Thermo- and Osmoregulation

[Note: This is the text version of this lecture file. To make the lecture notes downloadable over a slow connection (e.g. modem) the figures have been replaced with figure numbers as found in the textbook. See the full version with complete graphics if you have a faster connection.]

• **<u>Thermoregulation</u> = maintaining the most efficient body temperature**

Many physiological functions <u>generate heat</u> and are also <u>influenced</u> by heat.
(e.g. enzymes have ideal temperatures for maximal activity)

[See Fig. 40.7]

"<u>Goldilocks & the Three Bears</u>" <u>phenomenon....</u>

Colder is usually slower -- too cold = too slow = death
Hotter is usually faster -- too hot = denaturation = death
Warm is "just right"

Four ways of exchanging heat with the environment

1) <u>Conduction</u>: H_2O is 50-100X more effective than air, 2) <u>convection</u>: "wind chill factor," 3) <u>evaporation</u>: depends on H_2O in air, 4) <u>radiation</u>: emit or absorb IR wavelengths

[See Fig. 44.1]

Radiation of heat is in the <u>infrared</u> band of the <u>electromagnetic spectrum</u>

[See Fig. 10.5]

• **<u>Endotherms</u> are animals that generate their own heat--resting metabolic rate is called basal = BMR**

• **<u>Ectotherms</u> are animals that get most of their heat from their environment--metabolic rate depends on enviro. temp. and is called standard = SMR**

<u>metabolic rate</u> = rate of energy <u>consumption</u>. Units are usually kcal/time (e.g. kcal/day)

At 20ºC air temperature: MR for humans is 1300-1800 kcal/day whereas for a reptile, it can be as low as 60 kcal/day.

[See Fig. 44.2]

mammal body temp = 36-38ºC
birds = 40-42ºC

Four categories of adaptations for thermoregulation

1. <u>Regulation of heat exchange</u> with the environment

A. <u>Insulation</u> (e.g. hair, feathers, fat)

[polar bear]

Four categories of adaptations for thermoregulation

1. <u>Regulation of heat exchange</u> with the environment

B. <u>Vasodilation/vasoconstriction</u>

[See Fig. 42.11]

Four categories of adaptations for thermoregulation

1. <u>Regulation of heat exchange</u> with the environment

C. <u>Countercurrent heat exchange</u>

[See Fig. 44.3]

Four categories of adaptations for thermoregulation

1. <u>Regulation of heat exchange</u> with the environment

C. <u>Countercurrent heat exchange</u>

[See Fig. 44.6]

Tuna and white shark are endotherms that <u>generate heat with muscle</u> and use <u>countercurrent</u> to reduce loss to cold ocean.
(red = cold blood from gills, blue = warmer blood through body)

Four categories of adaptations for thermoregulation

2. Evaporation of water releases heat (usually by panting or sweating), and depends on humidity.

Four categories of adaptations for thermoregulation

3. <u>Behavioral adaptations</u>, including <u>migration</u> to a different climate or a different place in the region (like a cat on a warm lap, or a snake on a warm road)

[See Fig. 44.1]

[See Fig. 51.12]

Four categories of adaptations for thermoregulation

4. <u>Heat production</u>: endotherms can increase heat production by

a) moving or shivering
b) <u>non-shivering thermogenesis</u>

Hormones can trigger some tissues to <u>generate heat</u> instead of ATP

(e.g. <u>brown fat</u> is composed of adipocytes specialized to generate heat)

[See Fig. 40.7]

"Blood, sweat, fat and hairs"

Skin is designed to regulate body temperature

1. <u>hair</u> traps heat, regulated by <u>piloerection</u> (raising hair)

2. fat used for insulation

[See Fig. 44.7]

3. sweat for evaporation

4. blood vessels exchange heat (cooling or heating)

5. controlled by <u>nervous system</u>

[See Fig. 44.8]

Longer term adjustments can be made to changes in temperature

1. Acclimatization: a series of cellular adaptations to a different temperature

- **a) new proteins can be synthesized that work better at the new temp**
- **b) membrane fluidity can be changed (e.g. saturated and unsaturated lipids)**
- **c) stress-induced proteins, including heat-shock proteins, stabilize other proteins against denaturation**

2. Torpor: state of decreased metabolism used to conserve energy or water

- **a) during seasons (hibernation in winter, estivation during summer)**
- **b) daily (sleep)**

Water Balance

Need to maintain blood and interstitial fluid composition

[See Fig. 40.10]

Transport Epithelium

Simple columnar or cuboidal epithelium joined together with tight junctions to force solutes through cells.

[See Fig. 7.30]

Nitrogenous wastes

Breakdown of proteins and nucleic acids generate free amino groups

- **<u>ammonia</u> or ammonium (NH_4^+) is small and <u>highly toxic</u> (can’t be concentrated or stored)**

- **<u>urea</u> is 100,000X less toxic, made in liver, can be concentrated so reduces water loss.**

- **<u>uric acid</u> can be concentrated most, pastelike, best water conservation.**

[See Fig. 44.10]

Osmoregulation

- **The <u>osmolarity</u> of blood is usually ~300 mOsm (milliosmoles)**
300 mOsm = 0.3 M ions like 150 mM NaCl
seawater ~1000 mOsm, and freshwater 0-50 mOsm

- **<u>Osmoconformer</u> has same internal osmolarity as environment**
- **<u>Osmoregulator</u> adjusts internal osmolarity to optimal level**

[See Fig. 44.11]

Land animals balance water <u>gain and loss</u>

Comparison of water handling in <u>humans</u> and desert <u>kangaroo rats</u>

[See Fig. 44.13]

- **Humans die when ~12% water is lost (~5000 ml)**

Outline of water handling in a vertebrate kidney

Step one: <u>filtration</u>, resulting fluid is called <u>filtrate</u>

- **<u>blood pressure</u> forces fluid through size filter, "nonselective"**
- **<u>large proteins and cells stay</u> in blood,**
- **<u>small molecules</u> like salt, sugars, amino acids, nitrogen, and water <u>pass</u> through**

[See Fig. 44.14]

Step two: <u>refinement</u>, resulting fluid is called <u>urine</u>

- **molecules the body needs are <u>reabsorbed</u> into interstitial fluid**
- **extra unneeded molecules that didn't enter filtrate are <u>secreted</u> into fluid.**

The human excretory system

[See Fig. 44.18]

Detailed view of kidney structure

[See Fig. 44.18]

[See Fig. 44.19]

[See Fig. 44.20]

- **<u>Antidiuretic hormone</u> (ADH) regulates blood <u>osmolarity</u> (*diuresis* is increased urination).**
- **<u>Alcohol</u> decreases ADH secretion ⇒ ⇓ H_2O reabsorption ⇒ ⇑ urine volume ⇒ dehydration, <u>salt</u> has the opposite effect (see below)**

[See Fig. 44.21]

• **RAAS (renin-angiotensin-aldosterone) pathway <u>raises</u> blood pressure (Na and H_2O reabsorption in distal tubules)**
• **Atrial natriuretic factor (ANF) <u>decreases</u> BP (CD Na reabsorption)**

[See Fig. 44.21]

ANF decreases renin