Biological and Physiological Adaptations of Birds
Objectives

- Understand birds’ place in the animal kingdom
  - Where did birds come from?
- Understand adaptations that make flight possible
  - Skeleton
  - Musculature
  - Respiratory System
  - Circulatory System
  - Digestive System
  - Reproduction
  - Senses
  - Feathers
Class Aves

- In scientific taxonomy, birds are members of
  - Kingdom: Anamalia
  - Phylum: Chordata
- At the next level, birds are put into their own group
  - Class: Aves
Class Aves

- Worldwide, there are 27 orders of birds
- Within those orders, there are hundreds of bird families
- Within those families, there are approximately 10,000 species of birds
Fossil Record

Archaeopteryx
3-fingered hand

Strap-like shoulder blade

Crest on upper arm bone

Finger claws

‘S’-shaped neck

Teeth

Feathers

Anklebone fused to shin bone

Some fusion of foot bones

Sharp, curved claws on toes

Four-toed foot, three large forward toes and a smaller toe behind

Long, straight bony tail
Adaptations

Almost every feature of a bird’s anatomy has evolved in order to make flight possible

- Skeleton
- Musculature
- Respiratory System
- Circulatory System
- Digestive System
- Reproduction
- Senses
- Feathers
Skeletal Adaptations

- The sternum (breastbone), bears a prominent keel where the flight muscles attach
- The furcula (wishbone), serves as a brace during the flight stroke
- Secondary feathers of the wing are supported by the forearm
- Wrist and hand bones are fused to provide firm support for the primary feathers
Sternum and Keel

Forearm

Fused Wrist and Hand Bones

Primary Feathers

Secondary Feathers

Pygostyle

Furcula

Sternum and Keel
Skeletal Adaptations

- Solid bones replaced with hollow bones
  - Thin internal struts for extra strength where necessary

- Bones of the skull are extremely thin
- Teeth replaced by a horny bill
Light but Powerful Musculature

- Most birds have approximately 175 different muscles, mainly controlling the wings, skin, and legs.
- The largest muscles control the wings and run between the upper arm and the keel.
  - The pectoralis major provides the powerful downstroke.
  - The supracoracoideus muscle raises the wing.
    - Uses a pulley-like system to lift the wing.
  - These muscles constitute about 20 – 25 percent of the bird's total body mass.
Pectoralis major
Pulls the wing down
Respiratory System

- Due to the high metabolic rate required for flight, birds have a high oxygen demand.
- Birds ventilate their lungs by means of air sacs.
  - These structures are unique to birds, and perhaps dinosaurs, too.
- Birds’ lungs obtain fresh air during both exhalation and inhalation.
- Birds lack a diaphragm.
  - The entire body cavity acts as a bellows to move air through the lungs.
  - The active phase of respiration in birds is exhalation, requiring muscular contraction.
Respiratory System

- Air flows through the air sac system and lungs
  - There is no mixing of oxygen-rich air and oxygen-poor, carbon dioxide-rich air as in mammalian lungs
- The partial pressure of oxygen in a bird's lungs is the same as the environment
  - Birds have more efficient gas-exchange of both oxygen and carbon dioxide than do mammals
Circulatory System

- Birds, like mammals, have four-chambered hearts
  - Makes possible a double circulation
  - Blood makes a side trip through the lungs for gaseous purification before it is circulated through the body
- Bird’s heart is large, powerful, and rapid in its beat
<table>
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<tr>
<th>Animal</th>
<th>Heart as % of Body Weight</th>
<th>Heart Beats per Minute</th>
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<td>Hummingbird</td>
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Digestive System

- A bird’s digestive system can assimilate food at an extremely rapid rate
- Most birds have digestive tracts adapted to their diet
  - Herbivores
  - Carnivores
  - Omnivores
Herbivores

- Feed on seeds, fruit, and other vegetable matter
- Have a storage sac called the crop where food is macerated before it passes to the two-chambered stomach
  - Mixed with digestive juices in the first part
  - Ground into a pulp in the second part (the gizzard)
- Herbivorous birds swallow small stones which assist the grinding of food in the gizzard
Digestive System

- **Carnivores**
  - Feed on fish, animals, insects, and carrion
  - Do not usually have a crop
    - If they do, it is small
  - The gizzard is less muscular
    - Functions as a normal stomach
  - Some carnivores do not attempt to digest the bones and fur or skin of their prey
    - Regurgitated in the form of a hard pellet
The pancreas is slightly more well developed in birds than in mammals
- Possibly as partial compensation for the lack of saliva and chewing
- It produces enzymes for digesting carbohydrates, fats, and proteins

The liver has two distinct lobes each with its own duct leading into the small intestine
- Stores the bile
  - In birds, the bile is acidic and not alkaline as it is in mammals
Excretory System

- Another weight reducing adaptation in birds is the absence of
  - A urinary bladder
  - A urethra
- The kidneys excrete nitrogenous wastes in the form of uric acid
Adaptations of the Reproductive System

- Birds are the only class of vertebrates in which no species give birth to live young.
- Nearly all species possess only one ovary and oviduct.
- They lay their eggs in the nest soon after the eggs are formed.
- Reproductive structures atrophy during the non-breeding season.
Vision

- Birds have acute eyesight
  - Hawks are able to discriminate fine details at a much greater distance and much more quickly than humans
- Hawks have a bony "brow" above the eye known as a *supraorbital ridge*
- Raptors including owls have a "third eyelid" known as a *nictitating membrane*
- Eyes of a bird are relatively large
Hearing

- As an adaptation for flight, birds lack an externally visible ear.
- The range of hearing in many species of birds is comparable with that of mankind.
- Some birds have hearing that is much more sensitive than ours.
- Owls not only are more sensitive to small sounds but they have asymmetrical ears.
  - Allows them to pinpoint the source of a sound extremely accurately.
Smell

- The olfactory lobes of most birds are very small, suggesting that they have a poor sense of smell.
- Some birds do use smell to locate food:
  - Sea birds (Petrels, Shearwaters)
  - Vultures
  - Kiwis
Feathers

- Of all the organisms on earth, only birds have feathers
  - They are instrumental in flying
  - They play a critical role in temperature regulation
  - Their color patterns are essential in both display and camouflage
Feathers

Anatomy Of A Typical Feather

Quill  Cut Section

Rachis/Shaft/Stem
(Top or Front Side of Feather)

Barb

Barbules

Hooklets

© Wayne Luallen - 1995
Barbs and Barbules

An electron microscope photograph
Feathers

- The number of feathers on a bird’s body varies
  - Around 1,000 on a hummingbird
  - More than 25,000 on a swan

Photo © Bob Fairey
Feather Types

- Flight feathers
  - Feathers of the tail (retrices)
  - Long feathers of the wing (remiges)
    - Primaries
    - Secondaries
Feather Types

- Contour feathers
  - Coverts
  - Down
  - Semiplumes
How a Feather Grows

- Sheath
- Central stalk (rachis)
- Barbs
Feathers

- The mass of feathers on a bird’s body constitutes its plumage
- Feathers clump in distinct tracts with featherless areas in between
  - Birds’ color patterns are built of these units
- Worn feathers are periodically replaced through a process called “molt”
  - A knowledge of molts and plumages is useful for bird identification
Crested Argus Pheasant
Summary Questions
Resources

Books

The Life of Birds, by Joel Carl Welty

Birds: Their Life, Their Ways, Their World, by Dr. Christopher Perrins, and Dr. C.J.O. Harrison, published by Reader’s Digest

The Sibley Guide to Bird Life and Behavior, edited by Chris Elphick, John B. Dunning, Jr., and David Allen Sibley


Web Sites

The National Fish and Wildlife Forensics Laboratory Feather Atlas
http://www.lab.fws.gov/featheratlas/index.php

The Amazing World of Birds
http://www.earthlife.net/birds/intro.html

Introduction to the Aves
http://www.ucmp.berkeley.edu/diapsids/birds/birdintro.html