Lecture 39
23 April 2008

Vertebrate Physiology
ECOL 437 (MCB/VetSci 437)
Univ. of Arizona, spring 2008

Kevin Bonine & Kevin Oh

1. Metabolism (Ch5)

http://eebweb.arizona.edu/eeb_course_websites.htm



## Housekeeping, 23 April 2008

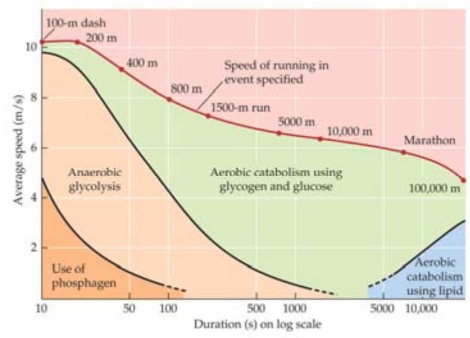
Upcoming Readings
Wed 23 Apr: Ch 4, 5
LAB 23 Apr: Kevin Oh emailed
Final Proposal due in lab 23 April or
beginning of lecture 25 April
Fri 25 Apr: Ch 4,5

Lab discussion leaders: 23 April
1pm – none
3pm – Nina



## Metabolism

## World Class Human Runners




(Hill et al. 6.9)



## Metabolism

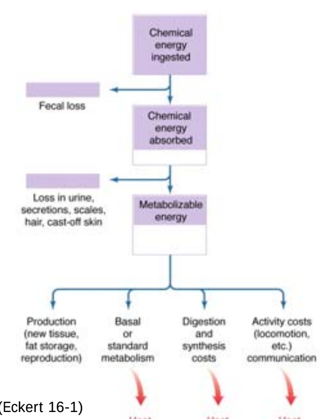
-Chemical reactions in the body
-Temperature-dependent rates
-Not 100% efficient, energy lost as heat
(not 'lost' if used to maintain Tb)

1. Anabolic
-creation, assembly, repair, growth
(positive nitrogen balance)

2. Catabolic
-energy release from complex molecules
(carbos, fats, proteins)
-energy storage in phosphate bonds (ATP) and
metabolic intermediates (glucose, lactate)

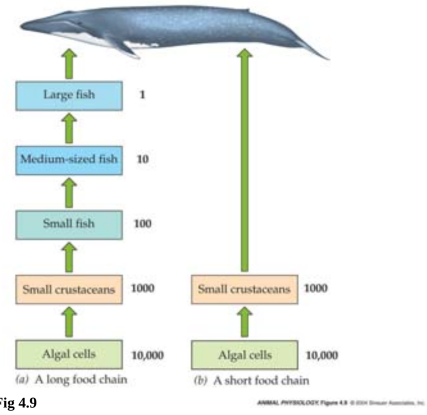


## Chemical Energy




(Eckert 16-1)

10% Rule




Hill et al. 2004, Fig 4.9

Metabolism

**Energy Available for:**

- Growth, Maintenance, Reproduction

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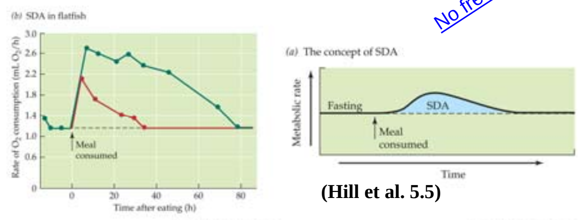
- SDA (specific dynamic action)

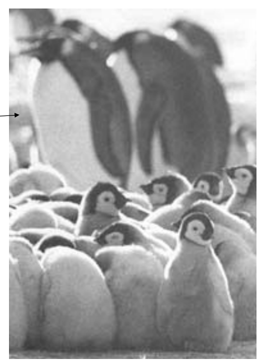
No free lunch!




(Hill et al. 5.5)

Metabolism and Ecology

Male emperor penguin
>100days w/o food when incubating eggs



Knut Schmidt_Nielsen 1997 9

Metabolism and Ecology

K vs. r selected
(logistic curve)

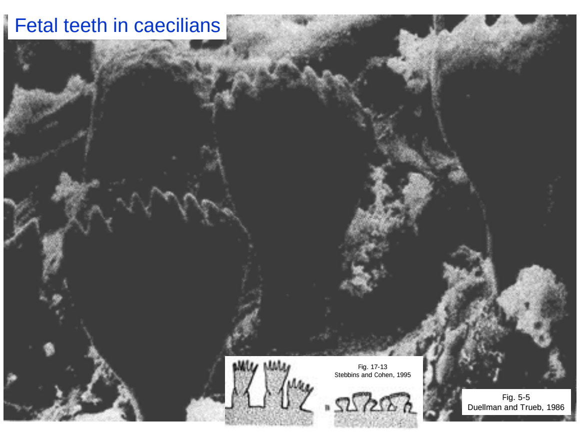
-Larger animals invest proportionally less in reproduction

-Sperm is cheap

-Direct and indirect costs

10

Fetal teeth in caecilians




Metabolic Rate

-measurable conversion of chemical energy into heat

-used to understand:
- -energy budgets
- -dietary needs
- -body size implications
- -habitat effects
- -costs of various activities
- -mode of locomotion
- -cost of reproduction

12

Much more difficult for water breathing animals to maintain body temperatures above ambient because rate of heat transfer is greater than rate of $O_2$ transfer in water (high specific heat)

*Amblyrhynchus cristatus*

SEAL BLUBBER This cross section of a frozen seal shows the thick layer of blubber. Of the total area in the photo, 58% is blubber and the remaining 42% is muscle, bone, and visceral organs. The measuring stick is graduated in inches. [Courtesy of P. F. Scholander, University of California, San Diego]

Knut Schmidt_Nielsen 1997

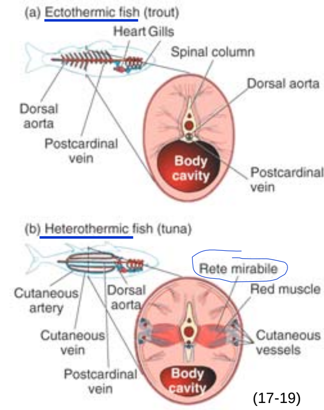


Fish Example:

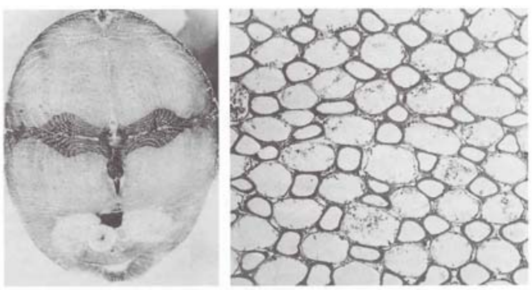
-Differences in vascular organization

-Tuna with warm, aerobic muscle medially

-Countercurrent blood flow (don't lose heat to cold water across gills)




(17-19)



HEAT EXCHANGER Cross section of a 2 kg skip-jack tuna (*Katsuwonis pelamis*) shows how this powerful swimming machine consists mostly of muscle (left). The red muscle, which is maintained at high temperature, appears nearly black in the photo. In some tunas the heat exchanger is located laterally, but in the skipjack the main heat exchanger is located just below the vertebral column, almost exactly in dead center of the photo. A cross section of the vascular heat exchanger (right) shows a roughly equal number of arteries and veins. The arteries (smaller and thick-walled) are interspersed with veins (larger and thin-walled). The diameter of the arteries is about 0.04 mm and of the veins 0.08 mm, and their length is about 10 mm. [Courtesy of E. D. Stevens, University of Guelph, Ontario]

Knut Schmidt_Nielsen 1997

Metabolic Rates

-Basal Metabolic Rate, BMR
  -minimal environmental and physiological stress (appropriate ambient temperature, post-digestive, resting etc.)

-Standard Metabolic Rate, SMR
  -similar to BMR, but at a given Tb

-Field Metabolic Rate, FMR
  -average metabolic rate of animal in natural setting
  -hard to measure



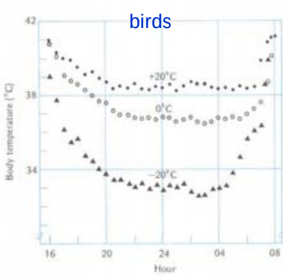
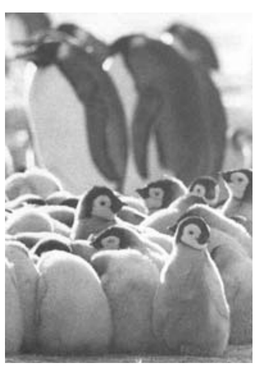



**Figure 7.11** Body temperature of a willow tit (*Parus montanus*) during the night hours at three different ambient temperatures. The records are from midafternoon one day to the following morning. [Reinertsen and Haftorn 1986]

Knut Schmidt_Nielsen 1997



Knut Schmidt_Nielsen 1997



Metabolic Rates

Basal Metabolic Rate, BMR
  -important components:

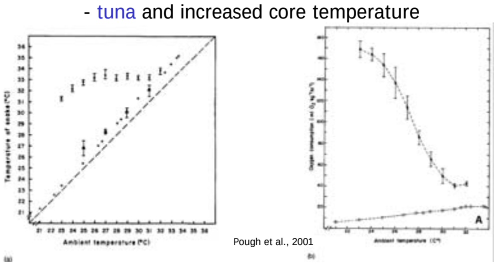
1. Membrane form and function
   maintenance of electrochemical gradients
   -proton pumps in mitochondrial membranes
   -Na/K-ATPase pumps in plasma membrane

2. Protein synthesis

3. ATP formation

Metabolic heat production
(chemical energy 'lost' as heat during metabolism)

-Endotherms
-surface area to volume ratio
-Larger ectotherms can be heterothermic
- leatherback (*Dermochelys coriacea*)
- pythons (female brooding clutch)
- tuna and increased core temperature

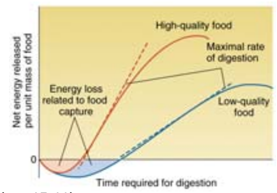



Pough et al., 2001

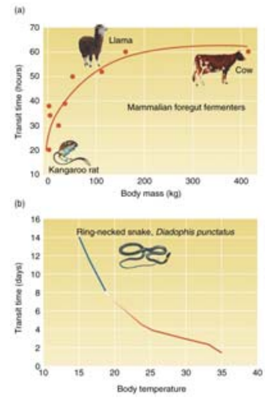
Digestive Systems

Transit time (time to digest), cost, and anatomy variable:

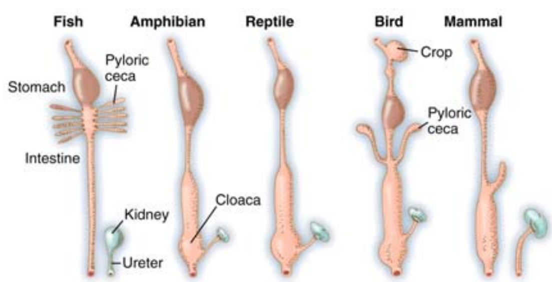
-Food quality
-Body Size
-Temperature (ectotherms)




(Eckert 15-11)




(Eckert 15-12)




(Eckert 15-16)

22

Gut Plasticity

Alter gut size, activity (reversible)

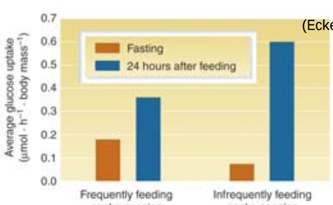
-Sustained increased metabolism can increase bird gut length by 1/5

-Mammals increase GI tract mass 3-4x post-hibernation


23

Gut Plasticity

Alter gut size, activity (reversible)




(Eckert 15-23)

-Some infrequently-feeding snakes:
- intestine 2x larger within 2 days
- microvilli length and area up 400%
- glucose transport rate up as much as 22x
- other transporters also up-regulated (e.g., a.a. absorption)

24

Alkaline Tide...

25