Osmoregulation by Birds

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Maintenance of the Internal Environment

- Osmoregulation means the maintenance of the homeostasis of internal environment.
- What constitutes the internal environment?

Birds osmoregulated well

Birds inhabit all environments

- Aquatic
  - Fresh water
  - Marine
  - Estuaries
- Terrestrial
  - Polar
  - Temperate
  - Desert

In terms of osmoregulation, mammals are the unusual group

Kidneys are only osmoregulatory organ

Osmoregulation among other vertebrates

- Fish, amphibians, reptiles, and birds
- Multiple organs function in osmoregulation

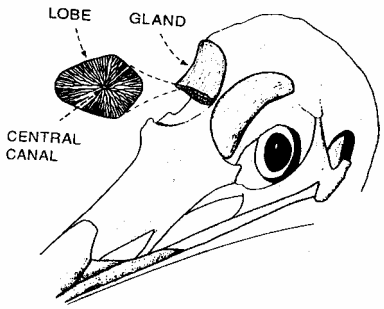
ORGANS THAT CONTRIBUTE TO OSMOREGULATION IN VERTEBRATES

Group	Osmoregulatory Organs
Fish	Kidneys Gills Bladder Intestine
Amphibians	Kidneys Gills Bladder Skin Intestine
Reptiles	Kidneys Salt Glands Intestine
Birds	Kidneys Salt Glands Intestines
Mammals	Kidneys

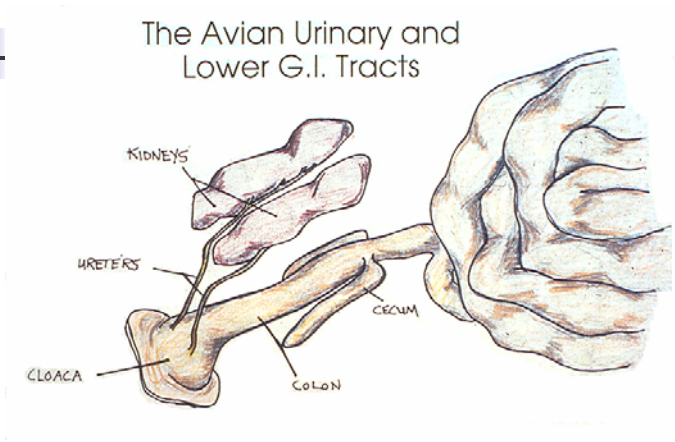
Osmoregulation by birds: Organs Involved

- Kidneys
- Lower gastrointestinal tract
- Salt glands

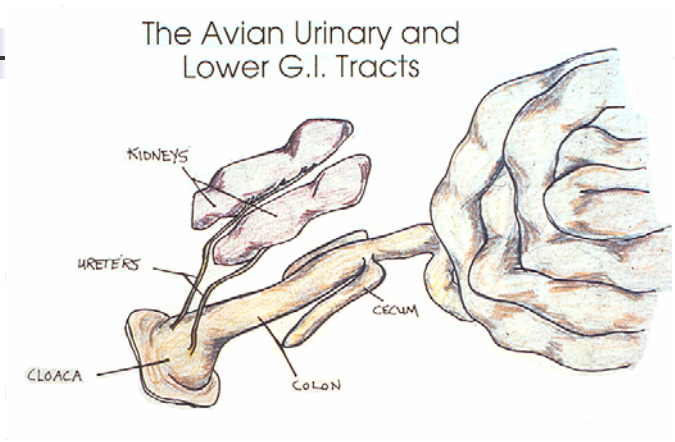
Avian salt glands



The avian renal and gastrointestinal systems must function in concert in the regulation of ion and fluid balance.



As birds do not have urinary bladders, the ureteral urine is refluxed from the cloaca into colon



Evolutionary Rationale for this Type of Arrangement

(i.e. urine entering lower GI tract)

Excess mass of urinary bladder

- GFRs of Birds and Mammals Do Not Differ
- Fraction of Filtered Water Reabsorbed by Kidney
  - Less by Avian Kidney
  - Urine of Birds in Constant "Flux"
- Argument does not "hold water"

Urine to plasma osmolar ratio

How well kidneys of animals concentrate urine is
Usually expressed as the ratio of the urine osmolality
To the plasma osmolality.

Or simply the U/P_{osm}

Birds or the avian kidney does not concentrate urine to a high degree

Maximum U/P_{osms} of some mammals

Values range from about 1 in the Mountain Beaver to ca. 25 in some of the small desert Rodents.

Humans U/P_{osm}?

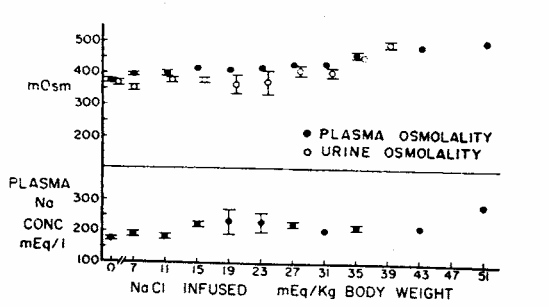
Urine-to-Plasma Osmolar Ratios for Birds

	(U/P_{osm})
Ring-necked Pheasant	1.5
Senegal Dove	1.7
Savannah Sparrow	1.7
King Quail	1.8
White-crowned Sparrow	1.8
Domestic Fowl	2.0
Budgerigar	2.3
House Finch	2.4
Singing Honeyeater	2.4
Stubble Quail	2.6
Mean	2.05

Comparison of U/P_{osms} between birds and mammals

- Not valid comparison to make
  - Urine in lower GI tract
    - Effects of conc. fluid in lower GI tract
  - End products of nitrogen metabolism
    - Uric acid vs. urea
      - Urea ca. 50% of solutes in urine
      - Uric acid not in solution

- Plasma and urine osmolality of Desert Quail



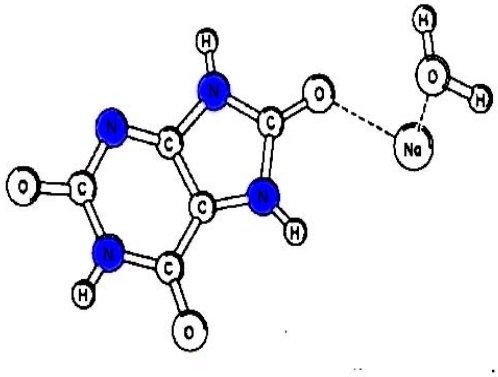
Nitrogen Excretion in Birds

Compound	Percent
Urea	4
Ammonium	20
Uric Acid	76

Solubilites of Nitrogen-Containing Compounds

Compound	Solubility (mmol/L)
Uric Acid	0.381
Ammonium Urate	3.21
Sodium Urate	8.32
Potassium Urate	14.75
Urea	16,650

Structure of Uric Acid



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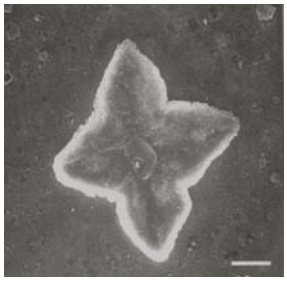
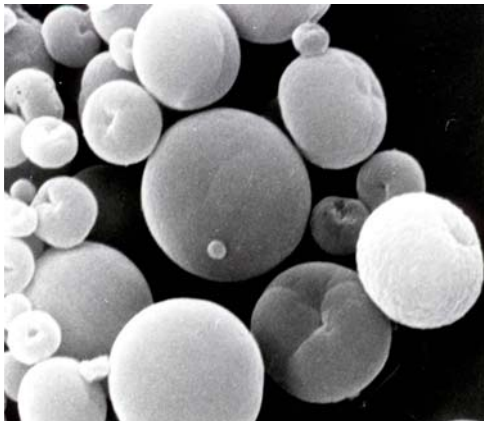
Crystal of Uric Acid



Evolutionary Rationale for this Type of Arrangement (i.e. urine entering lower GI tract)

Physical form of uric acid in avian urine



Small spherical structures

Spheres ca. 65% uric acid

Uric acid bound To a matrix protein

Prevention of Sphere Coalescence

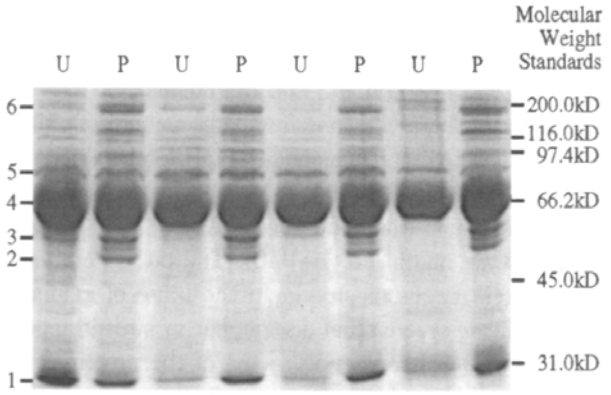
Protein in avian ureteral urine

Avian urine contains 5 mg/ml protein

Protein conc. in human urine
ca. 0.05 mg/ml

Nature of Protein in Urine of Birds

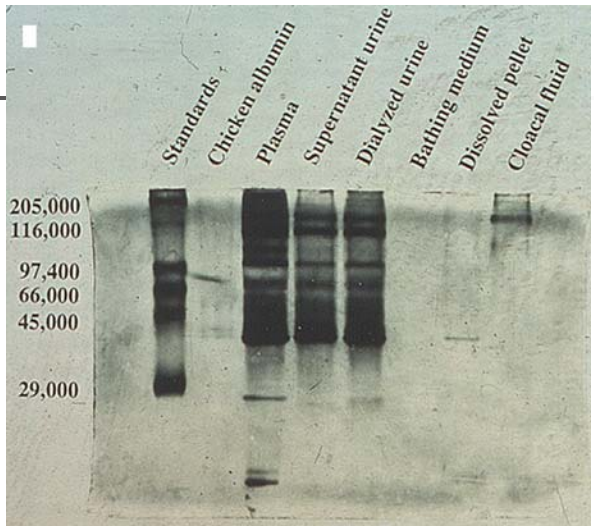
SDS PAGE of avian Urine and plasma



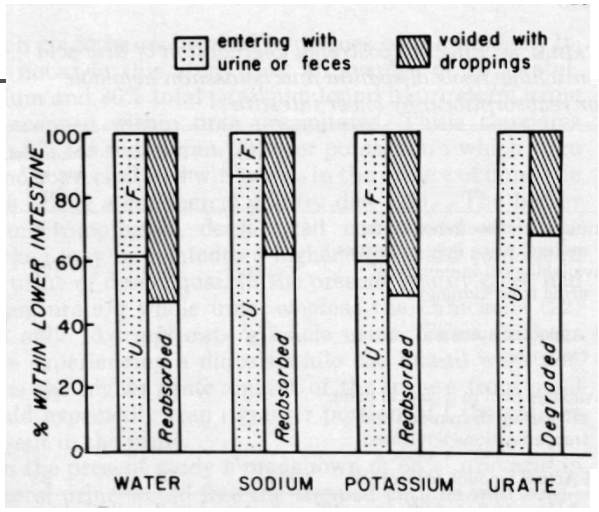
Energy in Avian Ureteral Urine

	Male	Female
Kcal/Day	5.3	12.4
% BMR	5.4	11.3

SDS PAGE of Avian Excreted Fluid



Modification of Urine in Lower GI Tract of Birds



Degradation of Uric Acid in Lower GI Tract

- ❖ 68% of uric acid in ureteral urine
  - ▪ Bacterial action
    - • Fate of liberated nitrogen
      - o Glutamic acid
        - ✓ Renal tubules--Buffer H ions
        - ✓ Gluconeogensis
        - ✓ Citric acid cycle
      - o Short chain volatile fatty acids

Products Formed From the Breakdown of Uric Acid in Avian Lower GI tract

77% of [^{15}N]uric acid introduced into ceca of cockerels disappeared in 60 min

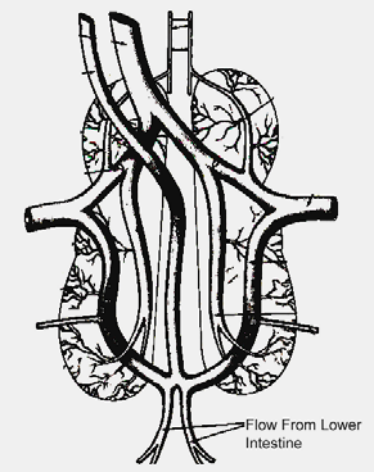
Labelled nitrogen appeared in plasma within glutamine

And nitrogen appeared as ammonia and rapidly absorbed

Where do these product go?

Karasawa, 1989

Vasculature Surrounding the Avian Kidney



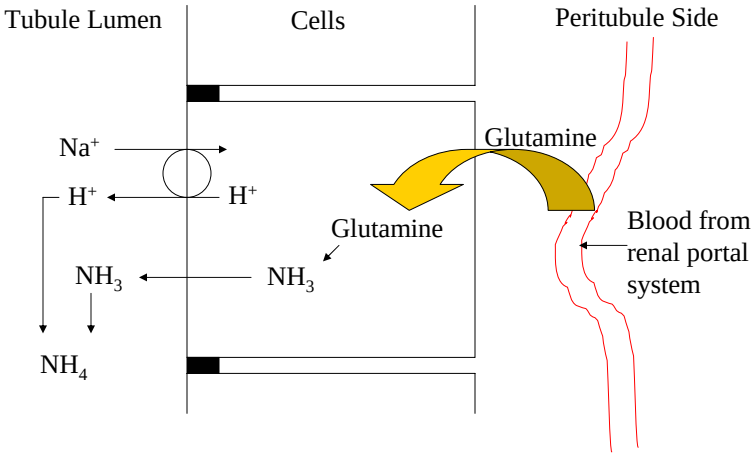
Coccygomesenteric vein drains into renal portal system

Birds have a functional renal portal system

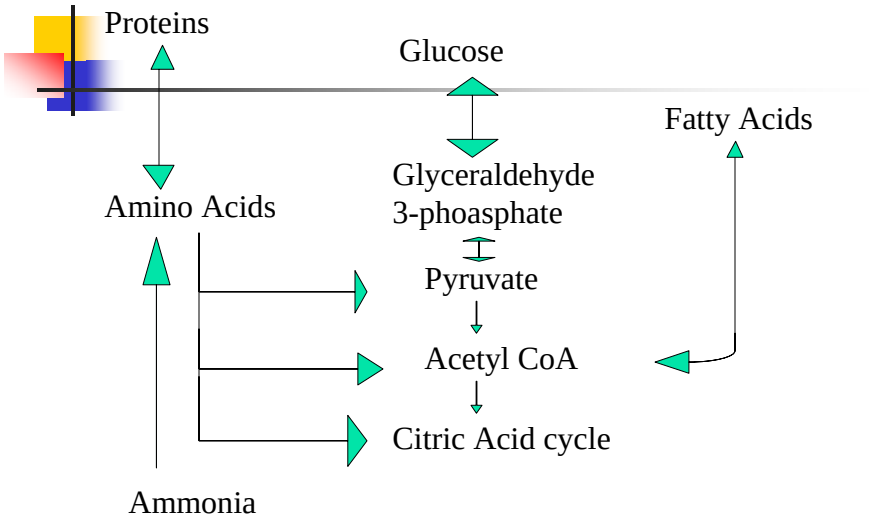
Akester

Use of glutamine by renal tubules

(To buffer hydrogen ions)



Possible Pathway for Utilization of Uric Acid



Also, deamination of glutamine produces ketoglutaric acid that can enter the krebs cycle

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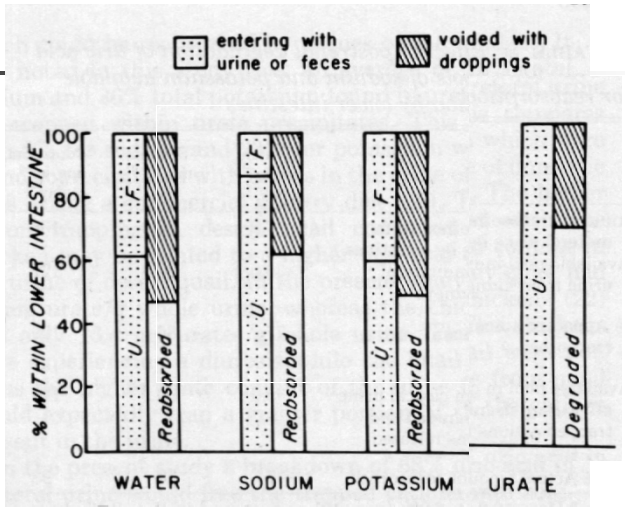

Anderson & Braun