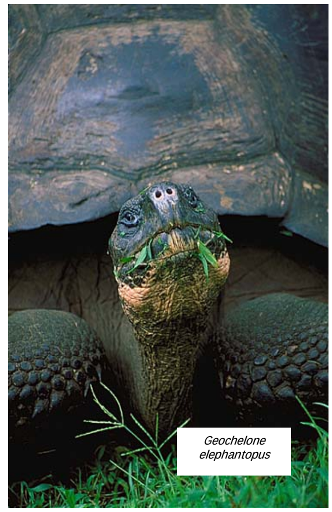
Lecture 38
21 April 2008

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

Kevin Bonine & Kevin Oh




1. Feeding (Ch 4)

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

1

Housekeeping, 21 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

2

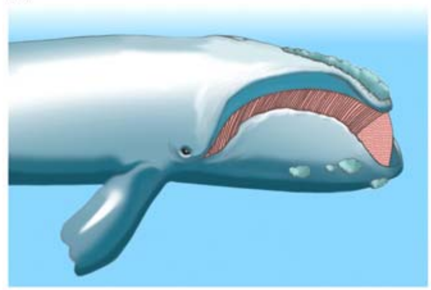
# FEEDING
(Hill et al. Ch 4)

3

## Feeding

Feeding


Filter Feeding
(Suspension Feedir
- -baleen whales
- -flamingoes
- -planktivorous fish with modified gill rakers
- -amphibian larvae




Fluid Feeding
- -lampreys
- -vampire bats
  (analgesic and
  anticoagulants)

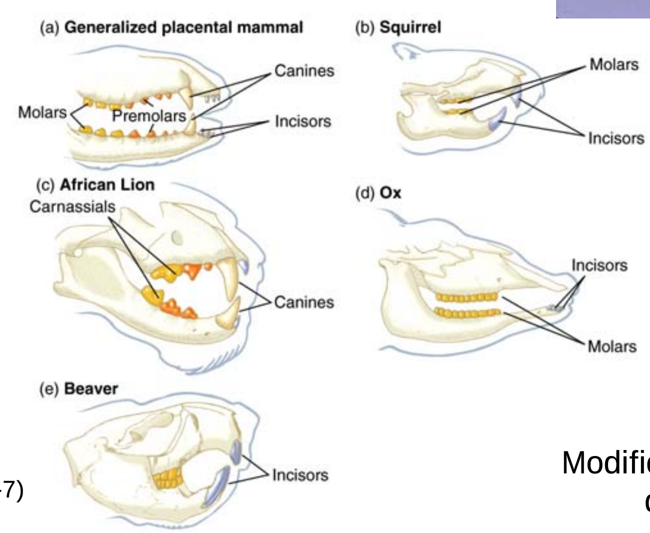
(Eckert 15-3)

5

Seizing with mouth etc.

- -Jaws, teeth, beaks
- -Form and function matched

*Eryx tataricus*



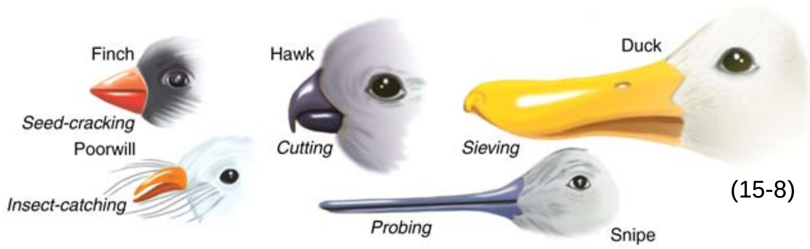

(15-7)

Modification for diet

6

Seizing with mouth etc.

Modification for diet



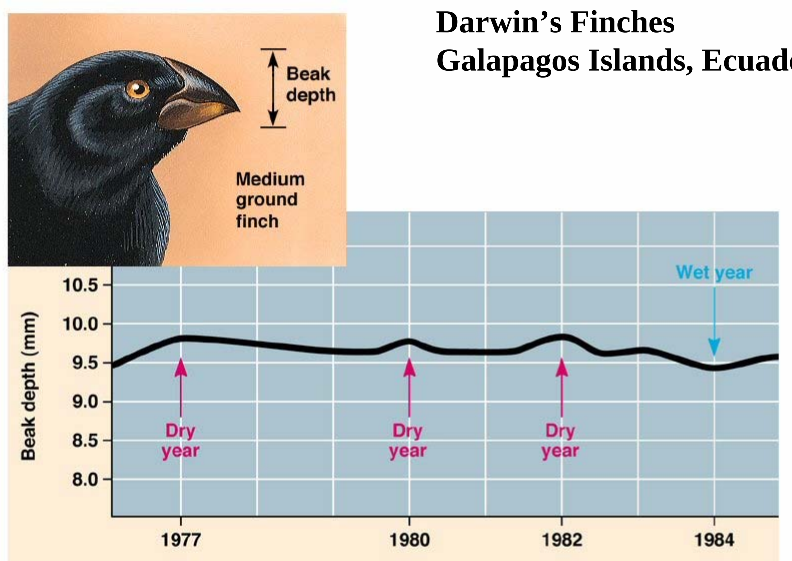

(15-8)

-Form and function matched

-Darwin's Finches in Galapagos



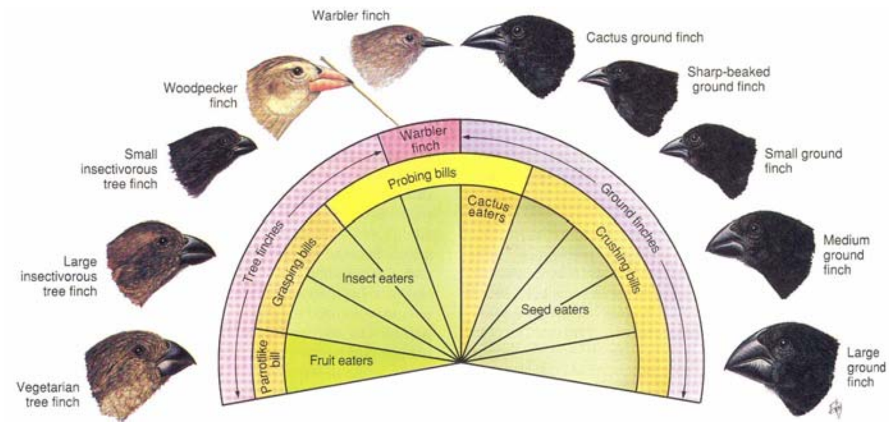
**Darwin's Finches**
**Galapagos Islands, Ecuador**






http://www.mun.ca/biology/scarr/Adaptation_in_Darwins_Finches.html

## Darwin's Finches
## Galapagos Islands, Ecuador




**http://www.mun.ca/biology/scarr/Adaptation_in_Darwins_Finches.html** 9

Seizing with mouth etc.

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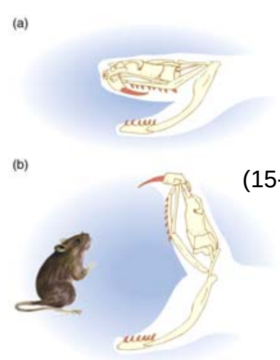
*Eunectes murinus*

Most toothed non-mammalian vertebrates have homodont dentition

-Exception: Some snakes




(15-6)

Some snakes also with venom

- hemolytic, neurotoxic

Viperidae, including rattlesnakes 10

*Heloderma*

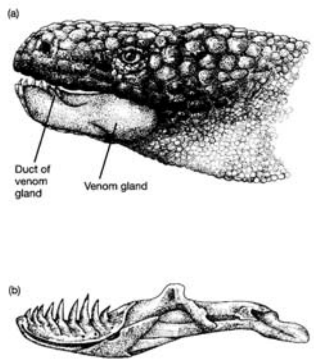



*Figure 9–39* **Venom gland and venom-conducting teeth of the Gila monster, *Heloderma suspectum*.** (a) Location of the venom gland, with skin removed. (b) Medial view of mandible, showing grooved teeth that conduct the venom. (*Source: (a) Based on Kochva 1978a.)*

Pough et al. 2001

Front Fanged
Hypodermic
Duvernoy's/Venom Gland

| | |
|---|---|
| Proteroglyph | Elapidae |
| Solenoglyph | Viperidae |

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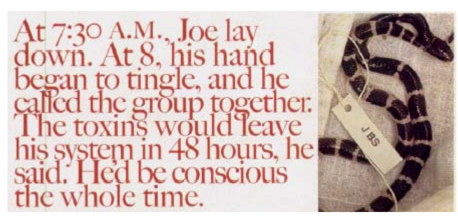
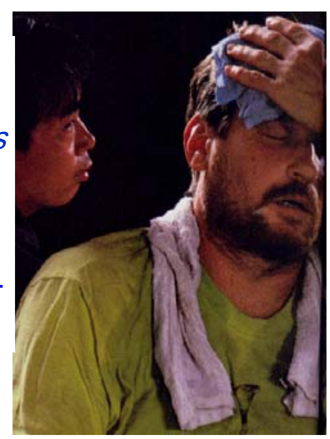
11 Sept 2001





Joe Slowinski
Myanmar/Burma
*Bungarus multicinctus*
Multibanded Krait
alpha bungarotoxin

nicotinic ACh receptor antagonist



... Alethinophidia, Macrostomata, Caenophidia, Colubroidea

## Elapidae

(62 genera, 300 species)

*Naja spp.*

- Cobras, coral, and sea snakes

- venomous
- proteroglyph dentition
    - maxilla longer than that of vipers
    - may have teeth posterior to fang
    - relatively fixed

*Micruroides euryxanthus*

- some with biparental care
- most terrestrial are oviparous
- most marine are viviparous

- corals often mimicked by non-venomous sympatrics

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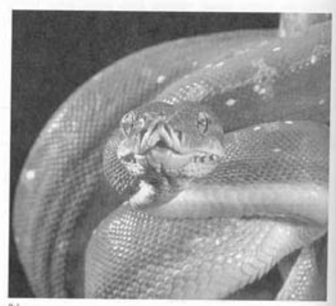
## Pit Organs

multiple origins -
vipers, boas, pythons

infrared image

(pit sensitivity to 0.003 C)

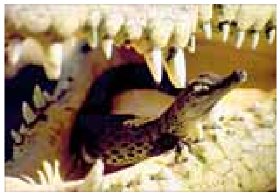
(a)



(b) Pough et al. 2001

*Figure 9–42* **Infrared-receptive pit organs.** (a) *Bothriechis schlegelii*, a crotaline viperid. All pit vipers have a single pair of facial pit organs located between the eye and nostril. (b) The green tree python, *Morelia viridis*. Many boas and pythons have a series of pit organs on the labial scales. *(Photographs by (a) Michael & Patricia Fogden, (b) David Northcott/ DRK Photo.)*

## Gastric Brooding Frog Etc.



*Python regius*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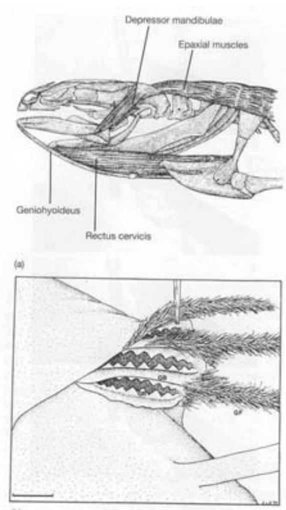
## Unidirectional Suction Feeding




Pough et al. 2001

*Figure 9–3* **The mechanics of suction feeding.** Skull, hyobranchial skeleton, and pectoral girdle of a larval tiger salamander (*Ambystoma tigrinum*) and the major muscles involved in the expansion phase. (a) Contraction of the muscles shown opens the mouth and lowers the hyobranchium (stippled), expanding the oral cavity. DM = depressor mandibulae, EP = epaxial muscles, GH = geniohyoideus, RC = rectus cervicis. (b) Gill rakers of *Ambystoma mexicanum*, a paedomorphic salamander, in ventrolateral view, with the gills pulled forward. Note the interlocking gill rakers, GR. GB = gill bar, GF = gill filaments. *(Source: (a) Redrawn from Lauder and Shaffer 1988; (b) modified from Lauder and Shaffer 1985.)*

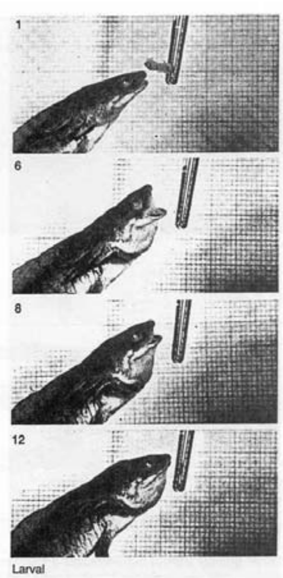



*Figure 9–2* **Suction feeding by a larval tiger salamander, *Ambystoma tigrinum*.** Film frames from a high-speed movie record of a salamander offered a piece of earthworm from forceps. Frame numbers appear at upper left. Sequential frames are 5 milliseconds apart. Note the rapid depression of the hyobranchium during the expansion phase (frame 6). *(Source: Shaffer and Lauder 1988.)*

## Suction Feeding

*Cryptobranchus alleganiensis*

### Salamanders

1. Jaws open
2. Hyoid apparatus
   (floor of mouth) drops
3. Muscles keep gills closed

A few genera asymmetrical
- flexible mandible
  (cartilage)

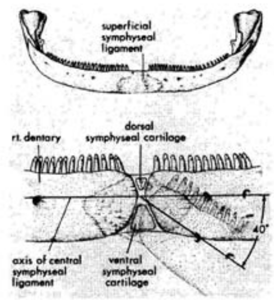



Figure 9-5
Pough et al. 2001

(b,c)

## Suction Feeding

### Anurans

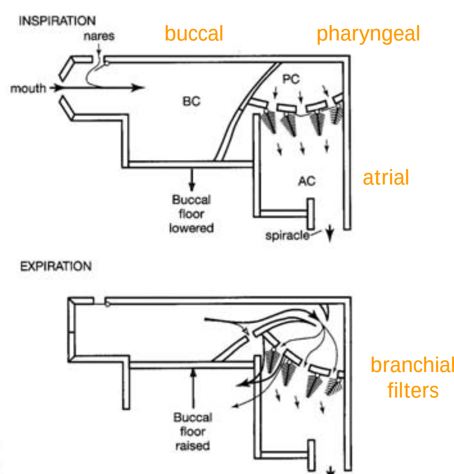
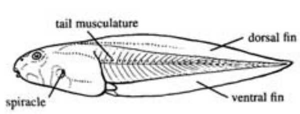



Figure 9-6f
Pough et al. 2001

<u>Tadpoles</u>
unidirectional
spiracle(s)

filter feeders
- strain
- mucus




Stebbins and Cohen, 1995

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## Turtle Suction Feeding

Bidirectional, no teeth
(keratinous beak)

1. Compensatory suction
   - displaced water

2. Inertial suction
   - modified hyobranchial
   - greater expansion

Esophogeal modifications
- prevent prey escape
- *Dermochelys*, 5 cm spines

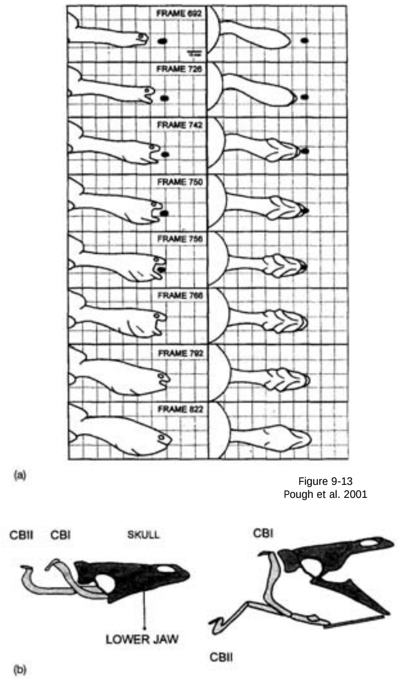


Figure 9-13
Pough et al. 2001

## Projectile Feeding

Salamanders

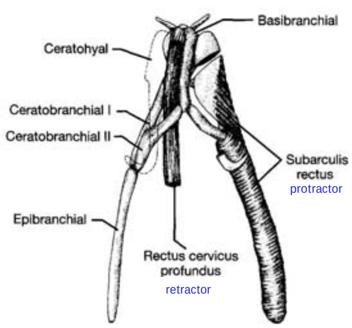


*Figure 9–20* **The mechanism involved in tongue projection and retraction by the two-lined salamander, *Eurycea bislineata*, a hemidactyliine plethodontid.** Dorsal view of the hyobranchial skeleton and major muscles (shown only on one side). Note the relatively long epibranchial cartilages and the spiral fibers of the subarcualis rectus I muscle, which contracts to project the tongue. The rectus cervicis muscle retracts the tongue. The glandular tongue pad would lie around the radial, lingual, and anterior ends of the basibranchial cartilages. *(Source: Modified from Lombard and Wake 1976.)*

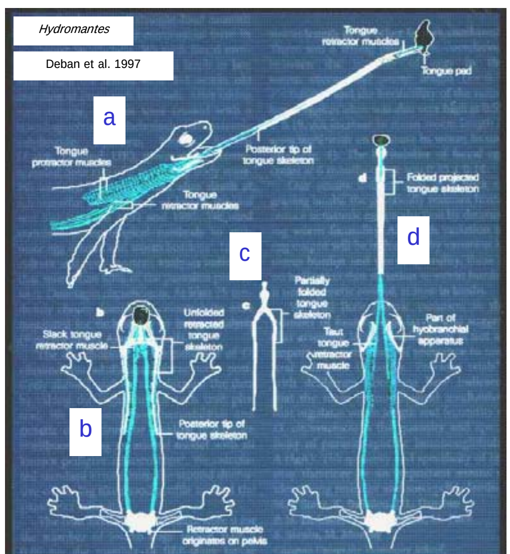


**Figure 2** Tongue projection system showing tongue skeleton, associated skeletal elements and the main tongue protractor and retractor muscles. **a,** Lateral view corresponding to Fig. 1 showing the tongue skeleton (black) projected completely from the mouth, and bilaterally paired tongue protractor (peach) and retractor (pink) muscles. **b,** Dorsal view with tongue skeleton in the unfolded retracted position, elongate posterior elements (dark grey) sheathed in protractor muscles, and slack, looped retractor muscles originating on the pelvis (medium grey). **c,** Tongue skeleton partially folded as in an early stage of projection. **d,** Dorsal view showing the tongue skeleton projected entirely from the body, beyond the contracted protractor muscles which are anchored anteriorly to the portion of the hyobranchial apparatus (light grey) that remains in the mouth. The retractor muscles, now taut, run the full length of the extended tongue and body.

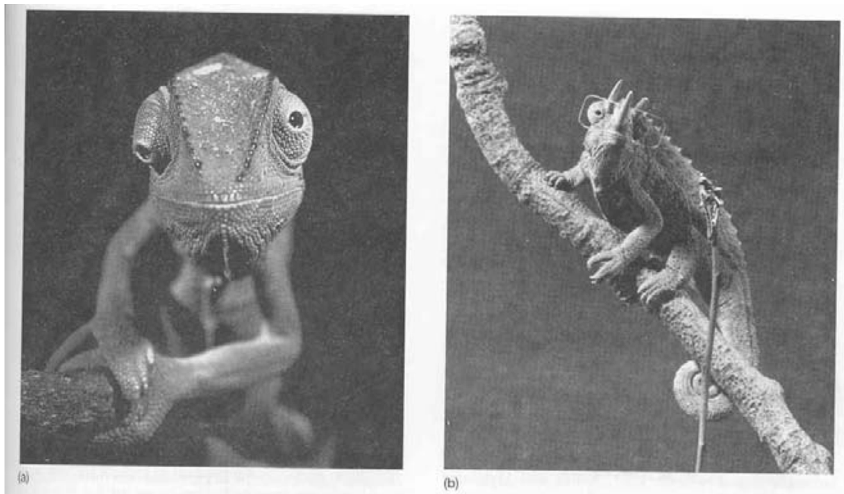


*Figure 9–25* **Eyes of chameleons.** (a) Eyes of *Chameleo vulgaris*, independently facing forward and down. (b) *Chamaeleo jacksoni* wearing spectacles to test binocular accommodation. (*Source: (a) Photograph by Dwight R. Kuhn/Bruce Coleman; (b) photograph courtesy of L. Harkness.*)

Fig. 9-25
Pough et al. 2001

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Egg Eating (e.g., *Dasypeltis*)
elastic neck skin, few teeth, vent. vertebral processes

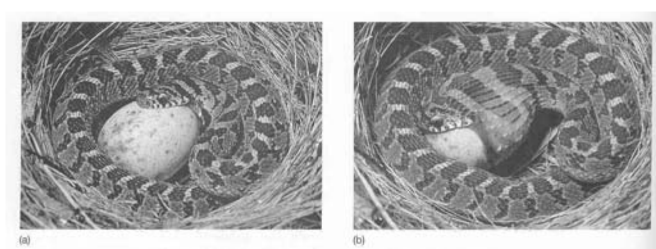


*Figure 9–36* **The African egg-eating snake, *Dasypeltis scabra*, swallowing a bird egg.** The egg is swallowed whole, and the shell is cracked in the throat. The contents are swallowed, and the shell is crushed and regurgitated. (*Photographs by Michael and Patricia Fogden.*)

Pough et al. 2001

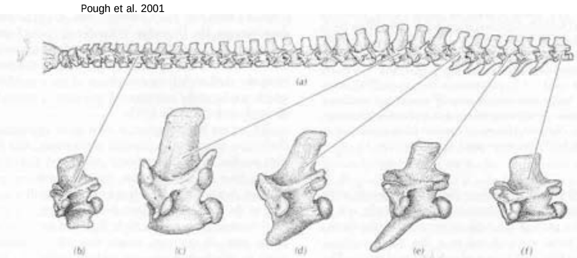


*Figure 9–37* **Anterior vertebral column of the African egg-eating snake, *Dasypeltis*.** Anterior is to the left, and the rear of the skull is shown. Note vertebrae with thickened hypapophyses (ventral processes) used for crushing eggshells and those with long, anteriorly directed hypapophyses that slit the egg membranes. (*Source: Gans 1974.*)

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Herbivory

- omnivores eat fruits and flowers
- true herbivores with specializations:
  - symbionts and gut morphology
- smaller indivs eat more nutritious parts

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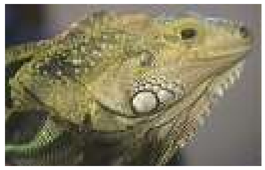
- Iguanas (need to acquire symbionts)
  - no parental care
  - communal nesting
  - hatchlings
    - eat soil
  - **juveniles**
    - **eat parental feces**



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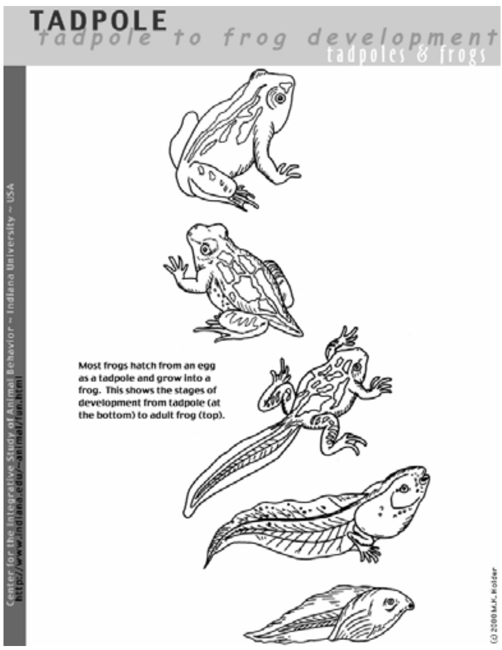
**Ontogenetic Changes**




**Mammals?**
**Lactase?**

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- Amphibian Larvae
  metamorphosing
  are most vulnerable

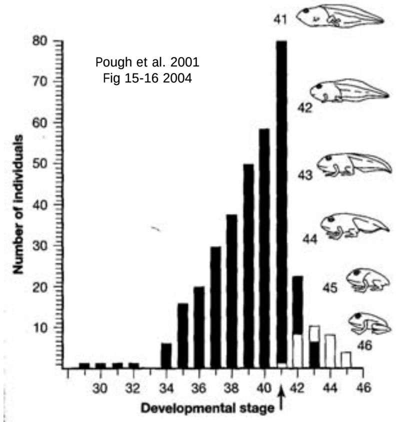


*Figure 13–15* **Differential predation on metamorphosing tadpoles.** The frequencies of developmental stages of *Pseudacris regilla* from a pond sample and from the stomachs of *Thamnophis.* The pond sample is indicated by solid bars, and the stomach sample is indicated by open bars. The arrow indicates the last premetamorphic stage of the frogs. *(Source: Arnold and Wassersug 1978.)*

**Cannibalism**

- rare in reptiles
- **widespread in amphibs** - esp. larval stages
- some with distinct cannibalistic morphs
- often **facultative**
  *Ambystoma, Spea, Scaphiopus*

*Scaphiopus couchii*

- Benefits
  energy
  reduced competition

- Costs
  eating a relative (kin recognition)
  acquire pathogens

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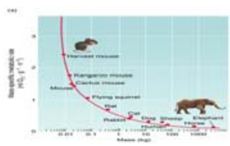
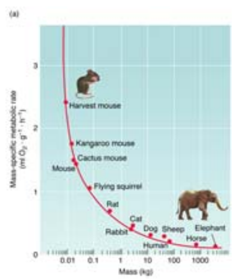
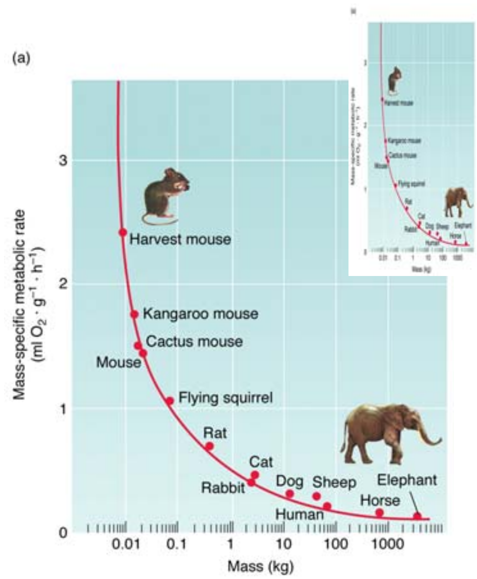
## Allometry:



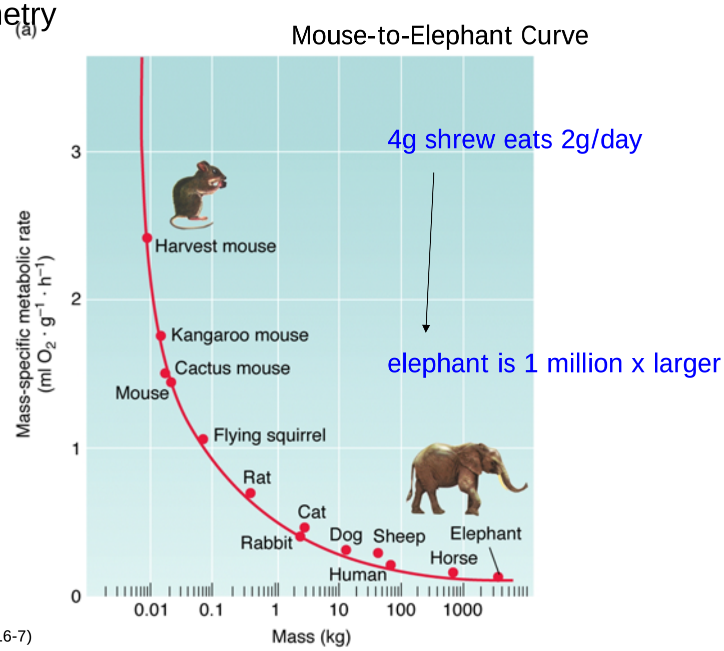







## Allometry

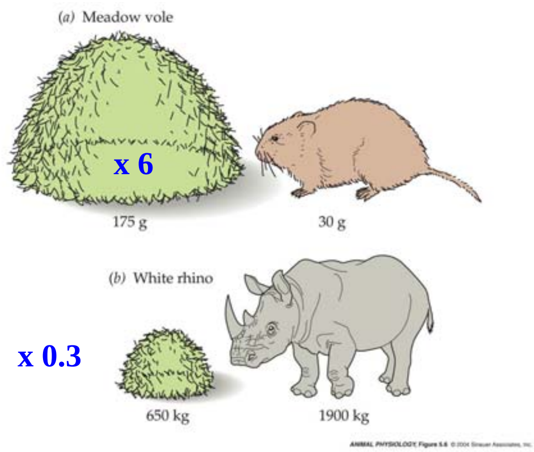
Mouse-to-Elephant Curve




(Eckert 16-7)

## Allometry

1 week of food




x 0.3

**(Hill et al. 5.6)**

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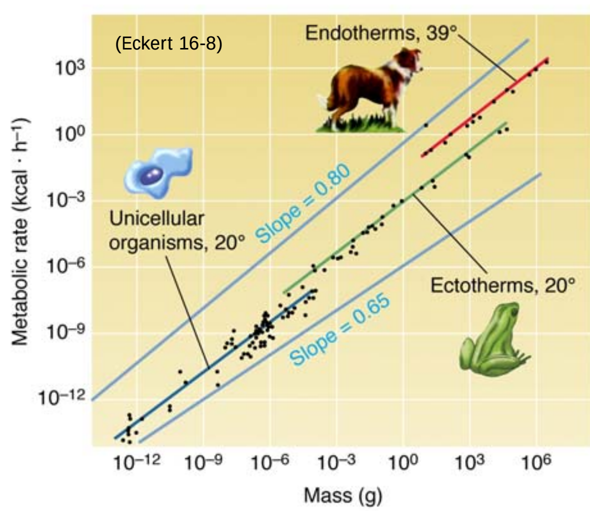
## Allometry




$MR = aM^{b}$

$\log MR = \log a + b(\log M)$

$b = 0.75$
(slope)

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Scaling

How do morphology and metabolism change with body mass?

Power Functions:

$$MR = aM^{b}$$

- MR: Metabolic rate
- M: Body mass
- b: Scaling exponent
- a: Y-intercept (of log-log plot)

Take log of both sides →

$$\log MR = \log a + b(\log M)$$

(Linearizes)

Can look at mass-specific rates by dividing through by M

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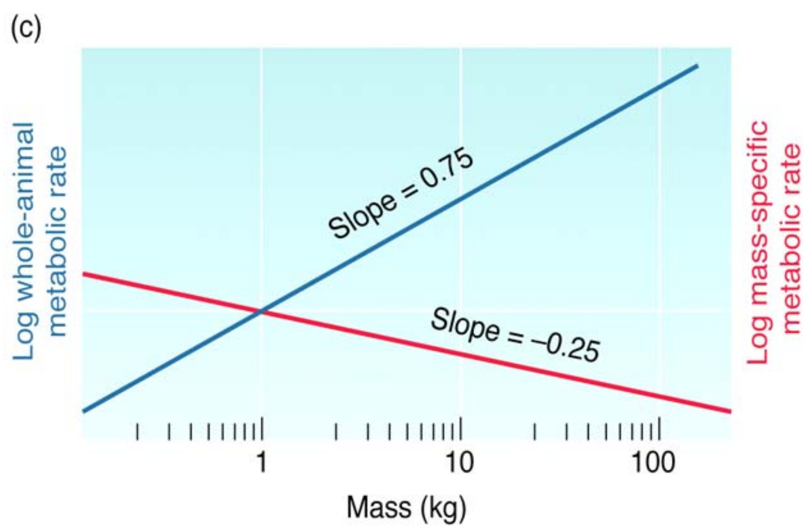
Allometry




(Eckert 16-7)

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$$\log M_{skeleton} = \log a + b(\log M)$$

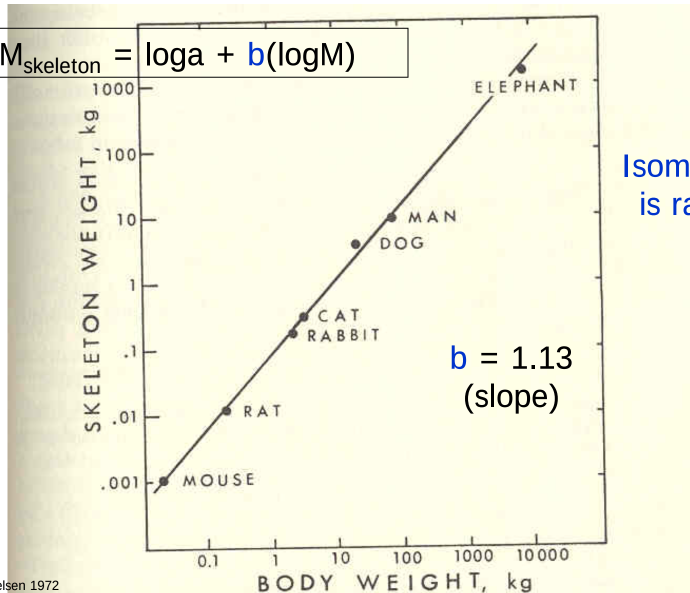


Figure 47. Weight of the skeleton of mammals increases more than proportionally to an increase in body weight. The slope of the regression line is 1.13. (Data from Kayser and Heusner, 1964.)

Isometry is rare

$b$ = 1.13 (slope)

Knut Schmidt_Nielsen 1972

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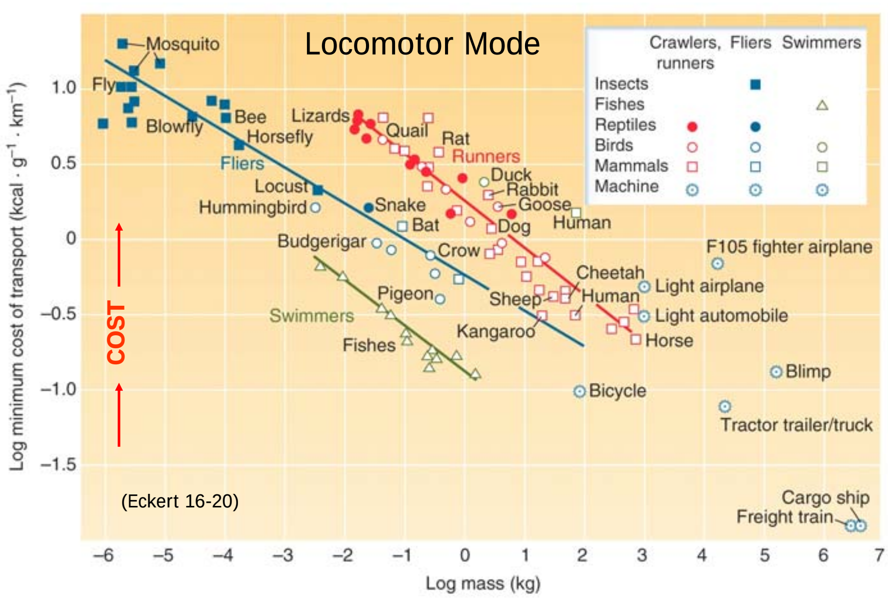
## Allometry



## Scaling Effects

Allometry - changes in body proportions as animals get larger (mouse vs. elephant)

Metabolic Rate - mass-specific metabolic rate decreases with increasing body mass

(a)

(16-6)

| | | | | | |
|---|---|---|---|---|---|
| Linear dimension | 1 | 2(2×) | 3(3×) | 4(4×) | linear |
| Volume | 1 | 8(8×) | 27(27×) | 64(64×) | cubed |
| Surface area | 6 | 24(3×) | 54(9×) | 144(24×) | squared |

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## Allometry

Table 6. *Possible calculations of a 'suitable' dose of LSD to give to an elephant*

Knut Schmidt_Nielsen 1972

| | | |
|---|---|---|
| (*a*) | Based on body weight and dose effective in cats 0.1mg/kg | 297 mg |
| (*b*) | Based on metabolic rates of elephant and cat | 80 mg |
| (*c*) | Based on body weight of elephant and dose effective in man | 8 mg |
| (*d*) | Based on metabolic rates of elephant and man 0.2mg for 70 kg | 3 mg |
| (*e*) | Based on brain size of elephant and man | 0.4 mg |

(a) = elephant freaked out and died (1960's) in a study of 'musth' [elephantine fallacy]

-What is the correct dose?

-Importance of Scaling!

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## Allometry

Hemoglobin dissociation curves and body size

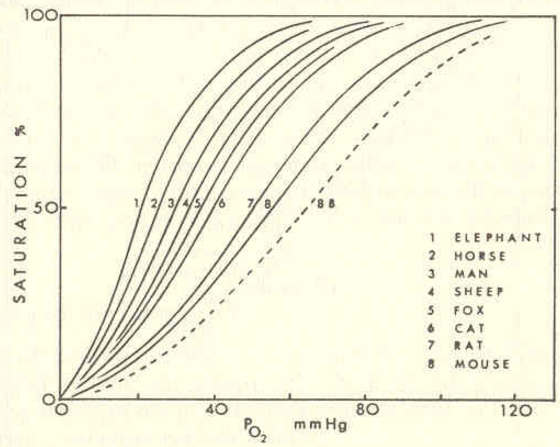


Figure 52. Dissociation curves of oxyhemoglobin from a number of mammals show that the blood of smaller mammals will unload oxygen under a higher oxygen pressure than that of larger mammals. This helps in the delivery of sufficient oxygen to the tissues to maintain the high metabolic rates of small animals. The dashed curve (8B) indicates the effect of acid (Bohr effect) on mouse blood (curve 8). (Data from Schmidt-Nielsen and Larimer, 1958. Elephant from Bartels *et al.* 1963.) Knut Schmidt_Nielsen 1972

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## Allometry

Bohr effect and body size

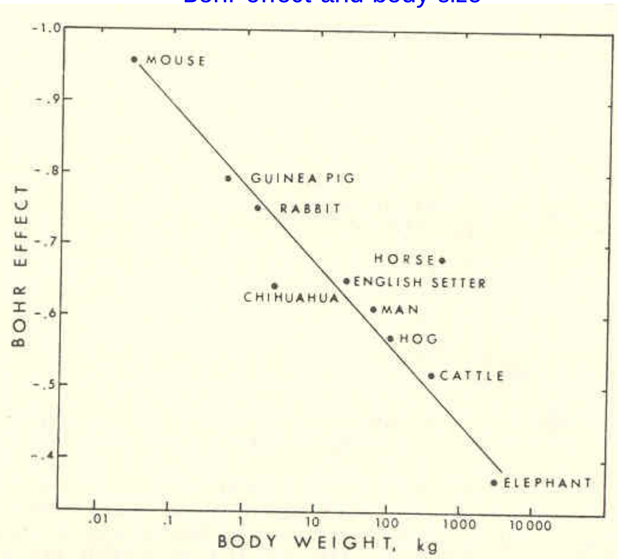


Figure 53. The effect of acid on the unloading of oxygen from the blood (Bohr effect, expressed as $\Delta \log P_{50}/\Delta \mathrm{pH}$) is greater in small than in large animals. (Data from Riggs, 1960.) Knut Schmidt_Nielsen 1972

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# Allometry

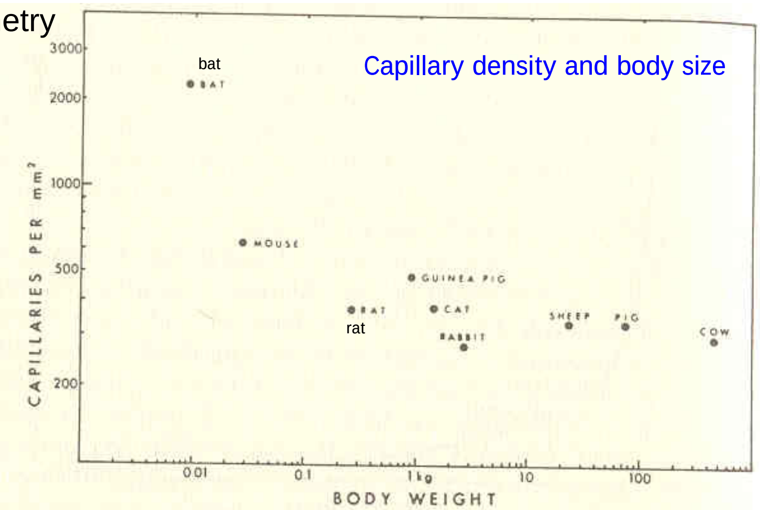


Figure 51. Capillary density in the gastrocnemius muscle. In very small mammals the capillary counts are high, but for a body size of a rat or larger there seems to be no clear trend in relation to body size. (Data from Schmidt-Nielsen and Pennycuik, 1961.)

Knut Schmidt_Nielsen 1972

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