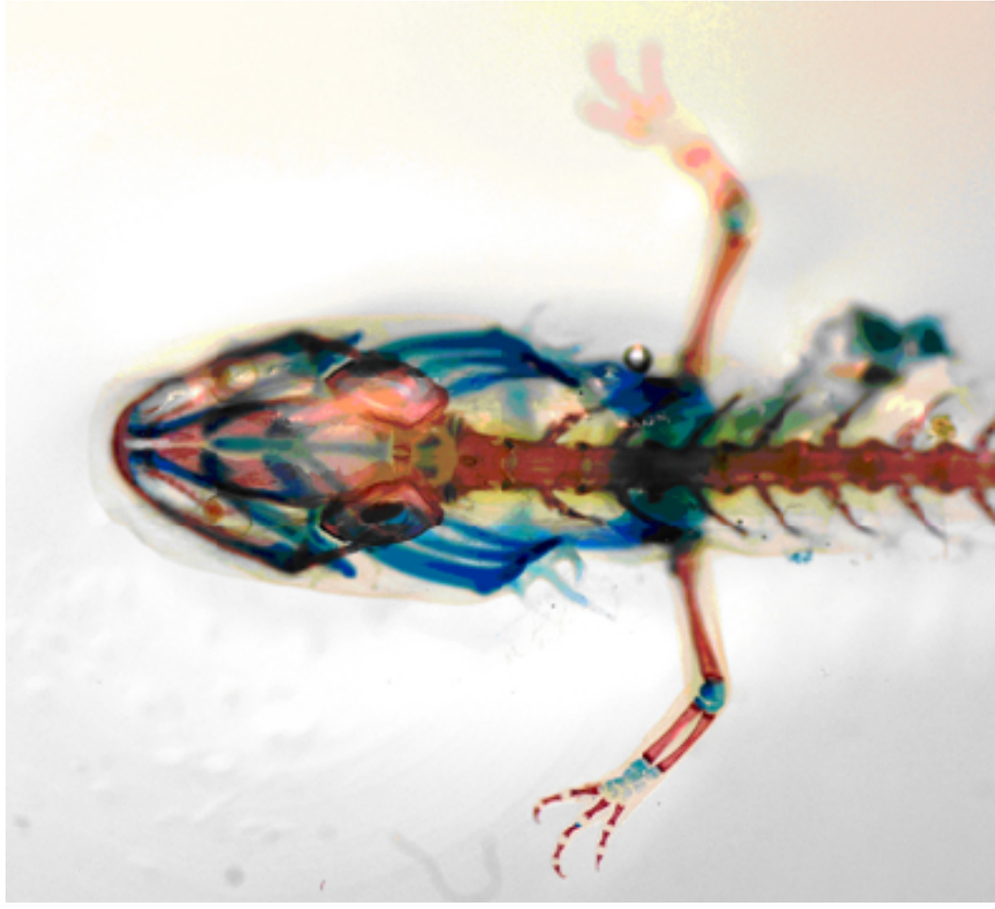
Physiology: Thermoregulation, Water Regulation, and Development

Monday May 15th 2017



Announcements

- All project proposals are returned!
    - Take time to read through my comments, and if you have more questions, talk to me today or tomorrow
- Field notebooks general feedback
    - Don’t just write a sentence per animal found! Someone in 6 months should be able to read your entry and roughly retrace your steps
    - Species names: underlined. Can abbreviate to <u>P. cinereus</u> after you’ve used the species name once in your entries already
- This week:
    - Normal lecture today, tomorrow night trip starting at 7pm until 10 pm - meet here!
    - Introduction drafts due tomorrow at 9:00am (I’ll spend the morning reviewing and returning them)
        - Methods due Wednesday
        - Results due Friday @ 5pm

Draft Introduction Guidelines

- Good introductions have three primary sections:

    1. An overview of the **general biological phenomenon** being investigated

    2. An overview of the **study system** used to study the general biological phenomenon, focusing on information relevant to the biological phenomenon

    3. A **statement of your research question(s) and hypothesis(es)** as it relates to addressing the general biological phenomenon

- These sections should be well cited from primary literature

    - I expect only citations from scientific journals (Google Scholar is your friend), and in dire circumstances, your field guide / the textbook

    - You shouldn't read every single paper you stumble across, focus on between 3-4 papers most relevant to your research question & system, and any others you can often glean enough info from the abstract

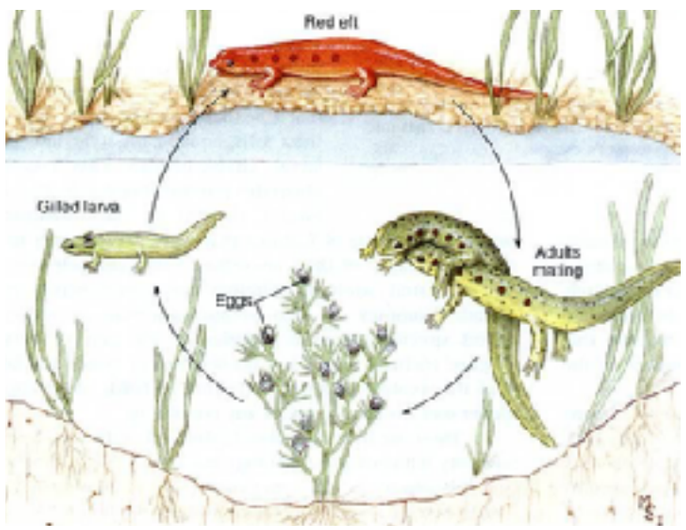
- Example on board

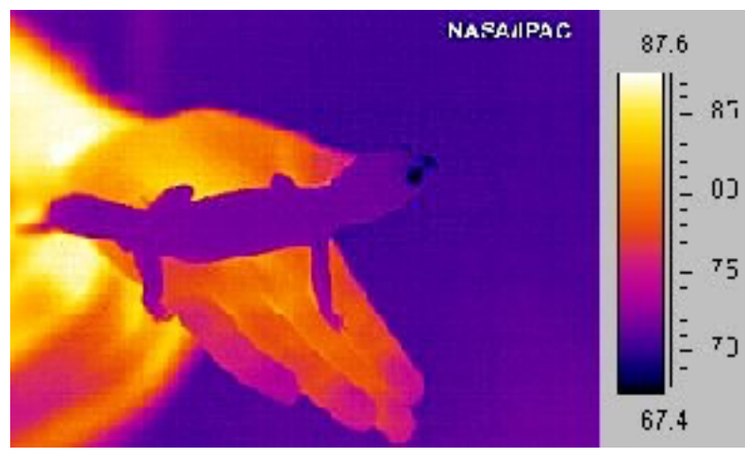
What is Physiology?

- The study of **chemical** and **physical processes** in the organism

- Aspects of the physiology can be informative for understanding organisms in their environment

- Water Regulation
- Thermoregulation
- Development





Amphibian Water Regulation

- Proper water balance is one of the most critical factors in habitat choice
    - Water in must = water out
- The fact that amphibians are “shackled” to the water is largely overblown, but there are important…
- adaptations for very dry conditions
- adaptations for very wet conditions

Dry Condition Adaptations

- Moist skin is a huge vector for water loss in terrestrial amphibians
    - Habitat choice
    - Skin anatomy
        - Warty skin (*B. americanus,* drinking patch)
        - Mucus *(P. glutinosus*)
    - Water storage in urinary bladder
- Many amphibians can take up water through the skin
- Adaptations NOT seen in CT:
    - Cocoon frogs
    - “Waterproof” frogs

Wet Condition Adaptations

- Smooth skin makes drinking via skin slower
- Fluctuating blood ion concentrations
    - Keep blood ion concentration low, so water flows out (opposite is true for terrestrial species)
    - Excrete nitrogenous waste via ammonia, which is toxic but very water soluble
- Secreting fungicidal chemicals and antibacterial agents to keep the skin clean and healthy

Reptile Water Regulation

- Proper water balance is critical to reptiles, but non-permeable skin makes adaptations very different from amphibians
  - Preventing evaporative water loss*
  - Ensuring water intake*
  - Storing water
  - Excreting nitrogen*
  - Salt glands

* Important for CT species

Evaporative Water Loss

- You might think keratinized scales are extremely effective in preventing water loss
  - You'd be wrong
  - Lipids in the skin
- 20-30x less evaporative water loss than in amphibians
- However, reptiles cannot uptake water through the skin
  - Many reptiles have behavioral and anatomical features for aiding in water collection

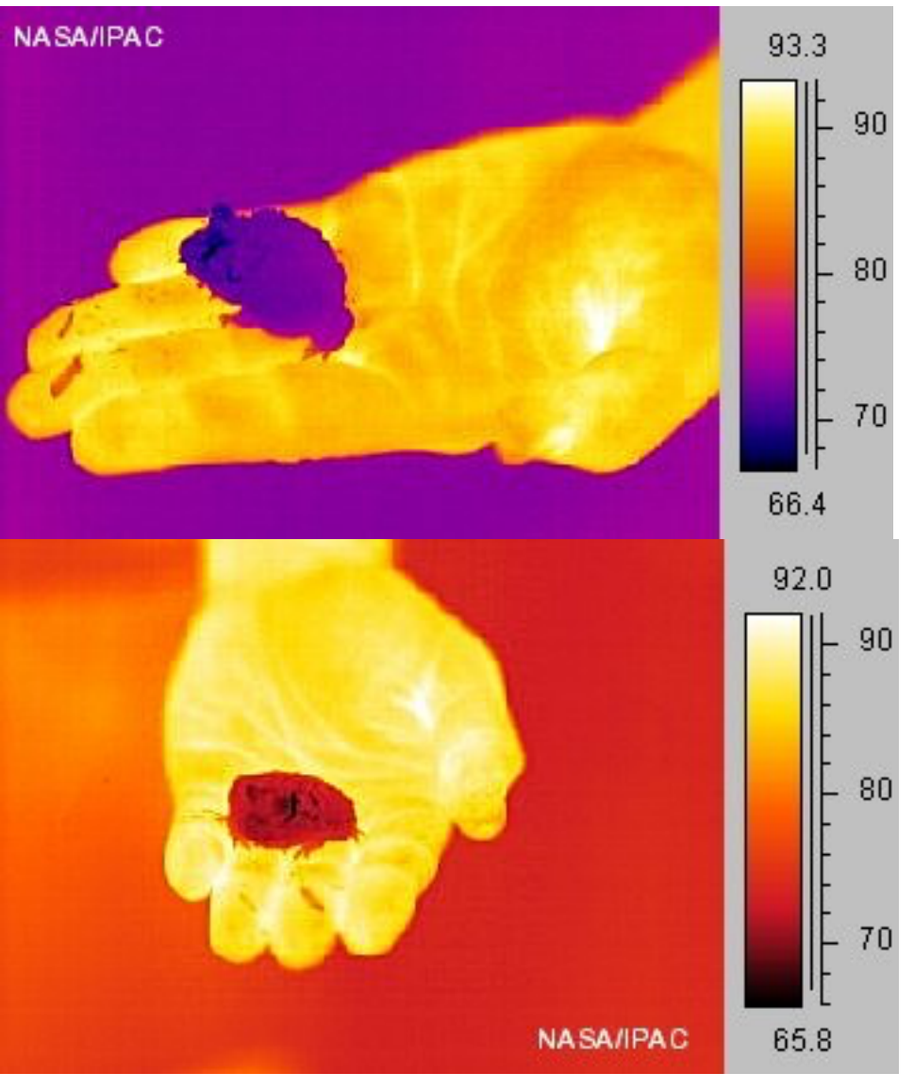
Water Intake

- Reptiles that drink either lap up water, or pump it into the mouth
- Some reptiles rely entirely on free water in food
- Some reptiles rely solely on water generated during metabolic processes

Excreting Nitrogenous Waste

- Reptiles in general have difficulty getting rid of salts
    - Incapable of concentrating urine higher than bodily fluids (unlike the mammalian kidney)
- Turtles excrete **urea**
    - Water soluble, non-toxic, but eventually becomes toxic
    - Terrestrial animals with easy access to water typically use urea
- Snakes and lizards excrete **uric acid**
    - Water insoluble, non-toxic
    - Almost no water loss

Thermoregulation



- All amphibians and reptiles are **ectotherms**
  - Their body temperature is governed by the environment.
  - Heat energy lost = heat energy gained
- Changes in temperature have cascading effects throughout the body
  - Brain function
  - Muscle function
  - Digestive function

Optimal functions occur at T_O

- Two primary methods of thermoregulation:
  - **heliotherms** (gain heat by absorbing solar radiation, basking)
  - **thigmotherms** (gain heat by absorbing conducted heat from substrate, under cover objects)

Amphibian Thermoregulation

- Amphibians, for the most part do not bask to warm their bodies
  - Salamanders - no evidence
  - Frogs - perhaps *R. catesbiana*?
- The vast majority amphibians will move to accommodate changes - seeking a new microclimate
  - Salamanders - Movement between underground (cold nights) and cover objects at the surface (warm days)
  - Frogs - Movement between middle of the pond (cold nights) and the shore (warm days)

Amphibian Thermoregulation

- **Plethodontids** are especially adept for life at cold temperatures
    - Lungless, allowing for a specialized feeding structure
        - Capable of shooting their tongues out like taut bow & arrow!
            - Gets around their cold muscle problem, since they can slowly contract tongue back in
- Cold water carries more oxygen (even in moist soils)

Overwintering

Moving to Non-Freezing Habitat

- Frogs - hibernate
  - Terrestrial hibernators in burrows (e.g. *Bufo*, *Scaphiopus*)
  - Aquatic hibernators in streams (e.g. *Rana catesbeiana, Rana clamitans, Rana pipiens*, etc.)
- Salamanders - reduced activity
  - Underground burrowers (e.g. *Plethodon*, *Ambystoma, N. viridescens* red-eft)
  - Active in aquatic habitat (e.g. *N. viridescens* adults)

Overwintering

Freeze Tolerant Frogs

- Some species are specially adapted to freeze
  - *Pseudacris crucifer*
  - *Hyla versicolor*
  - *Rana sylvatica*
- Possess large carbohydrate stores in their liver, which is converted to glucose or glycerol in the winter, serving as an antifreeze
- Allows a head-start before other frogs come out of hibernation at the bottom of ponds

Reptile Thermoregulation

- Reptiles regulate their temperature by…

    1. Controlling heat gain from environment

        - Microhabitat selection

    2. Controlling heat loss

        - Basking / conduction under cover object

    3. Redistributing heat in the body

        - Part of body in water, part in the sun

    4. Controlling metabolic heat generation

        - Found in female pythons (so not an adaptation seen in CT)

Reptile Thermoregulation

- Moving in and out of hot spots allows them to maintain a high body temperature throughout the day
    - Reptile brains adjust to **set-point temperatures**, upper and lower thresholds where they move to adjust temperature
    - Some special events shift set-point temperatures
        - Digesting food (increases lower set-point) / starvation (decreases lower set-point)
            - Vipers (like the copperhead and timber rattlesnake) lose digestive tissue between meals
        - Pregnancy (increases lower & upper set-points)
        - Infection causing “behavioral fevers” (increases lower & upper set points)
- **What times of day are we most likely to see basking?**

Overwintering

Snakes

- No snake is freeze tolerant
- Most snakes overwinter in communal dens - “hibernacula”
    - Used by many species simultaneously
        - *Agkistrodon contortix* and *Crotalus horridus* often den together
        - *Thamnophis sirtalis* does not necessarily hibernate, remains somewhat active in their hibernaculum

Overwintering

Turtles

- Many turtles burrow into muds at the bottom of ponds
  - Danger of freezing
  - Anoxia
- Some turtles have cloacal bursae
  - Allows for oxygen exchange in water… out of their butts

Overwintering

Juvenile Painted Turtles

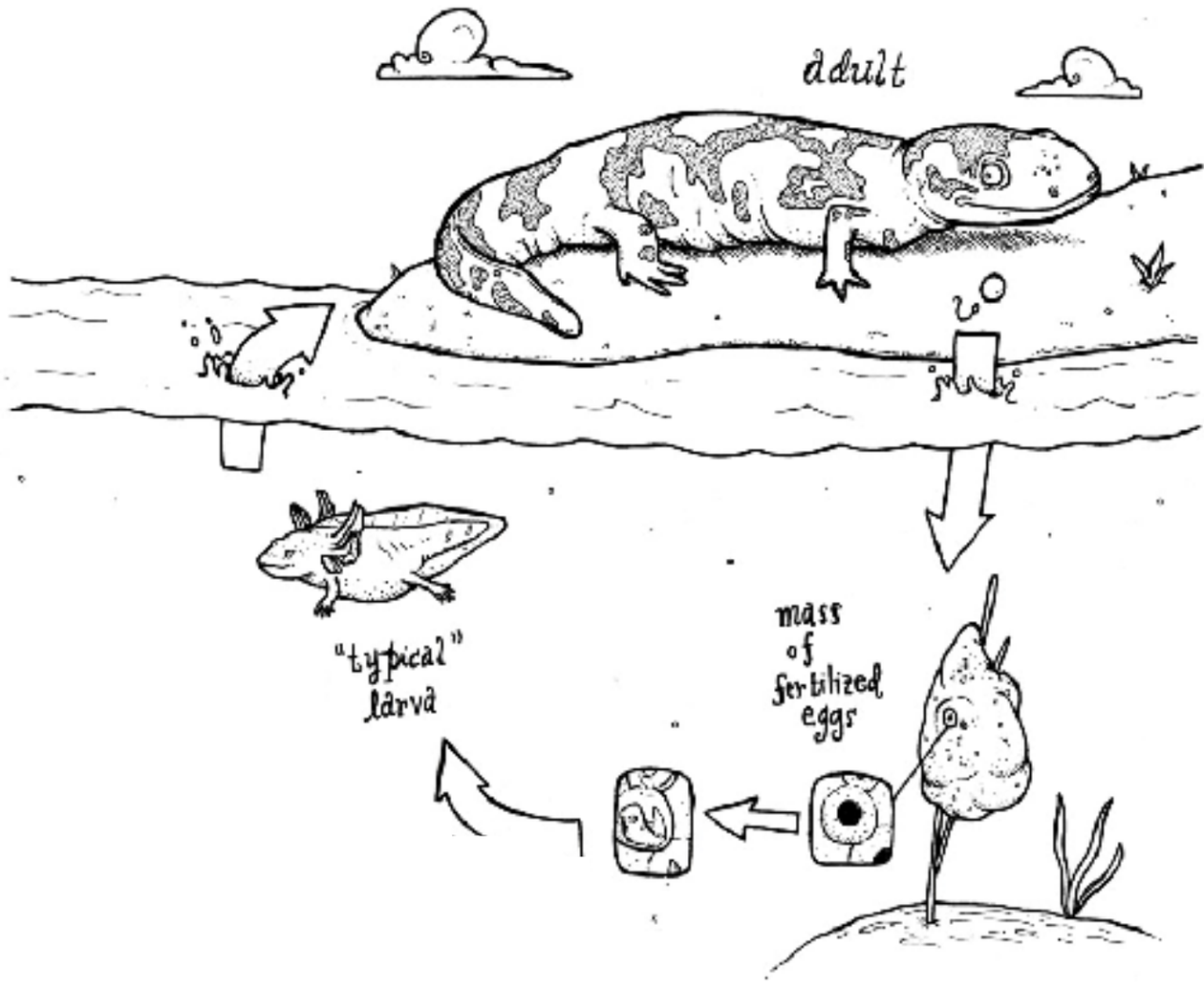
- Hatchlings remain in nest during winter
- Baby turtles build up glucose in their blood
- Dry nests also result in **supercooling**, the process of water cooling below freezing, but remaining liquid

[Video]

Amphibian Life Cycles / Development

- **Ontogeny** is the process of creation and development of an organism; the growth of an organism from embryo to mature adult
    - "Normal development"
    - Regeneration
- Amphibians in CT have **four** different ontogenies

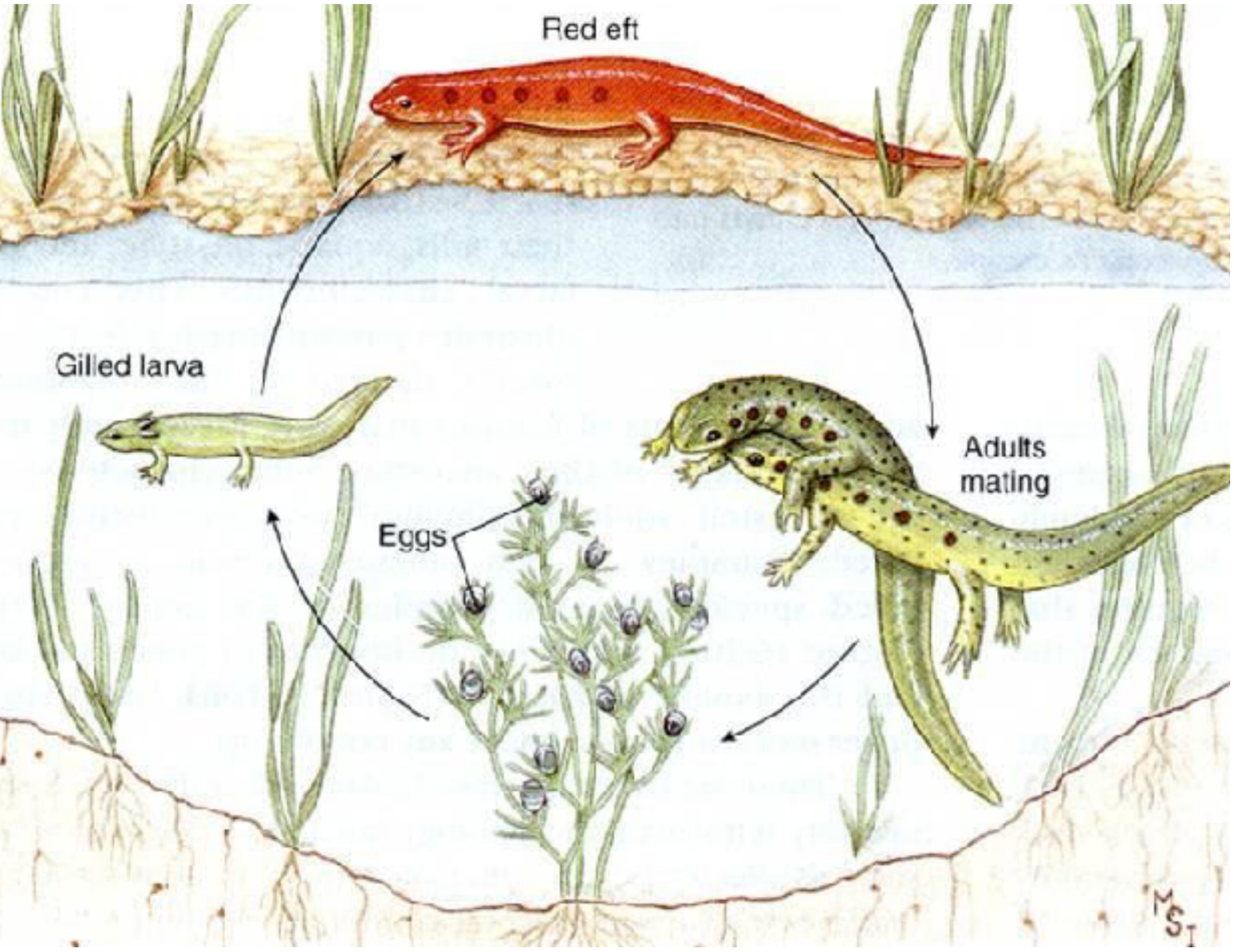
Ontogeny 1:
Egg, Aquatic Larvae, Adult



- All CT frogs

- All CT salamanders except for *Plethodon, Necturus maculosus, and Notothalmus viridescens*

Ontogeny 2:
Egg, Aquatic Larvae, Terrestrial Subadult, Aquatic Adult



- *Notophthalmus viridescens*
- "Adds another step"

Ontogeny 3: Egg, Terrestrial Subadult, Terrestrial Adult

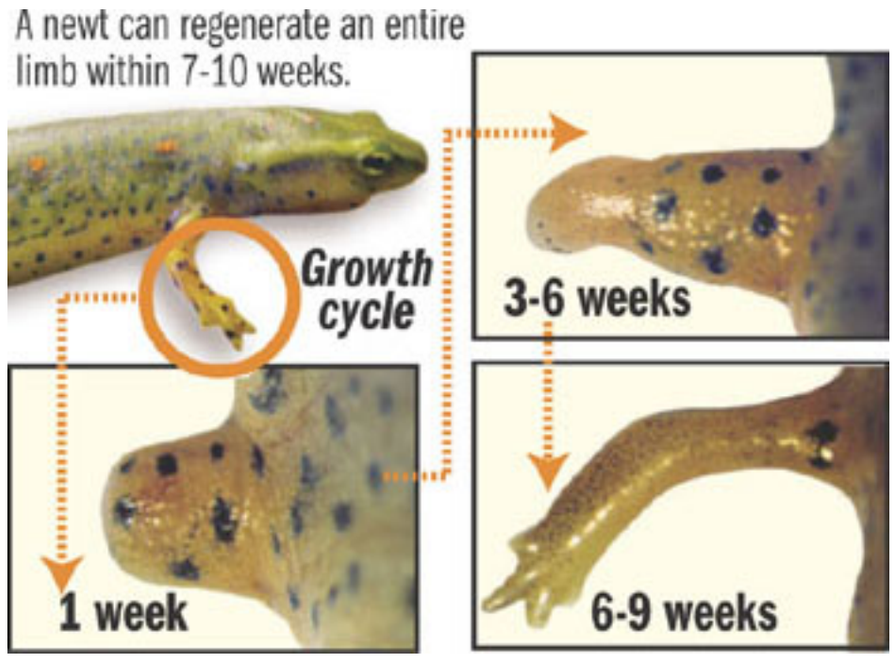
- *Plethodon cinereus* and *Plethodon glutinosus* salamanders
- “Skips aquatic larvae”

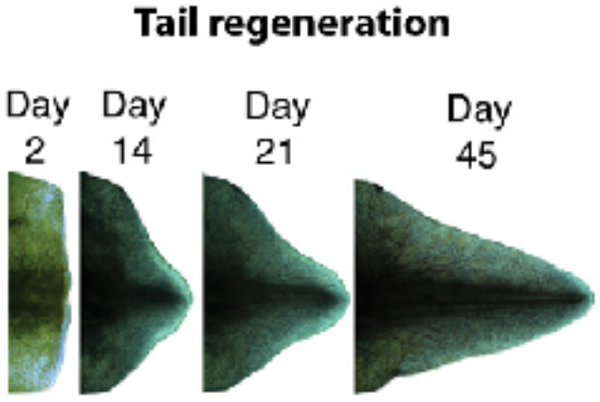
Ontogeny 4:
Egg, Aquatic Larvae,
Sexually Mature Aquatic Larvae

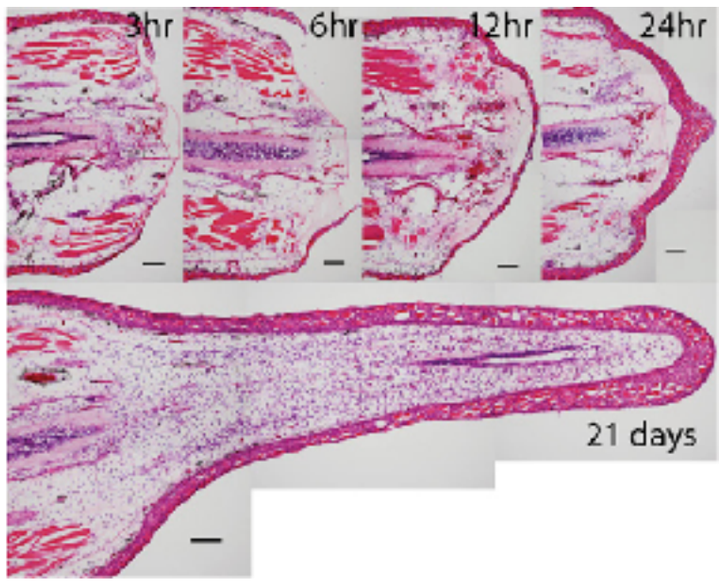
- *Necturus maculosus*
- “Skips adult stage”

Limb Regeneration

- Salamanders
  - Appear to retain this ability throughout their lifespan
    - Tails
    - Limbs
  - They get **everything** back, bone, muscle, and nerves!
- Frogs
  - Tadpoles capable of regenerating tail, but adult frogs cannot regenerate
  - Can only regenerate the notochord





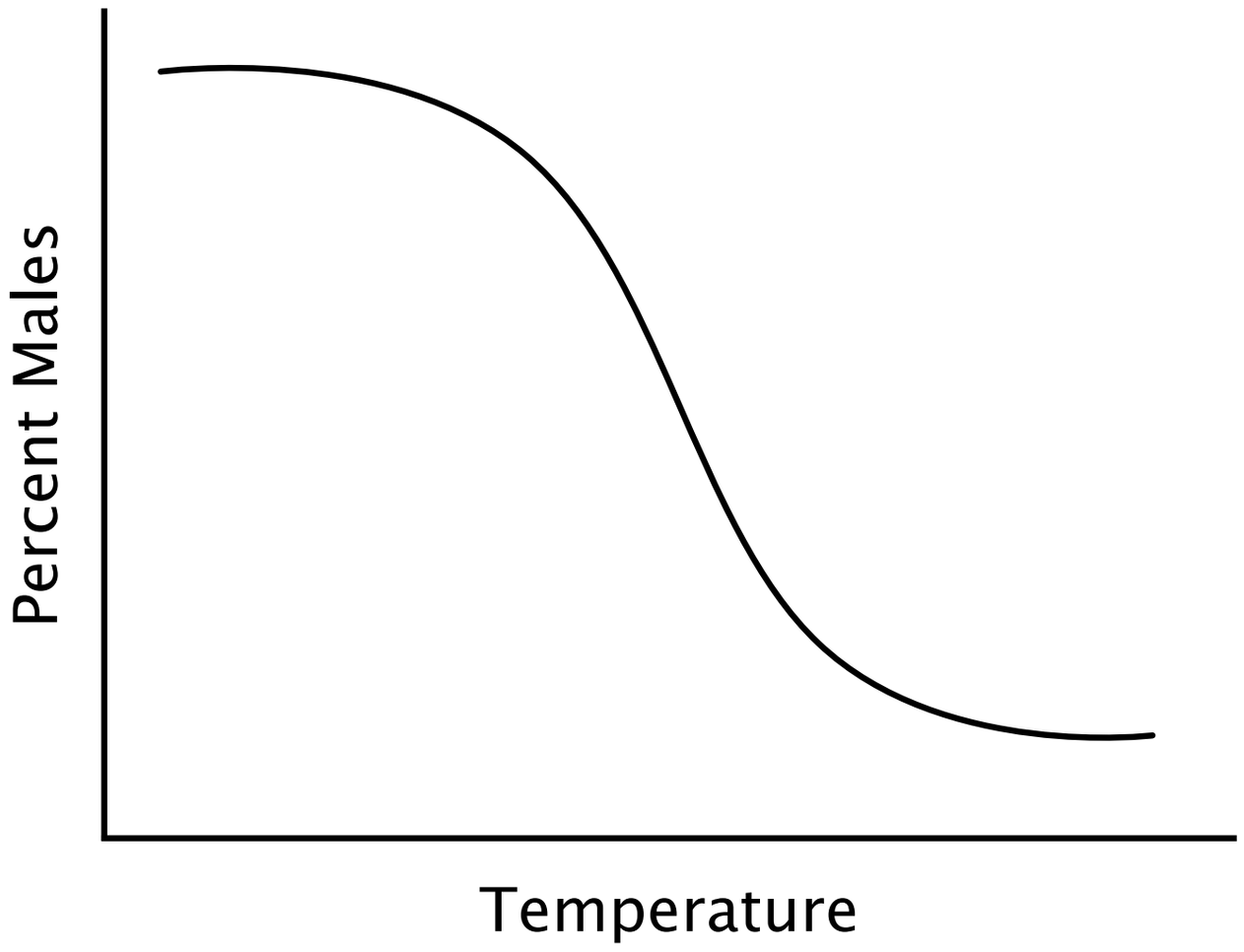


Reptile Life Cycles / Development

- Turtles
    - Follow Egg, Juvenile, Adult pattern
    - Interesting temperature dependent sex determination
- Snakes
    - Generally follow Egg, Juvenile, Adult pattern, with some species bearing live young

Turtle Temperature Dependent Sex Determination

- General method for sex determination in turtles
- Adaptive significance?
- May just be “phylogenetic inertia”, and may not be adaptive at all
- Sexes are differentially fitter in different temperatures



Snake Birthing Strategies

- Oviparity - typical egg development
    - *Carphophis amoenus, Coluber constrictor, Diadophis punctatus, Elaphe obsoleta, Heterodon platyrhinos, Lampropeltis triangulum, Opheodrys vernalis*
- Ovoviviparity - egg is retained in the female, young are born in membraneous sacs
    - *Nerodia sipedon, Storeria dekayi, Storeria occipitomaculata, Thamnophis sauritis, Agkistrodon contortrix*
- Viviparity - live young are born
    - *Thamnophis sirtalis, Crotalus horridus*