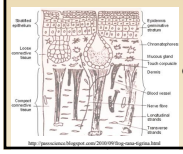
Amphibian Physiological Ecology



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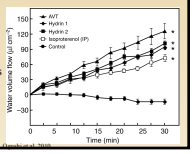
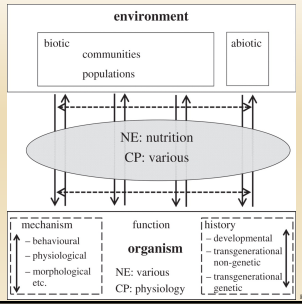


What is physiological ecology?

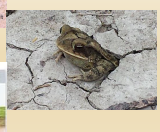


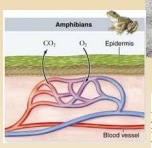
Raubenheimer et al. 2012

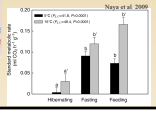
Amphibian Physiological Ecology

Relationships with the Environment:

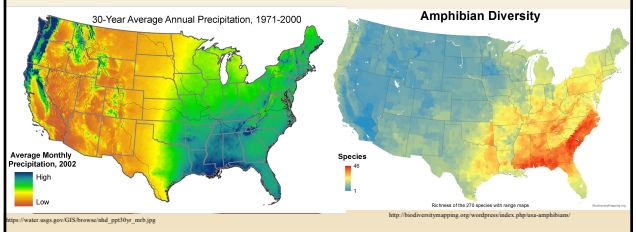
1. Water relations
2. Temperature Relations
3. Respiration
4. Energetics





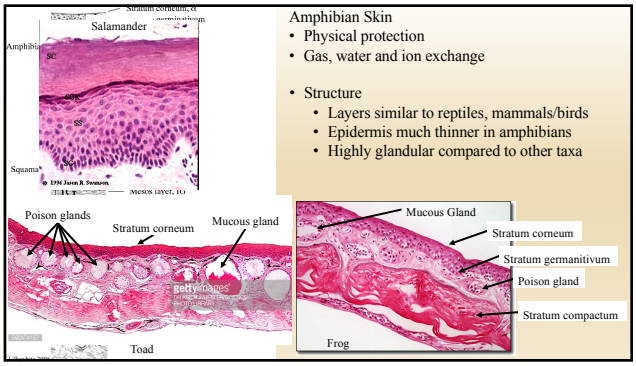


Water Relations



https://water.usgs.gov/GIS/browse/nhd_ppt30yr_mth.jpg

http://biodiversitymapping.org/wordpress/index.php/taxa-amphibians/

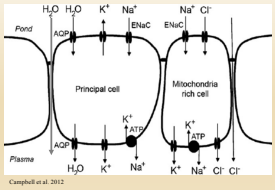


Amphibian Skin

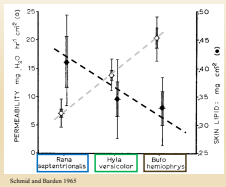
- Physical protection
- Gas, water and ion exchange

- Structure
  - Layers similar to reptiles, mammals/birds
  - Epidermis much thinner in amphibians
  - Highly glandular compared to other taxa

Skin Permeability: Water



Campbell et al. 2012

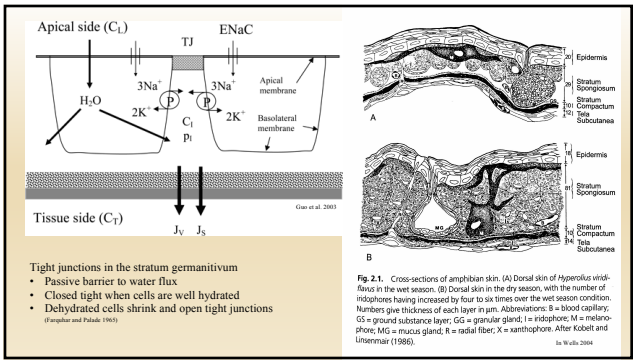


Schmid and Barden 1965

Transport of water across apical membrane surface

- Transcellular – Aquaporin channels
- Paracellular – capillary movement through tight junctions

- Permeability to water ***inversely*** related to lipid content
- Consider the life histories of the species in question… What does it suggest?


Apical side (C_L)
ENaC
TJ
$3Na^+$
$3Na^+$
Apical membrane
H_2O
$2K^+$
P
P
C_l
p_l
$2K^+$
Basolateral membrane
Tissue side (C_T)
J_V
J_S
Gao et al. 2003
Tight junctions in the stratum germanitivum
• Passive barrier to water flux
• Closed tight when cells are well hydrated
• Dehydrated cells shrink and open tight junctions
(Farquhar and Palade 1965)
A
B
Epidermis
Stratum Spongiosum
Stratum Compactum
Tela Subcutanea
Epidermis
Stratum Spongiosum
Stratum Compactum
Tela Subcutanea
Fig. 2.1. Cross-sections of amphibian skin. (A) Dorsal skin of Hyperolius viridiflavus in the wet season. (B) Dorsal skin in the dry season, with the number of iridophores having increased by four to six times over the wet season condition. Numbers give thickness of each layer in μm. Abbreviations: B = blood capillary; GS = ground substance layer; GG = granular gland; I = iridophore; M = melanophore; MG = mucus gland; R = radial fiber; X = xanthophore. After Kobelt and Linsenmair (1986).
In Wells 2004

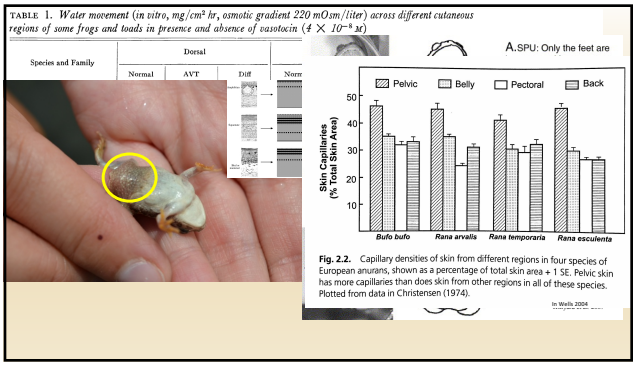


TABLE 1. Water movement (in vitro, mg/cm² hr, osmotic gradient 220 mOsm/liter) across different cutaneous regions of some frogs and toads in presence and absence of vasotocin (4 × 10⁻⁸ M)
Species and Family
Dorsal
Normal
AVT
Diff
A.SPU: Only the feet are
Pelvic
Belly
Pectoral
Back
Skin Capillaries (% Total Skin Area)
50
40
30
20
10
Bufo bufo
Rana arvalis
Rana temporaria
Rana esculenta
Fig. 2.2. Capillary densities of skin from different regions in four species of European anurans, shown as a percentage of total skin area + 1 SE. Pelvic skin has more capillaries than does skin from other regions in all of these species. Plotted from data in Christensen (1974).
In Wells 2004

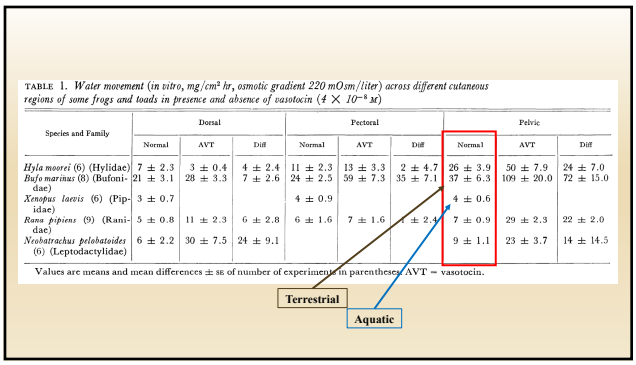


TABLE 1. Water movement (in vitro, mg/cm² hr, osmotic gradient 220 mOsm/liter) across different cutaneous regions of some frogs and toads in presence and absence of vasotocin (4 × 10⁻⁸ M)
Species and Family
Dorsal
Pectoral
Pelvic
Normal
AVT
Diff
Normal
AVT
Diff
Normal
AVT
Diff
Hyla moorei (6) (Hylidae) 7 ± 2.3 3 ± 0.4 4 ± 2.4 11 ± 2.3 13 ± 3.3 2 ± 4.7 26 ± 3.9 50 ± 7.9 24 ± 7.0
Bufo marinus (8) (Bufonidae) 21 ± 3.1 28 ± 3.3 7 ± 2.6 24 ± 2.5 59 ± 7.3 35 ± 7.1 37 ± 6.3 109 ± 20.0 72 ± 15.0
Xenopus laevis (6) (Pipidae) 3 ± 0.7 4 ± 0.9 4 ± 0.6
Rana pipiens (9) (Ranidae) 5 ± 0.8 11 ± 2.3 6 ± 2.8 6 ± 1.6 7 ± 1.6 1 ± 2.4 7 ± 0.9 29 ± 2.3 22 ± 2.0
Neobatrachus pelobatoides (6) (Leptodactylidae) 6 ± 2.2 30 ± 7.5 24 ± 9.1 9 ± 1.1 23 ± 3.7 14 ± 14.5
Values are means and mean differences ± SE of number of experiments in parentheses. AVT = vasotocin.
Terrestrial
Aquatic

Temperature Relations

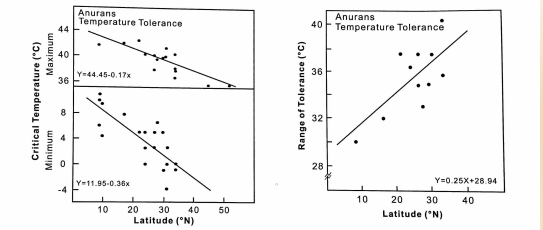


Fig. 3.7. Relationship of critical maximum temperature (top) and critical minimum temperature (bottom) to latitude for various species of anurans. The relationships have not been corrected for phylogeny and include tropical and temperate zone species from different families. After Snyder and Weathers (1975).

Fig. 3.8. Range of temperature tolerance (the difference between critical maximum and minimum temperatures) in anurans as a function of latitude. The data have not been corrected for phylogeny. The increased range of temperature tolerance at high latitudes is due mainly to increased tolerance for cold temperatures. After Snyder and Weathers (1975).

Hillman 2009

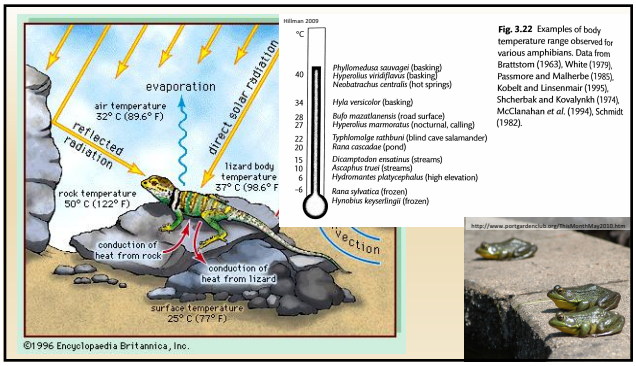


Fig. 3.22 Examples of body temperature range observed for various amphibians. Data from Brattstom (1963), White (1979), Passmore and Malherbe (1985), Kobelt and Linsenmair (1995), Shcherbak and Kovalynkh (1974), McClanahan *et al.* (1994), Schmidt (1982).

Fig. 3.26 Effect of hydration status on behavioral thermoregulation by the "waterproof" frog *Chiromantis xerampelina*. Data from Shoemaker *et al.* (1989).

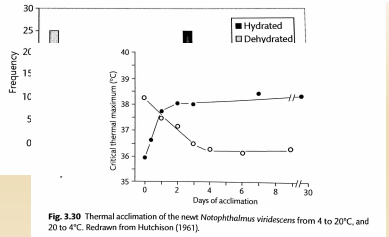
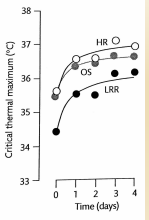


Fig. 3.30 Thermal acclimation of the newt *Notophthalmus viridescens* from 4 to 20°C, and 20 to 4°C. Redrawn from Hutchison (1961).

Fig. 3.29 Critical thermal maximum measured by three different endpoints; loss of righting response (LRR), onset of spasms (OS) and heat rigor (HR), and changes in CT_{max} with acclimation time, for the salamander *Ambystoma jeffersonianum*. Modified from Claussen (1977).



Though ectothermic, physiology and behavior play a role in thermoregulation
- Hydration status drives behavioral thermoregulation
- Acclimation influences thermal tolerance

Hillman 2009

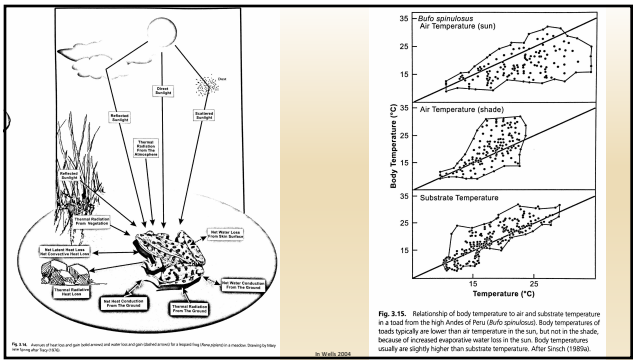
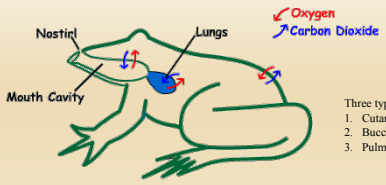


Fig. 3.15. Relationship of body temperature to air and substrate temperature in a toad from the high Andes of Peru (*Bufo spinulosus*). Body temperatures of toads typically are lower than air temperature in the sun, but not in the shade, because of increased evaporative water loss in the sun. Body temperatures usually are slightly higher than substrate temperature. After Sinsch (1988a).

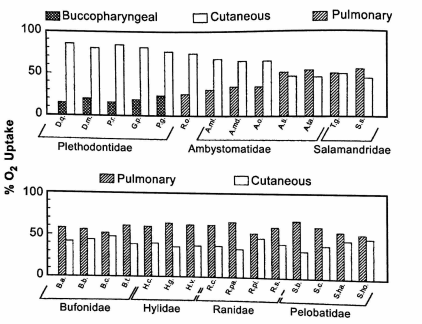
Respiration



https://www.brown.edu/Departments/Engineering/Courses/En123/MuscleExp/Frog%20Respiration.htm

Three types of respiration in terrestrial amphibians:

1. Cutaneous
2. Buccopharyngeal
3. Pulmonary



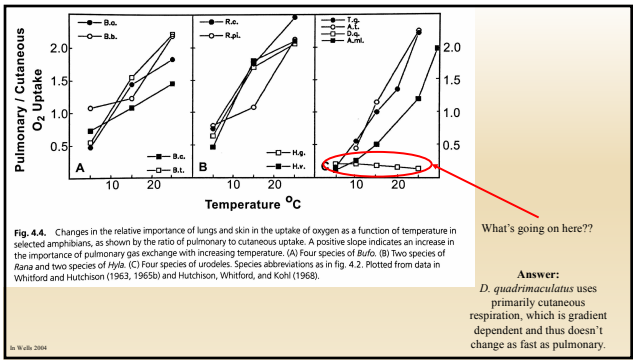


Fig. 4.4. Changes in the relative importance of lungs and skin in the uptake of oxygen as a function of temperature in selected amphibians, as shown by the ratio of pulmonary to cutaneous uptake. A positive slope indicates an increase in the importance of pulmonary gas exchange with increasing temperature. (A) Four species of *Bufo*. (B) Two species of *Rana* and two species of *Hyla*. (C) Four species of urodeles. Species abbreviations as in fig. 4.2. Plotted from data in Whitford and Hutchison (1963, 1965b) and Hutchison, Whitford, and Kohl (1968).

In Wells 2004

What's going on here??

Answer:
D. quadrimaculatus uses primarily cutaneous respiration, which is gradient dependent and thus doesn't change as fast as pulmonary.

Aquatic Species/life stages: gills

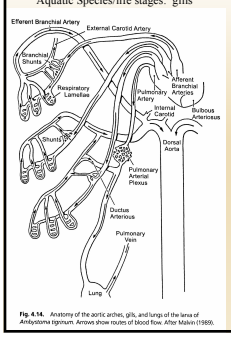


Fig. 4.14. Anatomy of the aortic arches, gills, and lungs of the larva of *Ambystoma tigrinum*. Arrows show routes of blood flow. After Malvin (1969).

https://commons.wikimedia.org/wiki/File:Salamander_larva_closeup.jpg

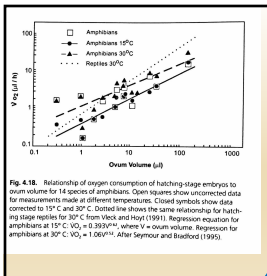


Fig. 4.18. Relationship of oxygen consumption of hatching-stage embryos to ovum volume for 14 species of amphibians. Open squares show uncorrected data for measurements made at different temperatures. Closed symbols show data corrected to 15° C and 30° C. Dotted line shows the same relationship for hatching stage reptiles for 30° C from Vleck and Hoyt (1991). Regression equation for amphibians at 15° C: $\dot{V}O_2 = 0.393V^{0.66}$, where V = ovum volume. Regression for amphibians at 30° C: $\dot{V}O_2 = 1.06V^{0.66}$. After Seymour and Bradford (1995).

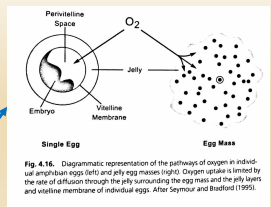
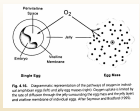


Fig. 4.16. Diagrammatic representation of the pathways of oxygen in individual amphibian eggs (left) and jelly egg masses (right). Oxygen uptake is limited by the rate of diffusion through the jelly surrounding the egg mass and the jelly layers and vitelline membrane of individual eggs. After Seymour and Bradford (1995).

- In comparison with reptiles, amphibian embryos have slower metabolic rates at hatching.
- What is the evolutionary significance of this??



Density and size of egg masses affect oxygen profiles throughout the egg mass.

- Oxygen concentrations near the edges of the mass are higher than those at the center of the mass
- Changes in oxygen perfusion over development = smaller differences in oxygen levels throughout the egg mass

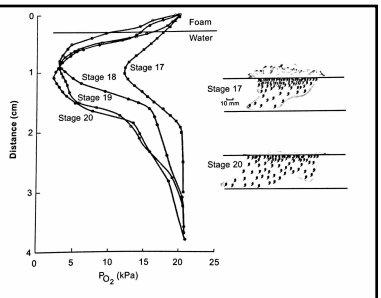


Fig. 4.23. Oxygen profiles through the center of a foamy egg mass of *Limnodynastes tasmaniensis* at four Gosner (1960) stages of development. Distance is measured from the top of the egg mass, which is exposed above the water surface, to the bottom of the egg mass about 3.5 cm underwater. Diagram at right shows the spatial distribution of embryos in the egg mass at stages 17 and 20. After Seymour and Roberts (1991).

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- Campbell CR, Voyles J, Cook DI, Dinudom A. 2012. Frog skin epithelium: electrolyte transport and chytridiomycosis. *Int J Biochem Cell B* 44(3): 431-434.
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