

Avian digestion

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A wonderful bird is the pelican,
His bill will hold more than his belly can.
He can take in his beak
Food enough for a week,
But I'm damned if I see how the hell he
can.

--Dixon Lanier Merritt (1879-?)
The Pelican (1910)

I. Introduction

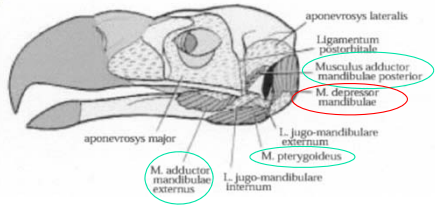
High metabolic rates require large amounts of fuel

- warbler might eat 80 percent of its body weight in a day!

Digestive system needs to be

- as light as possible
- extremely efficient

Loss of teeth and minimum jaw musculature



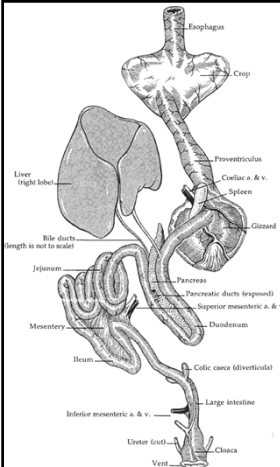
Stellar's Sea Eagle

Problem for birds – need to keep low body weight

Thus, little fat storage

need to locate, ingest, digest food as quickly and efficiently as possible

Major components of avian digestive system



- oral cavity
- pharynx
- esophagus (+ crop)
- stomach (proventriculus, ventriculus)
- small intestine
- large intestine
- cloaca

II. Taxonomy of food habits

Many birds are generalists but many are also specialists

Specializations are evident through the entire alimentary canal.

As a group birds consume about any kind of food

- ants
- buds
- crustaceans
- fish
- fruit
- grass
- insects
- leaves
- nectar
- pollen
- roots
- sap
- snails
- wax
- etc.


A. Herbivores

Granivores

Frugivores

Nectivores

Folivores



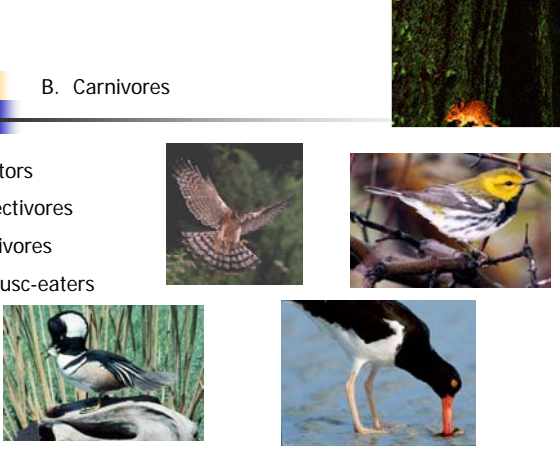
B. Carnivores

Raptors

Insectivores

Piscivores

Mollusc-eaters




III. Mouth and Pharynx

A. Bill

Function – seize, kill, prepare food for swallowing

Correlation between food and food handling machinery is often obvious


edges of the bill are especially hard and sharp and are called 'tomia', singular 'tomium'



Bill shape typically doesn't vary between sexes



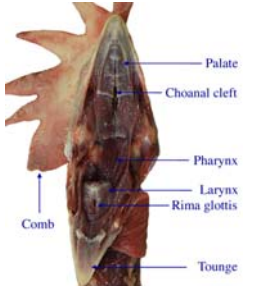
Rictal bristles – sensory function, prey capture



B. Palate

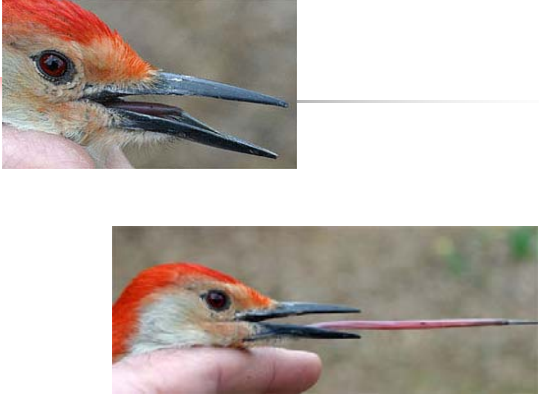

Mouth roofed with hard palate
Floor membranous

choanal cleft
no soft palate
salivary glands
taste buds



C. Tongue

Typically small, covered with a cornified epithelium, sharply pointed




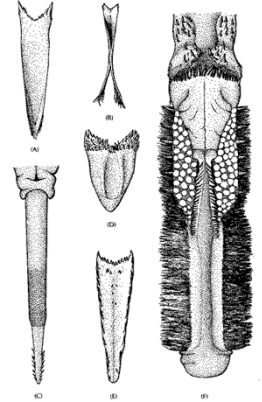
Parrots – very muscular
Most species –
few intrinsic muscles



Poorly supplied with taste buds


• barbed





• tubular
• brushy

Figure 7-10 Bird tongues (dorsal view): (A) generalized passerine tongue with terminal finger (American Robin); (B) sabbler, finch-like insect-feeding tongue (Parula); (C) probing and pecking woodpecker tongue (White-headed Woodpecker); (D) short, broad tongue of a fruit eater (Black's Tanager); (E) fish-eater tongue (Sooty Shearwater); (F) food-straining tongue (Northern Shorebird). (Adapted from Gauthier, 1923)




Tactile corpuscles widely distributed on tongues of woodpeckers and finches

Parrots - high # on bill

D. Salivary Glands

Serous – produce enzymes
Mucous – produce polysaccharides


Density of glands depends on diet



Piscivores – few
Granivores – dense
Woodpeckers


Usually present in pharynx
Also secrete amylase

Swifts and Swallows




<http://news>

Many use dried saliva to cement their nests




Edible Swiftlet



Hong Kong largest consumer of bird nests, importing about a hundred tons every year, at a price of about U.S. \$25 million.


Suppliers are Indonesia, Malaysia, Myanmar, Singapore, southern parts of India, Sri Lanka, Thailand, and Vietnam.



Salivary glands enlarge ~ 50x during nest-building

Chimney Swift ~ 12x

Gray Jay – secrete sticky saliva for caching food



IV. Esophagus and Crop

Esophagus – tube connecting oral cavity and stomach

- produces peristalsis
- large in diameter (relative to other verts)
- usually provided with mucous glands and somewhat muscular
- lined with heavy epithelium

A. Storage

Seed-eating finches - side of esophagus has paired out - pockets for storage (swallowed or regurgitated for nestlings)

Geese pack full of food

Large structure for food storage – Crop

Food can be stored ~ 1 day+

If amylase in saliva some digestion occurs in crop

B. Shapes

Figure 7-11 Avian crops: (A) cormorant; (B) vulture; (C) fowl; (D) pigeon; (E) parakeet. (From Pernkopf and Lehner 1937)

Fusiform – Trochilidae, Emberizidae
 Bilobed – Columbiformes
 Single Sac – Falconiformes, House Sparrows


C. Grinding Function

Hoatzin – crop serves as grinding organ

Muscular, numerous glands, contains bacteria

Figure 7-12 Bird stomachs: (A) Domestic Chicken; (B) Anhinga; (C) Hoatzin (all 66 percent of natural size). (After McLelland 1975; Garrod 1876; Pernkopf and Lehner 1937)

D. Crop Milk




Provides food for young

Stratified epithelial lining proliferates under effect estrogen

Estrogen → Growth of lining → Prolactin → Shedding

25-35% lipid
10-15% protein
70% water




Mourning Dove –

- proliferation of lining begins after 8 days incubation
- sloughing 14 – 18 days
- continues to 16 days after hatching

E. Other Functions


Greater Prairie Chicken – anterior end modified as resonating chamber

Air forced into sac from trachea via pharynx



Flamingoes and male Emperor Penguins
Oily esophageal secretion


59% protein
28% lipid



Male E. Penguins incubate alone and
females don't return to nest ~ 7
days after hatching

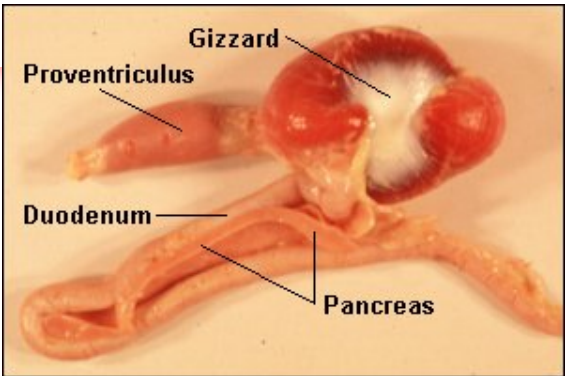
Male has to provide some food

Chicks double body weight on this alone!!!



V. Stomach

Birds possess two kinds of stomachs:
Anterior glandular stomach
Posterior muscular stomach



Gizzard
Proventriculus
Duodenum
Pancreas

A. Proventriculus

Spindle-shaped glandular stomach – avian innovation
Not found in reptiles

Size related to bulk of food intake
Large – piscivores, frugivores, granivores

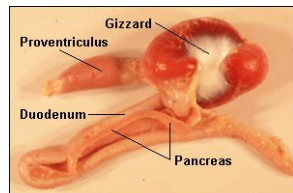
Initial site of protein digestion

- HCl (pH 0.2 – 1.2)
- proteases
- chitinases

B. Ventriculus

Strong muscular organ (granivores)
Prepares food for digestion (analog of teeth)

Mucous glands present in walls – secrete koilin lining



Fruit eaters – glands secrete mucous only, ventriculus has appearance of proventriculus

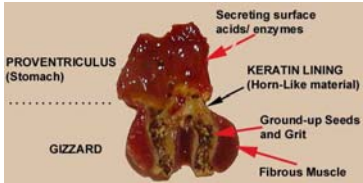


Functions as principle barrier to indigestible material

- feathers
- hair
- bone
- teeth

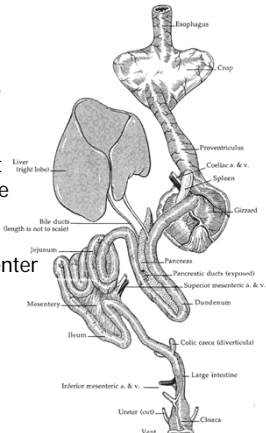


- In granivores may contain grit
- lined with tough, abrasive, keratin layer (koilin) – cutica gastrica



avian gastrointestinal tract - distinct reverse peristaltic movements (Duke 1994).

allows material in the gizzard to reenter the proventriculus for additional treatment with acid and pepsin.




Seasonal change in structure of stomachs corresponding to seasonal change in diet

Bearded Tits

Winter diet – seeds, stomach 0.88 – 1.2g

Summer diet – insects, stomach 0.5 – 0.6g



VI. Small Intestine

Chief organ of digestion and absorption

Once food enters intestine undergoes complete chemical alteration via enzymes

Contents mixed and absorbed by intestinal mucosa

A. Duodenum

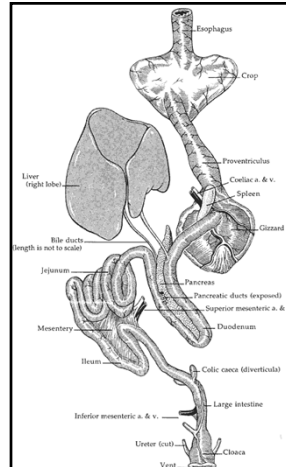
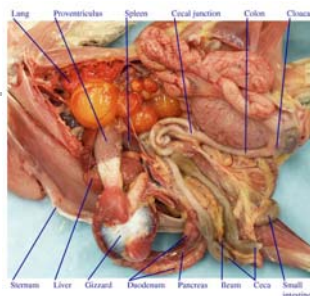
Histologically – not clearly differentiated from rest of stomach

1st loop after stomach




Anatomy

- Small intestine
 - duodenal loop
 - ileum
- generally shorter than mammals



Receives – bile ducts, pancreatic ducts and secretions from glands in mucosa




Secretions

- Amylase
- Saccharidases
- Peptidases
- Lipase
- Maltase, isomaltase
- Sucrase
- Enterokinase
- Secretin, CCK, vasoactive intestinal peptide




B. Function

1. Enzymatic activity – carbohydrases, lipases, proteases, and nucleases
2. Primary site of absorption – by time product reaches large intestine it is completely absorbed

- 
-
3. Length variable – varies with diet,

Long and tightly coiled– granivores,
omnivores

Short and slightly coiled – raptors,
insectivores frugivores

- 
-
4. Retention time related to diet

Long – granivores

Short – carnivores, frugivores



C. Lining

Lined with villi – projections that increase surface area available for absorption.



Villi contain blood vessels, lymph vessels that absorb nutrients for transport



VII. Large Intestine

Primary function is for water & electrolyte reabsorption

No relation between diet and structure

Relatively short organ



Contains minimum amount of non-digestible waste

- wastes voided as quickly as possible
- wastes sometimes voided in other ways (e.g. pellets)

Has out-pockets called caeca

VIII. Intestinal Caeca

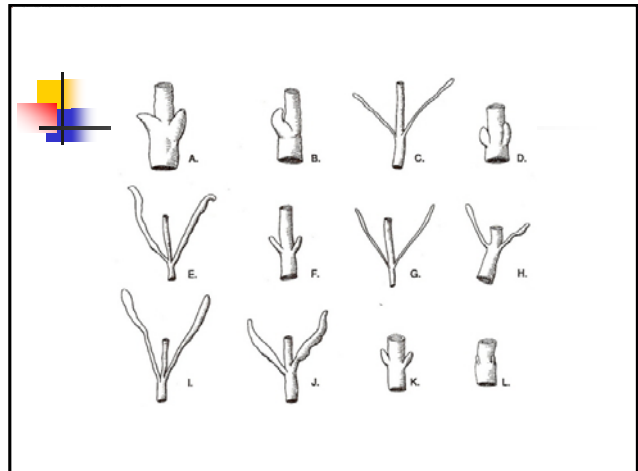
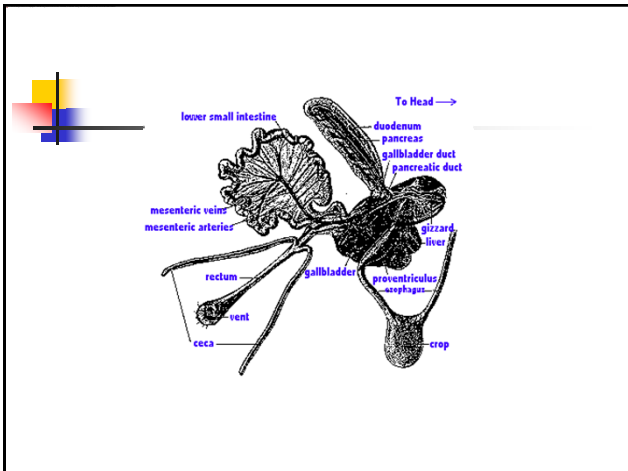
Posterior end of intestine occur pair of caeca


Size variable

Large – Folivores (Cranes, ducks, geese)

Small – Falcons, woodpeckers, insectivores, passerines, piscivores


Absent - Parrots





Functions:


1. Absorption of water
2. Absorption of non-protein nitrogen
3. Digestion of carbohydrates and proteins
4. Microbial breakdown of cellulose
5. Microbial synthesis of vitamins(?)



IX. Cloaca


A. Structure and Function

Receives waste from large intestine and materials from urinary and reproductive systems



Divided into 3 sections

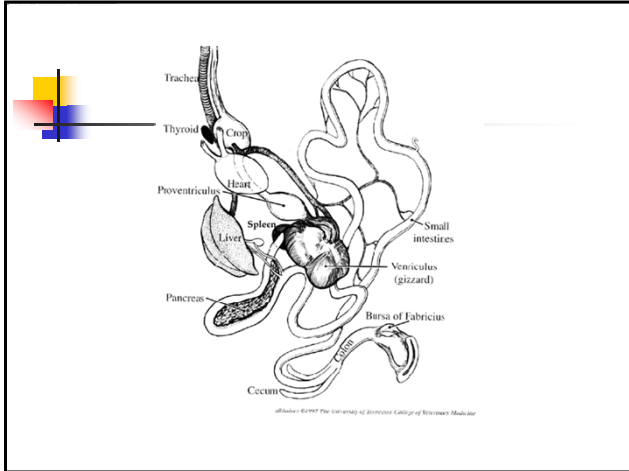
- Coprodaeum – receives waste from large intestine
- Urodaeum – receives urine from kidneys (via ureters), sperm and eggs from gonads
- Proctodaeum – stores (temporarily) and ejects materials; closed posteriorly by muscular anus



B. Bursa of Fabricus

Located on dorsal wall of cloaca

Lymphatic pocket prominent in young birds but atrophied in adults



Serves as the area where B – lymphocytes (wbc that produce antibodies) are generated.

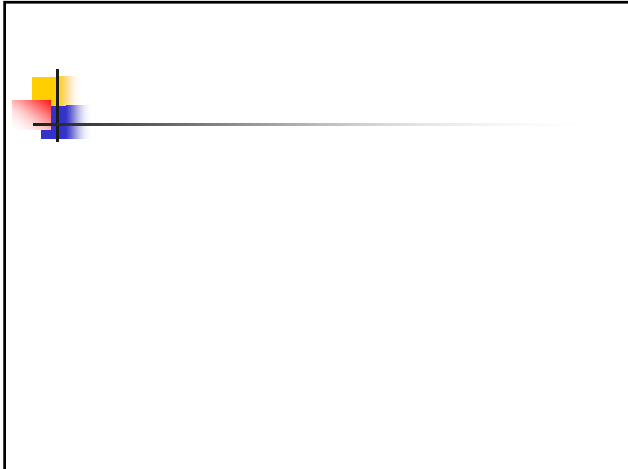
Once produced B – lymphocytes migrate to lymphoid tissue in other parts of body.

Farmer and Breitenbach (1966) inoculated 2 wk old chickens with malaria

½ had Bursa Fabricius removed

Controls recovered, but 11 of 15 bursectomized died

Now - Go take the Test!



Motility

- Food in the mouth stimulates salivation and swallowing
- Food in the esophagus or crop is directed by the gizzard contraction state
- Coordinated gastroduodenal contractions
 - thin muscles-> duodenum-> thick muscles-> proventriculus
 - about 3 cycles per minute

Motility

- Refluxes of GI contents
 - gizzard to proventriculus
 - small intestine to gizzard
 - cloaca to colon or rectum
- Egestion
- Passage rate

Regulation of feeding

- Body weight and age
- Environmental temperatures
- Day Length
- Activity
- Reproductive cycle
- Food quality
- Water availability
- Food energy content



Digestibility

- In birds, because of the combined urine and fecal excretion, metabolizability is usually determined rather than digestibility