FEATHERS

- Feathers are the most distinctive feature of birds
- Extraordinary evolutionary invention
- Feathers are fundamental to many aspects of bird existence
  - Insulation, aerodynamics, communication, camouflage

FUNCTIONS OF FEATHERS

- Primary functions are to provide protection, insulation, and capacity for flight
- Insulation is essential to regulate body temperature
- Feather color important for communication (mate selection, territory dominance) and camouflage
- Modified feathers are important for swimming, sound production (communication), hearing (owls), tactile sensation (night hawks), breeding displays

FEATHER STRUCTURE

- Central shaft – RACHIS
- Broad flat VANE on both sides
- Base - CALAMUS
  - Calamus anchors feather into follicle
- Inferior umbilicus provides access to blood flow during development

FEATHER STRUCTURE - TERMS

- Vane grade from hidden, fluffy, insulating section at base = PLUMULACEOUS
- To the visible PENNACEOUS section on distal end
- Lateral branches off the RACHIS are called BARBS and provide the primary structure
- The central shaft of a BARB is called the RAMUS

STRUCTURE OF THE VANE

- Each BARB is divided into more branches called BARBULES
- BARBULES consist of single cells linked end to end, many bearing BARBICELS or HOOKLETS
- The BARBS and BARBULES form an interlocking strong, flexible surface and one of the most precisely adapted epidermal structures in the animal kingdom
Feather Types

- **Pennaceous:**
  - Contour
  - Bristles
  - Flight

- **Plumulaceous:**
  - Semiplumes
  - Filoplume
  - Down

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**CONTOUR FEATHERS**

- Contour feathers are the basic, vaned feathers of body and wing
- Includes large flight feathers of wings and tail with asymmetrical vanes
- Smaller contour feather cover body and have symmetrical vanes

**CONTOUR FEATHERS – REMIGES and RECTRICES**

- REMIGES and RECTRICES are a subset of contour feathers
- Includes flight feathers of the wing, including primaries, secondaries, and tertials, and tail feathers
- Feather vanes are usually asymmetrical

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**REMITGES AND RETRICES**

**BRISTLE FEATHERS**

- Bristle feathers are contour feathers without the vanes
- Bristle feathers consist of a RACHIS but lack BARBS and BARBULES
- Bristle feathers are found around the eye for protection, and around the mouth for tactile sensitivity (insectivorous species)
Semiplumes

- Semiplumes are intermediate between PENNACEOUS (stiff) and PLUMULACEOUS (down) feathers, which lack a RACHIS
- Semiplumes are distinguished from down feather by having a RACHIS that is longer than any BARB
- Semiplumes lie at edge of contour feather tracts, provide insulation, and serve in courtship displays

FILOPLUMES

- FILOPLUMES are long, hair-like feathers that monitor the position of the PENNACEOUS feathers on the wing and tail
- Sensory corpuscles at the base of each FILOPLUME detect fine movements in feather shafts
- Each flight feather may have 8-12 FILOPLUMES
- FILOPLUMES are most abundant at the base of the wing

DEFINITIVE DOWN FEATHERS

- These are PLUMACEOUS feathers that provide a layer of insulation under the contour feathers
- DOWN feathers usually do not have a rachis or it is shorter than the barbs
- Nasiad down covers most hatchlings and is usually simpler in structure than adult down

FEATHER DISTRIBUTION

- There are eight major feather tracts or PTERYLAE
  - Capital
  - Femoral
  - Ventral
  - Crural
  - Humeral
  - Caudal
  - Alar
  - Spinal
- The feather coat of many species includes over 25,000 feathers
- Feather coats weigh 2-3 times the amount of bones
- Feathers cover the entire body but are not evenly attached to the skin
- Feather attachments are grouped into FEATHER TRACTS
  - pteryla = areas with feathers
  - apteria = areas without feathers
**FEATHER TRACTS**

- **CAPITAL TRACT**—Extends over the entire dorsal surface of the head
- **SPINAL TRACT**—Runs down the dorsal midline of the body from the base of the skull to the pygostyle (fused caudal vertebrae)
- **VENTRAL TRACT**—Covers the ventral neck, breast, and abdominal regions
- **CAUDAL TRACT**—Includes the major flight feathers of the tail (THE RETRICES)

**FEATHER TRACTS**

- **HUMERAL TRACT**—A band of contour feathers that overlie the humerus on the dorsal side of the wing
- **ALAR TRACT**—A series of small pterylae over the dorsal and ventral surfaces of the outer wing. Includes all the major flight feathers (primaries, secondaries, alula, tertials)
- **FEMORAL TRACT**—Covers the thigh upward to the base of the tail
- **CRURAL TRACT**—Includes lower leg feathers

**FEATHER DEVELOPMENT**

- Feather, once grown, are dead structures – the only mechanism to repair a feather is to grow a new one
- Feathers grow by proliferation and differentiation of keratinocytes
- Keratinocytes are keratin-producing cells in the epidermis
- Keratins are filaments of proteins that polymerize to form solid structure like hair, nails, bills, scales, and feathers

**FEATHER DEVELOPMENT**

- Feather development starts via a special layer of epidermal cells that differentiate into the protective sheath that will surround the developing feather
- The specialized dermis layer becomes the pulp at the base that supplies nutrients to the developing feathers
- Feather growth begins on the epidermis with the placode – a thickening of the epidermis over the condensation of cells in the dermis

**FEATHER DEVELOPMENT**

- The growth of a new feather starts with the thickened dermal papilla located in the follicle
- The cells of the epidermal layer divide rapidly to form the main axis of the feather which will eventually become the rachis
- New feathers grow rapidly – towards the end of growth the cells form a calamus that anchors the feather to the follicle
- The new feather pushes the old feather out of the follicle
ORIGIN OF FEATHERS

- Feathers evolved in Dinosaurs
- Feathers developed from an initial hollow tube to the asymmetrical flight feathers we see in modern birds
- The precursor of a feather may have been a conical papilla developed from a cylindrical follicle within the skin
- The papilla becomes a tuft of unbranched filaments (barbs), and then each filament becomes branched (barbules)
- The branched filaments then become organized around a central stem (rachis) to produce the pinnate arrangement of present-day feathers


ORIGIN OF FEATHERS

- It has long been accepted that feathers evolved from reptilian scales
- But now there is conclusive evidence that dinosaurs evolved feathers before birds
- The evolutionary question is “What was the adaptive value to evolve the intermediate structures that ultimately led to feathers?”
- There are two main theories that attempt to answer this question
Flight versus Insulation Theory

**FLIGHT THEORY**
- Flight theory postulates that each modification of the early hollow tubes of the arboreal ancestors to birds made them better and better gliders and eventually fliers.
- Everything about modern feathers is aerodynamic and very complex in structure.
- If insulation was the driving adaptive mechanism then why not something simple like hair?
- Any mutation of a reptilian scale that conferred an advantage in parachuting or gliding would have a selective advantage.

**INSULATION THEORY**
- Feathers are the most efficient natural insulator.
- This theory believes feathers evolved to regulate bird temperature and only later did feathers elongate into structures facilitating flight.
- Birds are small homeotherms and lose proportionately more heat than larger homeotherms.
- Insulation theory states that feathers evolved with the homeothermic ancestry of modern birds.

A Chinese fossil shows that primitive feathers covered a small predatory dinosaur from head to tail (Ji et al. 2001).

This fossil is the first to show feathers over the whole animal, showing that dinosaurs may well have evolved feathers for insulation before they were used for flight.


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FEATHER COLORS

FEATHER COLORS

- There are 3 principal pigments in bird feathers:
  - (1) **MELANINS** — The most common and produce black, grays, and browns
  - (2) **CAROTENOIDS** — Produce intense reds and yellows
  - (3) **PORPHYRINS** — Produce a range of reds, browns, and greens

**Feather Pigments**

**Melanins**

**Carotenoids**
**PORPHYRINS**

**STRUCTURAL COLORS**
- Structural colors are either iridescent or non-iridescent.
- Iridescent changes occur according to the angle at which light strikes the feather structure.
  - Produced via thin layer of keratin on the barbules.
  - Light is split into its component colors before being reflected back to the observer.
- In contrast, non-iridescent colors are produced as light scatters when it passes through minute spaces in the keratin or the barbs.
- Non-iridescent colors do not change based on the angle of reflection.

**MOLTS AND PLUMAGES**
- Blue and green birds have no such pigment in their feathers.
- The Blue Jay's feathers reflect blue light wave lengths which give them the appearance of blue color.

**COSTS OF MOLTING**
- **ENERGETIC** --- Up to 25% of lean body mass can be replaced in the form of new feathers.
- **PREDATION** --- Some species are flightless during part of molting period.
TERMS AND DEFINITIONS

• Humphrey and Parkes (1959) molt and plumage naming system

• MOLTING --- The normal shedding and replacement of feathers by a new generation of feathers

• PLUMAGE --- The new or resulting generation of feathers produced after a specific molt

TERMS AND DEFINITIONS

• A specific plumage is prompted by a specific molt

• The Humphrey-Parkes system equates the number of plumages with the number of molts

• PLUMAGE CYCLE --- The time elapsing between occurrence of a given plumage or molt until the next occurrence of that plumage or molt

TYPES OF PLUMAGES

• There are 5 major plumage types in the Humphrey-Parkes system:
  – NATAL,
  – JUVENILE,
  – BASIC,
  – ALTERNATE,
  – SUPPLEMENTAL

• For each plumage there is a synonymously named molt

• For example, the prebasic molt precedes the acquisition of the basic plumage

TYPES OF PLUMAGES

• NATAL DOWN --- Worn by young birds during the first few weeks of life

• JUVENILE --- Most birds wear this plumage during their first summer

• FIRST BASIC --- In most species this is the “immature” plumage, does not include flight feathers, and is acquired in fall or early winter

• FIRST ALTERNATE --- Completed by the first spring, before birds arrive on breeding grounds

• Once an individual gets to its’ First Alternate molt the pattern goes back and forth from BASIC molt to ALTERNATE molt

• The terms BASIC and ALTERNATE are used because the plumages can no longer be differentiated from preceding plumages and are now termed DIFFINITIVE

TYPES OF PLUMAGES

• BASIC --- Describes the plumage of birds that as adults have one plumage per cycle that is replaced by a complete feather molt (=pre-basic molt)

• ALTERNATE --- Describes the plumage of birds that as adults have 2 plumages per cycle

• The pre-basic molt results in basic plumage

• The alternate molt results in alternate plumage
ECOLOGICAL STRATEGIES

- The production of new feathers requires a change in energy budget which can be met via 3 basic strategies:
  1. Increased food intake
  2. Reduction of other energy-demanding activities
  3. Use of stored reserves

ECOLOGICAL STRATEGIES

- Most wetland birds (waterfowl, grebes, loons) molt their flight feathers synchronously.
  
- These species can not fly well with the loss of even 1 or 2 flight feathers so the best (fastest) strategy is to molt them all at once.

- These species can “afford” this strategy because they can dive (loons and grebes) or hide (ducks) from predators while flightless.

End Feathers