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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

<u>Group</u>
Fish
Amphibians

Osmoregulatory Organs

**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



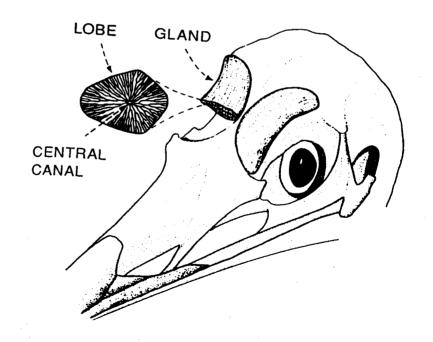
#### Kidneys

Lower gastrointestinal tract

Salt glands



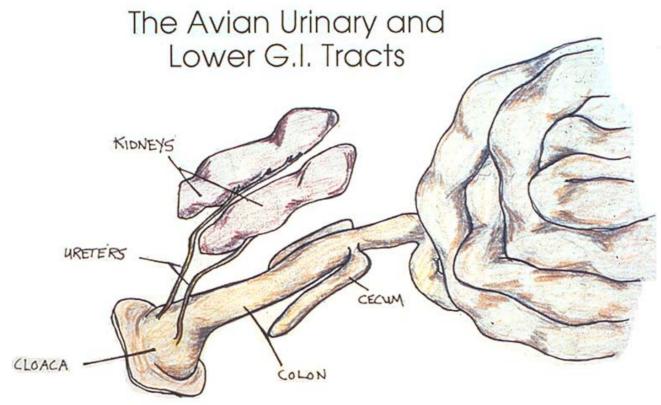
#### Avian salt glands





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

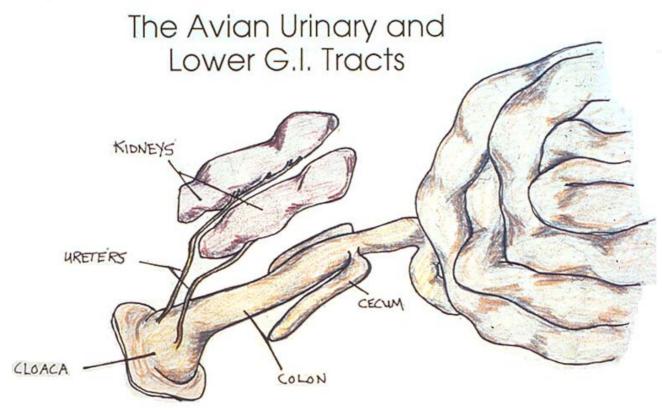






As birds do not have urinary bladders, the ureteral urine is refluxed from the cloaca into colon





#### 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<sub>osm</sub>



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



### Maximum U/P<sub>osms</sub> 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<sub>osm</sub>?

#### Urine-to-Plasma Osmolar Ratios for Birds

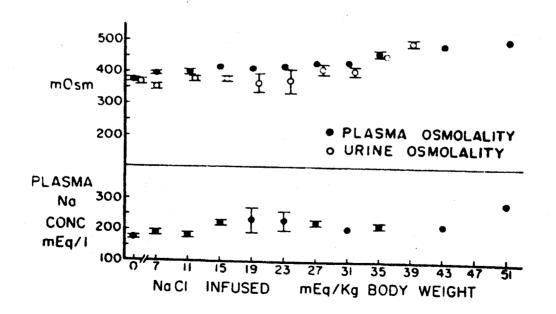
	$(U/P_{osm})$
Ring-necked Pheasant	1.5
Senegal Dove	1.7
Savannah Sparrow	1.7
King Quail	1.8
White-crowned Sparrow	1.8
Domestic Fowl	2.0
Budgerigar	2.3
House Finch	2.4
Singing Honeyeater	2.4
Stubble Quail	2.6
Mean	2.05



### Comparison of U/P<sub>osms</sub> 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. ureaUrea ca. 50% of solutes in urineUric acid not in solution

#### Plasma and urine osmolality of Desert Quail





#### **Nitrogen Excretion in Birds**

Compound	Percent
Urea	4
Ammonium	20
Uric Acid	76

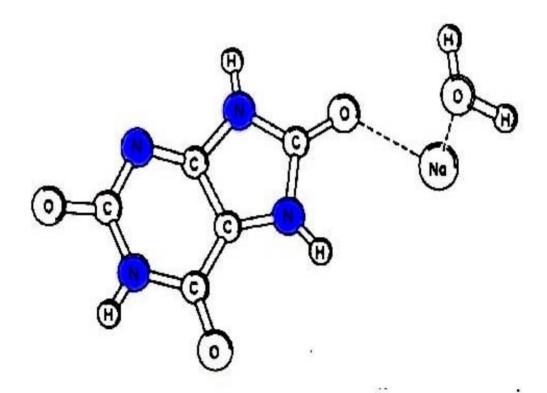


#### Solubilites of Nitrogen-Containing Compounds

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



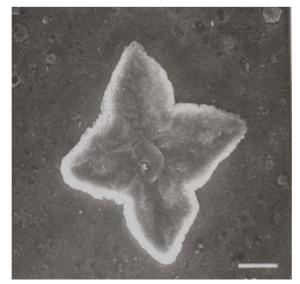
#### **Structure of Uric Acid**





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

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

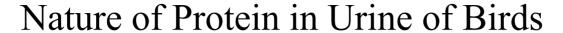


#### **Prevention of Sphere Coalescence**

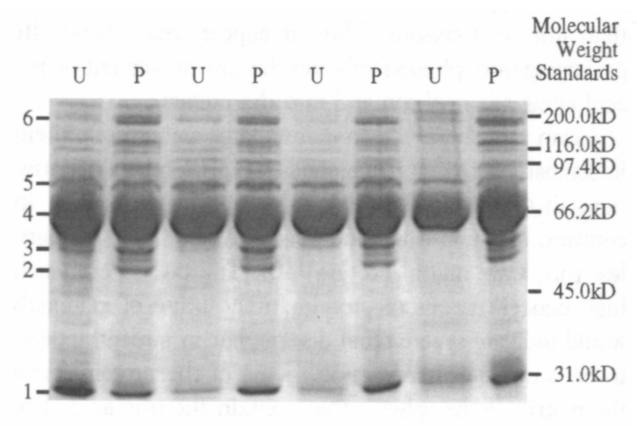
Protein in avian ureteral urine

Avian urine contains 5 mg/ml protein

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



SDS PAGE of avian Urine and plasma



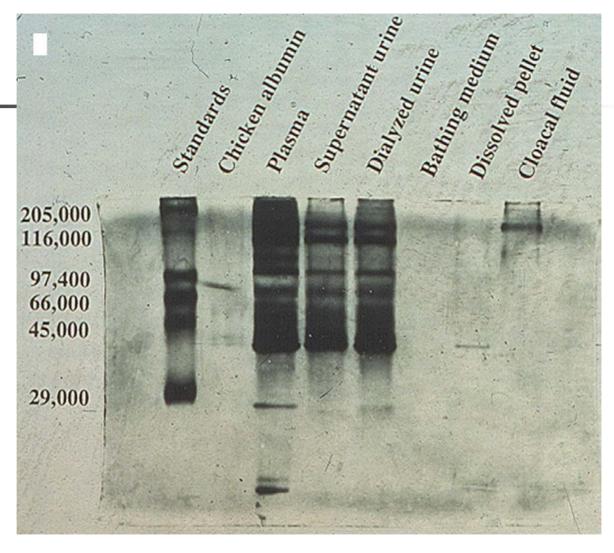




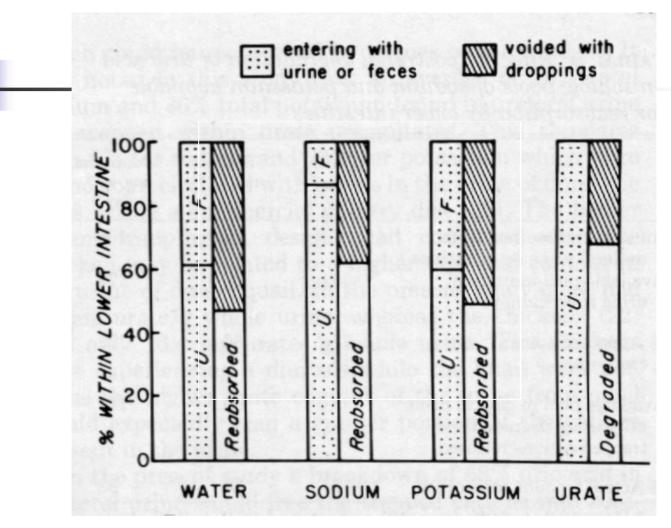
#### Energy in Avian Ureteral Urine

	<u>Male</u>	<u>Female</u>
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 [15N]uric acid introduced into ceca of cockerels disappeared in 60 min

Labelled nitrogen appeared in plasma within glutamine

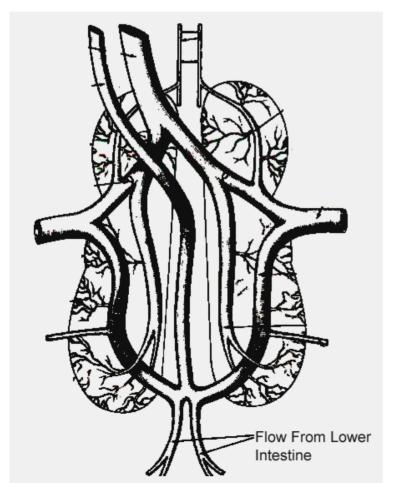
And nitrogen appeared as ammonia and rapidly absorbed

Where do these product go?

Karasawa, 1989



#### Vasculature Surrounding the Avian Kidney



Coccygomesenteric vein drains into renal portal system

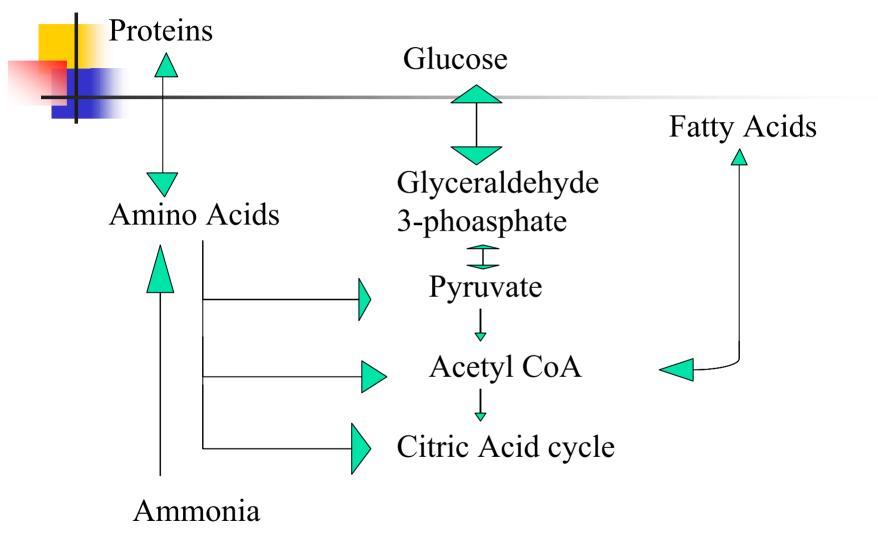
Birds have a functional renal portal system

Akester

# Use of glutamine by renal tubules (To buffer hydrogen ions)

Tubule Lumen Peritubule Side Cells Glutamine  $Na^+$  $H^+$ Blood from Glutamine renal portal NH<sub>3</sub><sup>+</sup> **◆** system  $NH_4^+$ 

#### Possible Pathway for Utilization of Uric Acid



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