Lecture 4
Adaptations

- Digestive system
  - Respiration
  - Excretion
- Nervous System (Chapter 7)
Digestive System
Bill Structure

Key adaptation examples for feeding:
1 Conical - seed-cracking; finches
2 Long - nectar or probing
3 Highly specialized - filtering, etc.
Bill Adaptations
Brown and Lomolino (1998) Biogeography
Hawaiian Honeycreepers
Figure 8.15  The variety of beak shapes resulting from the adaptive radiation of Hawaiian honeycreepers (Drepanidinae). Compare this group with the examples of Galápagos finches (Figure 8.8) and African cichlid fishes (Figures 8.9 and 8.10). (From Primack 1998.)
Avian Digestive System

- Lack teeth
- Possess specialized digestive system to process unmasticated food
- Highly efficient & fast nutrient extraction
Major Parts of Digestive System

1 Oral cavity
2 Esophagus
3 Crop
4 Stomach
5 Liver
6 Pancreas
7 Intestine
8 Cloaca
Oral Cavity

- Taste buds - poorly developed
- Salivary glands - in pharynx
  - initiates digestive process - relatively well developed in some seed-eaters
  - traps insects
  - building nests - noteworthy in Edible-Nest Swiftlet of East Indies; millions of nests used to make delicacy of “birds nest soup”
- Tongue - usually simple but can be highly modified
Esophagus

- Size – related to type of food eaten; small in insectivorous species but large in herbivores
- Distensible in many species – e.g., in seabirds
- Sound production
- Doves & Pigeons can produce crop milk
Stomach

• 2-chambered
  - Proventriculus
    • highly developed in Piscivores and other protein eaters
    • secretes acidic gastric juices
  - Gizzard
    • Functional analog to mammalian molars
    • Striated muscle; keratinous ridges
    • May contain grit
    • Most pronounced in seed-eaters
Food Pellets

• Formed in gizzard
• Indigestible portions of food
  - fur, bones, chitin, etc.
• Found in wide range of species
  - Owls, Hawks, Shrikes
Food Pellet

- Useful in food analyses
- Found under roosts
- Can form in < 4 hours
Liver

- Largest gland in bird
- Proportionately larger than in mammals
Pancreas

- Relatively large
- Secretes digestive enzymes
- Endocrine gland
  - regulates carbohydrate & fat metabolism
Intestine

• Organ where most of digestion occurs
• Absorption
• Short & moderately coiled in carnivores
• Long & highly coiled in omnivores & herbivores
Figure 2-11  Digestive tracts of (a) a granivorous herbivore (12 week old turkey) compared to (b) a carnivore (Red-tailed Hawk [*Buteo jamaicensis*]). The crop is only a slight swelling of the esophagus in the hawk and the ceca are absent; the stomach of the turkey is much more muscular. (Modified from Duke 1986.)
Caeca

- 2 dead-end sacs at posterior end of intestine
- aids digestion of plant material (e.g., cellulose)
Ceca or cecum (singular)

-Poorly developed in arboreal birds, well-developed in ground-dwelling and flightless birds
Cloaca

1. Receives excrement from intestines
2. Receives kidney discharge & gametes
3. Storage
Digestion Summary

• Overall digestive system reflects food habitats of organism
• Overall – many species show an increasing specialization of diet (e.g., Snail Kite on Pomacea snails, limpkin on snails)
• Many highly “successful” species are highly omnivorous such as gulls and crows
• Diet varies considerably according to the season, habitat, geographic area, and physiological demands
Digestion Summary Continued

- Huge energetic and food demands during migration - individuals can increase their weight by 50%.
- Winter-time demands for food - very frequent need for food during cold and minimal daylight hours.
- Hummingbirds need to visit 1500–2700 flowers each day to meet energy demands in cold, mountainous regions - also drop body temperature.
- Seabirds (e.g., petrels) forage up to 600 km from breeding colonies.
Physiology/Morphology Continued

• Nervous system
• Respiration
• Excretion
Nervous System

1. Brain – complexities of flight have led to increased need for brain power
   - Brain – 2-9 % of body mass
   - Large size of birds (and mammals) due to enlarged cerebral hemispheres
   - Jargon term “bird brain” is unfounded
   - Small olfactory lobes
Nervous System continued

- Large optic lobes - “eye-brained” animals
- Large cerebellum - muscular coordination during flight
- Hyperstriatum - unique in birds, associated with learning and intelligence

2. Sense organs
  - Touch - overall sense is similar to man
  - Taste - generally poorly developed - e.g., 50-60 taste buds in tongue of most birds compared with 10,000-17,000 in mammals
Figure 7-11 (note drawn to same relative scale)

A. Lizard

B. Macaw
Cross section of the cerebrum

Crow
- Cortex
- Wulst
- Hyperstriatum
- Neostriatum
- Archistriatum
- Paleostriatum

Quail
- Cortex
- Wulst
- Hyperstriatum
- Neostriatum
- Archistriatum
- Paleostriatum

Monkey
- Cortex
- Paleostriatum
- Archistriatum

Rat
- Cortex
- Paleostriatum
- Archistriatum

Alligator
- Cortex
- Neostriatum
- Archistriatum
- Paleostriatum
Nervous system continued

- Smell – poorly developed in most birds, but some have excellent abilities to smell – e.g., vultures, quail, mallards, chicken -- albeit, specialized sensitivity to specific odors
- Hearing – well-developed but not as good as in most mammals
  - Hearing via a single cartilaginous bone, columella
  - Owls have special ability to hear – long, oblong ear openings; assymetric ear openings; and sound collecting and focusing devices such as concentric circles and facial disks
- Vision – most advanced of all the senses
Partner-Specific Odor Recognition in an Antarctic Seabird

Francesco Bonadonna and Gabrielle A. Nevitt

Individual odor recognition has been recognized in mammals for decades, yet the ability to discriminate individuals by scent alone has rarely been investigated in birds (1). Procellariiform seabirds are prime candidates for such studies. These birds have an excellent sense of smell (2), breed in colonies, and are monogamous for life (3). Although several burrowing species can relocate their nests by smell, the nature of 0.01, binomial test) (Fig. 1B). This result was surprising because incubating birds do not typically explore other burrows. Pairs are philopatric to specific burrows, and predation on roving birds is extreme (3).

Because prions spend up to 2 weeks foraging at sea between incubation shifts, our results suggest that prions may use odor cues to return to the burrows of their mates. Our results show that Antarctic prions are able to recognize and discriminate individual odor cues that likely contribute to the olfactory signature of their burrows. Prions may also use scents for sex discrimination, but this hypothesis was not directly tested and needs to be further explored (Supporting online text).
Nervous System continued

Vision continued

• Eye of man is 1 % of head weight; 15 % of head weight in the European Starling
• Shape of the eye varies considerably from flat to tubular
• Nictitating membrane found among diving birds that functions like a contact lens
• Pecten – large vascularized structure in the eye
• Fovea – concave depression of high cone density
• Color vision
• Eye positioning – monocular in many herbivores, but binocular in most raptors
Retina
FIGURE 5-19. Left, Front and rear views of a Yellow-billed Cuckoo, a species able to converge its eyes on objects either in front of or behind its head. After Polyak. Right, A bittern’s head viewed from below, showing its downward-facing eyes. After Berlioiz, in Grassé, 1950.
Circulatory/Respiratory System

- Generally this system is very highly advanced - much more so than in mammals
- Heart size is 1.4 to 2 times larger than in mammals
- Heart size larger in more “advanced” forms
- Resting rate is generally lower than in mammals, but peak rates are higher (e.g., heart rates are 93 beats per min in turkey, but 1,260 in an active hummingbird)
- Blood has high sugar content - 2 x glucose as in mammals
  - Small red-blood cells (high surface to volume ratio)
  - 6 seconds for blood to make a complete circuit in active birds
Respiratory system continued

- No stagnation period in the lungs with the air sacs – 20% in mammals
- Air sacs – 9 in most birds but varies from 6 to 14
  - Unidirectional flow of air is possible with air sacs
  - 2 full respiratory cycles are necessary for complete air passage from intake to exhale
- Anatomically – trachea, syrinx, bronchus, and lungs (with parabronchi – the actual respiratory unit)
Respiratory System cont.

- Many physiological adaptations to deal with cold and hot weather
- Hibernation – known in caprimulgids, drop body temperature, reduced heart rate and breathing (thought to occur in Aristotle’s time but finally discovered in 1949!)
Figure 6-5

Inspiration

Expiration
Figure 6-5 (continued)

Inspiration

Expiration
Excretion System

1. Kidneys – primary organ for removal of waste products from the blood and for maintaining homeostatic balance of ions
   - Overall less efficient than in mammals
   - Salt gland prominent in some birds (e.g., marine-dwelling)

2. Urine – mixed with fecal material with high concentration of uric acid rather than urea (found in mammals)
   - Urea – $\text{CH}_4\text{N}_2\text{O}$
   - Uric acid – $\text{C}_5\text{H}_4\text{N}_4\text{O}_3$
   - 2 times the amount of nitrogen excreted with uric acid
Figure 6-8

Total daily energy expenditure (kJ) vs. Body mass (g)

- Flight metabolism
- $E_{tot}$
- Passerine basal metabolism
- Nonpasserine basal metabolism

Total daily energy expenditure
Figure 6-12  Scholander’s model of endothermy

- Increased metabolism
- Shivering
- LCT
- UCT
- Thermoneutral zone
- Evaporative cooling

Metabolism (kJ/h) vs. Ambient temperature (°C)