique form of beta-keratin (different from that found in modern reptiles, and from that found in your fingernails and hair).

B) PARTS OF A FEATHER

- i) Parts you need to know: **calamus** (quill), **rachis**, **vane**, **barbs**, **barbules**, **barbicels**, **hooklets**, **afterfeather**.
- ii) You also need to know the functions of each of these parts.
- iii) On a typical feather the barbs at the base of the vane are **plumulaceous** (“fluffy”, without strong interlocking structure); those forming the bulk of the vane are **pennaceous** (tightly interlocking).

3. Types of feathers

- i) Birds have a wide variety of different feather types, which have different functions and consequently different structures.
- ii) **Contour feathers** (basic body covering): symmetrical, pennaceous & plumulaceous, have afterfeathers.
- iii) **Down** and **semiplumes** (insulation): symmetrical, plumulaceous, may lack the rachis.
- iv) **Remiges** and **rectrices** (“flight feathers”, with aerodynamic function): asymmetrical, mostly pennaceous, occasionally modified for additional functions (e.g., rectrices used as props by woodpeckers, remiges altered for sound reduction in owls, both types of feather altered for sound production in a few species).

- v) **Bristles:** vaneless contour feathers, found mainly on the head. Function varies among species and is not well known in some cases (e.g., the rictal bristles around the mouths of aerial insectivores which seem to play a role in eye protection; note that these bristles appear not to be used as “insect catching nets” as has been hypothesized).
- vi) **Filoplumes:** hairlike, sensory structures, lacking vanes; distributed throughout plumage and used to monitor the position of vaned feathers.

4. What are feathers used for?

A) FLIGHT

- i) Flight feathers help to produce forward thrust on the downstroke of the wingbeat.
- ii) Smooth covering of the feather coat streamlines the birds body, reducing turbulence.

B) INSULATION

- i) Feathers trap air, which helps reduce heat loss. Birds have a lot of control over the way their feathers lie. In cold weather they will fluff their feathers up to trap more air. When hot, they will sleek their feathers down to help them off-load heat.
- ii) Feathers also help protect birds from solar radiation.

C) WATERPROOFING

- i) Aquatic birds, especially, rely on their feathers to keep their skin from getting wet (which would cause heat loss). Ducks and geese do not get wet when they go swimming!
- ii) Waterproofing is possible because of both the structure of feathers (which prevents water from passing between the barbs) and because birds apply special oils from their preen gland (which helps repel water).

D) DISPLAY

- i) Visual displays (many examples to come in future lectures).
- ii) Auditory displays (e.g., modified tail feathers on snipes).

5. Pterylosis

- i) On most birds, the points at which feathers attach to the body are not distributed across the entire body. Instead they are grouped into certain areas, known as **feather tracts** (or **pterylae**). The remainder of the skin is naked, with few feathers – these regions are called **apteria**. Of course, the feathers from the pterylae are sufficiently large that they generally cover the apteria.
- ii) Why feathers are grouped in this way is unclear, however, it may be that grouping feathers that are used for different purposes facilitates the development of an effective system for controlling feather position. The presence of apteria may also help birds to lose heat.
- iii) Exceptions: a few species of birds have feathers distributed evenly over their bodies. Many of these are flightless birds: including penguins, ostriches, kiwis.

6. Feather colors

A) PIGMENT COLORS (formed by chemical compounds)

- i) Three main types: melanins (grays, browns, black), carotenoids (reds, oranges, yellows), and porphyrins (bright brown, some greens and reds).
- ii) Nearly all birds can produce melanins directly from amino acids.
- iii) Carotenoid pigments are derived from the bird’s diet. Consequently, individual birds that do not have access to carotenoid-rich food will not develop colors that require carotenoid pigments. Examples: captive flamingos lose their pink colors if they are not fed enough carotenoids; yellow house finches.
- iv) As feathers wear and barbules are lost, underlying colors become apparent. Consequently, birds can “change” their colors without changing their feathers. Example: crossbills.

B) STRUCTURAL COLORS (formed by the physics of light)

- i) Some colors are formed by the physical structure of the feathers, which alters the way in which light is scattered or absorbed by the feathers.
- ii) Blues and greens are formed when short wave light (at the blue end of the spectrum) gets scattered by melanin particles in the barbules, while longer wavelengths of light (at the red end of the spectrum) gets absorbed.
- iii) Iridescent colors (e.g., hummingbirds) depend on the angle at which light hits the feathers. If the angle is wrong, the feathers just look black.
- iv) Many birds can see ultraviolet light. So, the way a bird looks to you is different from the way another bird will see it.

7. Molt and feather care

A) FEATHERS DO NOT LAST FOREVER.

- i) As they are used, feathers fade, become worn, break, etc. etc. These changes reduce the feather's ability to function efficiently in flight, insulation, mate attraction, etc. The production of new feathers is energetically costly and takes time, consequently birds spend a lot of time taking care of their feathers.
- ii) In addition, birds periodically replace their feathers through the process of molt.

B) PREENING

- i) Preening involves rearranging, straightening and cleaning feathers. Most birds also apply special oils, produced by the **preen** (or **uropygial**) **gland** at the base of the tail.
- ii) Preen oils help to keep feathers moist (prevent brittleness that leads to breakage), contain chemicals that deter bacteria and fungi that digest keratin and feather-chewing parasites, and help maintain waterproofing and insulation.
- iii) While preening birds may also remove parasites, such as feather lice, with their bill or feet.

C) MOLT

- i) All birds replace their feathers periodically. At a minimum, birds will replace the down they are born with, with a **juvenal plumage**, and then replace the juvenal plumage with a basic plumage. This **basic plumage** is then replaced periodically (usually annually) thereafter.
- ii) Some birds, have an additional molt into a different plumage (called the **alternate plumage**). Alternate plumages typically differ substantially from the basic plumage, and are used by birds that need to change their appearance for part of the year. Many birds (usually males, e.g. ducks, some warblers) obtain a "flashy" alternate plumage during the mate attraction period, in order to augment their breeding displays. Others change their plumage, so that their colors match changes in their surroundings (e.g., ptarmigan).