Osmoregulation and Disposal of Metabolic Wastes Notes

AP Biology Mrs. Laux

I. Water in a multicellular animal

A. Terrestrial animals

→water is the main constituent in any animal: 60-98%

1. cells of most animals, all but cnidarians and sponges, are bathed in extracellular fluid

a. open circulatory system: hemolymph

b. closed circulatory system: interstitial fluid and blood

2. water enables internal environment of an animal to remain stable

a. prevents temperature fluctuations

b. allows for diffusion of nutrients, wastes, and gases

c. dissolves wastes for easier exit from body

3. excretory system, in addition to eliminating wastes from the body, also controls osmoregulation in the organism

a. water→waste product of cellular respiration

b. maintains concentration of water by excreting or maintaining solutes

B. Aquatic Animals

1. face problem of osmosis

2. must carry out osmoregulation

→absorption and excretion of water and dissolved solutes so proper water balance is maintained

a. marine animals

i. environment: 96.5% water, 3.5% dissolved solutes

ii. most marine invertebrates are isotonic to water

iii. bony fishes are hypotonic; therefore, water is constantly being lost

a. compensate by:

i. drinking large amounts of water

ii. pumping excess salt through gills

iii. excrete only small amounts of urine- very concentrated

b. freshwater animals→hypertonic to environment: therefore, water consistently rushes in

i. in constant danger of taking on too much water

ii. compensate by:

a. excreting large amounts of dilute urine

b. salts constantly diffuse out: therefore, compensate by eating substances high in salt concentration and by actively taking in salt ions by gills

C. Terrestrial animals

1. cannot survive desiccation

2. humans die if they lose 12% total water

3. ways animals reduce water loss:

a. arthropods→waxy cuticles

b. snails→shells

c. vertebrates→multi-layered skin of epithelial cells
d. drinking, eating, metabolic activities (respiration and condensation synthesis) replaces water loss
e. desert animals→nocturnal
f. some animals (ex: kangaroo rat) produce large amounts of water as metabolic wastes
g. excretory organs→conserve water while eliminating toxic substances

II. Excretory organs in animals

A. Protists (*Paramecium, Amoeba*)

1. contractile vacuole in freshwater protozoans
2. accumulate water, merge with plasma membrane and expel water
3. prevents uptake of too much water

B. Invertebrates have evolved nephridia

→simple or branching tubes that take up wastes and excrete through a pore to the external surface of an organism

1. Platyhelminthes (Planaria)

a. protonephridia

i. tubes with no internal openings
ii. large ends→flame cells (bulbs)

a. interstitial fluid passes into a flame cell as it is propelled by action of cilia ("flame")
b. excretes nitrogenous wastes, salts, and water through pores at end of protonephridia onto body surface
c. most parasitic tapeworms are isotonic to host; therefore, osmoregulation is not a big problem

2. Annelida (earthworms)

a. metanephridia

i. each segment has one pair
ii. excretory tubes with internal and external openings to collect body fluids
iii. inner opening→nephrostome (ciliated funnel)→collects interstitial fluid [FILTRATION]
iv. fluid collects through collecting tubule
v. blood capillaries surrounding the tubule reabsorb the needed materials [REABSORPTION]
vi. at end of tubule, dilute urine is excreted through nephridiopore
vii. adaptations:

a. tube-like excretory system where body fluids are selectively filtered as they pass through tube
b. also, loss of water (not much is reabsorbed) offsets the continual loss of water from damp soil across skin

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C. Insects→Malpighian tubules

1. remove osmotic wastes from hemolymph and regulates osmotic pressure

2. outpocketing of gut

3. dead-end at tip and are bathed in hemolymph

4. lining collects: [FILTRATION]

a. by diffusion: solutes and water

b. by active transport: uric acid, K+ ions, salts

→accumulation of N-wastes and salts bring water by osmosis

5. fluid in tubules pass into hindgut (with undigested food) to rectum

6. salts and water are reabsorbed across epithelium of rectum

7. dry N-wastes (uric acid) and other wastes (salts) are excreted with feces

8. uric acid-solid-adaptation that allows for water regulation and avoids desiccation

D. Vertebrates-kidneys

1. compact organs that contain millions of tubules called nephrons

a. each nephron is associated with a dense capillary network

b. function in both excretion and osmoregulation

2. excretory system

a. kidneys

b. blood vessels serving the kidneys

c. structure that carries urine from kidneys out of body

→variations of basic system are found among vertebrate classes

d. aquatic vertebrates-freshwater fishes

i. continuous challenge of osmoregulation

ii. take in water osmotically

iii. excrete large volume of dilute urine

e. marine bony fishes

i. lose water osmotically

ii. compensate by drinking seawater

iii. excrete salt through gills

iv. small volume of urine produced

f. marine cartilaginous fishes

i. retain large amounts of urea

ii. take in water osmotically through gills

iii. water used to excrete a hypotonic urine

g. marine birds and reptiles

i. salt glands excrete excess salt

h. Mammals

i. kidney-bean shaped organ- ~10 cm long; 2 of them

ii. blood to kidney→renal artery, back to heart via renal vein

iii. urine exits each kidney through a ureter (2) and both drain into a urinary bladder
iv. leaves body through urethra
→sphincter muscles at junction of urethra and bladder- control urination

III. The Nephron-functional unit of kidney
A. Structure of kidney
1. outer renal cortex
2. middle renal medulla
a. contain 8 to 10 renal pyramids
i. tip of each pyramid is a renal papilla
ii. as urine is produced flows into collecting ducts, empty through renal papilla into #3
3. inner renal pelvis
4. each region contains many microscopic nephrons and collecting ducts
5. each nephron is associated with its own network of capillaries
B. Structure of a nephron
1. Bowman's capsule
a. end of nephron that receives filtrate from blood
b. cup shaped
c. surrounds ball of capillaries called glomerulus
i. branch off renal artery to renal arteriole to glomerulus to efferent arteriole to
ii. peritubular capillaries, which wrap around renal tubule, then regroup to form renal vein
→exchange nutrients and wastes with nephron
→reabsorption
d. water, salts, urea, and other small molecules are separated from blood in glomerulus and enter Bowman's capsule
e. material that leaves glomerulus and enters Bowman's capsule is called the filtrate
2. Renal tubule
a. 3 sections
i. proximal convoluted tubule
ii. loop of Henle
iii. distal convoluted tubule
b. whole renal tubule is surrounded by capillaries
3. filtrate empties into collecting duct
a. one duct receives filtrate from many nephrons
b. filtrate is now urine (pee-pees)
c. flows through collecting duct and into renal pelvis→space inside kidney
4. Cortical nephrons
a. small glomeruli
b. located almost entirely in cortex or outer medulla

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5. Juxtamedullary nephrons

a. large glomeruli

b. long loops of Henle, extend deep into medulla

c. important in concentrating urine

C. Kidneys regulate the composition of blood via filtration, secretion, and reabsorption

1. Filtration

a. blood pressure forces fluid (plasma) from glomerulus across Bowman's capsule (inner wall, podocytes, serve as filtration membrane) to convoluted tubule

b. filtrate→(non-selective) glucose, salts, vitamins, nitrogenous wastes (urea) and small molecules

→similar in concentration to blood plasma

→larger substances, blood cells stay in blood

2. Secretion

a. filtrate is joined by substances in the interstitial fluid that flow into nephron

b. adds solutes to filtrate

c. occurs in proximal and distal tubule

d. very selective process

e. substances: K^+, H^+, NH_4^+, penicillin

i. H^+→regulates pH

ii. K^+→allows for nerve transmission

→too high and nerves don't work properly; heart is weakened

f. involves both active and passive transport

3. Reabsorption-99% of filtrate reabsorbed

a. highly selective process in which filtrate substances are transported from nephron→ICF→capillaries (vasa recta)

b. reclaims small molecules that are essential to body (glucose, a.a., water)

c. occurs in proximal and distal tubule, loop of Henle, and collecting duct

d. nearly all sugar, vitamins, organic nutrients, and water are reabsorbed

e. wastes, excesses to be excreted

4. Secretion and reabsorption modify the composition of filtrate

a. concentration of beneficial substances in filtrate is reduced

b. concentration of wastes and non-useful ions is increased and excreted

5. therefore, Kidneys are central to homeostasis

a. clear metabolic wastes from blood

b. respond to fluid imbalances by selectively secreting ions

6. Urine consists of:

a. excess water, nitrogenous wastes, excess salts, and other substances not needed by the body

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D. Properties of Nephron and Collecting Duct:

1. proximal tubule

→reabsorption and secretion

a. here, ammonia, drugs, and poison from liver are secreted to join filtrate

b. nutrients, glucose, water, and a.a. are reabsorbed by active transport: tube→ICF→blood in capillaries

2. Descending limb of loop of Henle

→reabsorption

a. freely permeable to water, not to salts, solutes

b. water diffuses out of tubule

c. therefore, filtrate becomes more concentrated

3. Ascending limb of loop of Henle

→reabsorption

a. permeable to salts, not to water

b. salts diffuse out

c. therefore, filtrate becomes more dilute

4. Distal tubule

→ secretion and reabsorption

a. regulates K+, Na+, Cl- ions' concentration in body fluids by regulation of secretion into filtrate and reabsorption from filtrate

b. osmoregulation

i. salts are secreted→water follows and leaves body

ii. salts are reabsorbed, water follows and water is retained

c. also regulates pH by controlling the secretion of H+ and reabsorption of bicarbonate

5. Collecting ducts

a. carries filtrate back through medulla into renal pelvis

b. permeable to water, not salt

i. will diffuse to hypotonic fluid outside duct

ii. result→concentrated urine

E. Regulation of kidney function

→concentration of salts in urine; therefore, osmoregulation

1. Antidiuretic hormone (ADH):

a. increases reabsorption of water by increasing the permeability of the distal tubule and collecting duct to water

b. makes more concentrated urine

c. ADH is produced in posterior pituitary

d. when large volume of water has been ingested, little ADH is released and kidneys produce dilute urine

e. alcohol inhibits ADH→causing dehydration

2. Aldosterone and atrial natriutetic peptide (ANP)

a. increases reabsorption of water by increasing reabsorption of Na+

b. increases distal tubule permeability to Na+
c. increases concentration of Na+ in ICF that surrounds tubule, causes water to follow
d. when blood pressure decreases, cells of juxtaglomerular apparatus secrete
i. renin-activates production of
a. angiotensin II, hormone that increases release of aldosterone

F. Nephrons vary in structure and function for osmoregulation in different vertebrates

→allows adaptation to various habitats
1. desert animals have a long loop of Henle
a. allows large amounts of water to be reabsorbed, excreting very concentrated urine
2. aquatic environment mammals (beavers) have short loops of Henle
a. small amount of water reabsorption; therefore, very dilute urine

G. Nitrogenous wastes-different forms:

→vary with structure and habitat of mammal
→deamination (metabolism) of amino acids, nucleic acids; produces ammonia
→small, very toxic waste
→some animals excrete NH3 directly; others first convert to urea or uric acid
1. Ammonia
a. excreted directly by most aquatic animals
b. easily permeates membranes because very soluble
c. sometimes NH4+
2. Urea
a. NH3 is unsuitable for terrestrial habitat
b. produced in the liver from ammonia
c. far less toxic than ammonia; can accumulate in higher concentrations without causing tissue damage
d. highly soluble in water

3. Uric acid
a. produced from ammonia and breakdown of nucleotides from nucleic acids
b. insoluble in water
c. excreted as a crystalline paste; important water conserving adaptation
d. insects, birds, reptiles
i. in birds: no urinary bladder; frequently excreted as part of feces; keeps them light for flight
e. non-toxic
i. advantage, if start life as an enclosed egg

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