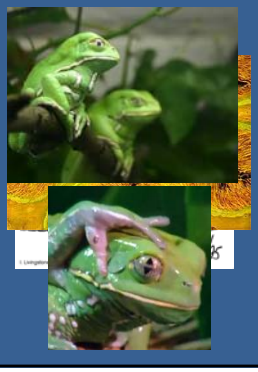
Amphibian Physiology and Immunology

Lecture Road Map

- Amphibian organ systems
- Function of systems
- Physiological adaptations
  - Hibernation
  - Immune response

Integumentary system

- Amphibian Integument
- Epidermis-single or few layers of Epidermis-keratinized cells
  - Aquatic amphibians-no keratinized cells
- Extremely permeable Absorb water directly from environment
- Dermis-chromatophores and glands produce secretions which help protect the amphibian's skin



Vision

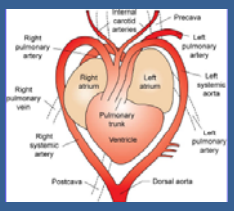
- Lacrimal and harderian glands present in most amphibians
- Produce secretions that combine to form the tear film
- Eyes protected by nictitactin membranes
- Caecilians-eyes covered with skin
- Amphibian eyes-often protrude ventrally into the oral cavity when animal swallowing

Circulatory system

- Double circulatory system
- Heart is not always completely separated into two pumps.
- Three-chambered heart.

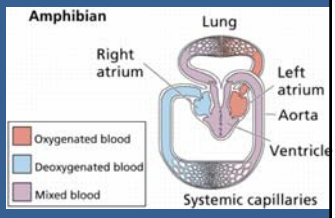
Heart

- Two atria
- One ventricle



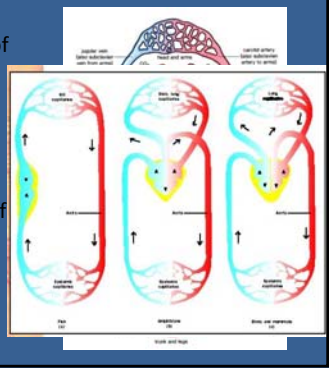
Heart

- Ventricle Regions
- Cavum venosum:paired aortic arches,lead to aortic arches,lead to systemic circulation
- Cavum arteriosum:receives blood from pulmonary veins and directs oxygenated blood to cavum venosum
- Cavum pulmonale: receives blood from right atrium and directs into pulmonary circulation



Heart

- Pressure differences of out flow tracts and muscular ridge that partially separates cavum venosum and cavum pulmonale maintain separation of oxygenated and deoxygenated blood

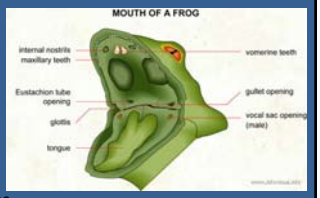


Heart rate

- Depends on species, size, temperature, activity level, and metabolic function
- Heart rate=33.4 ×(Weight in kg-0.25))

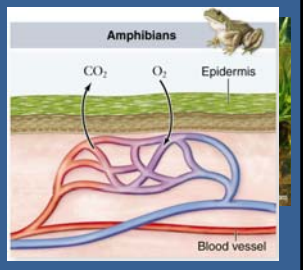
Respiratory system

- Frogs and toads-vocal sacs arise from trachea
- Honey comb appearance
- Openings of honey comb end at faveoli
  - Fixed structures surrounded by capillaries
  - Site of gas exchange



Respiratory system

- Simple saclike lungs
- Some salamanders have no lungs
  - Cutaneous respiration
- Pulmonary ventilation results from pumping of buccal cavity and pharynx
- Gas exchange can also occur across mucous membranes of buccal cavity, pharynx, and cloaca

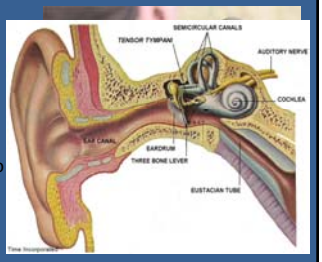


Telmatobius culeus

Video

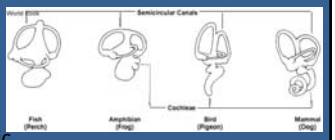
Hearing

- Ears- both sides of head
- Tympanum-may lie in depression and/or be covered by folds of skin
- Columella- single bone in middle ear Connects to tympanum and quadrate bone Transmits vibrations to oval window of cochlea
- Converted to nerve impulses and transmitted to the brain via the vestibulocochlear nerve



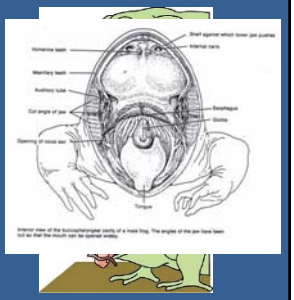
Hearing

- Semicircular canals control balance and equilibrium
- Salamanders and caecilians-no tympanic membranes; columella may be degenerate



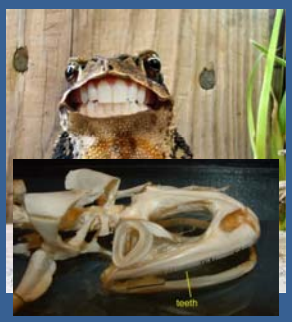
Digestive system

- Tongue used to capture prey
- lingual flipping
- Numerous salivary glands
- Salivary secretions provide lubrication that aids in ingestion of large prey
  - Also has enzymatic properties



Dentition

- Most amphibians have teeth
- Caecilians and salamanders-both maxillary and mandibular teeth Palatal teeth in some species
- Maxillary dentition present in some anuran species

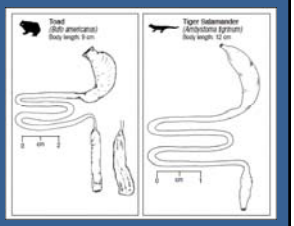


Larvae

- Very specialized
- Most lack a stomach
- The gastric region of the digestive tract usually forms a thickened sheath, which produces mucus, a proteolytic cathepsin, and a low pH
- The intestine is relatively long, with no distinct separation into a midgut and hindgut.

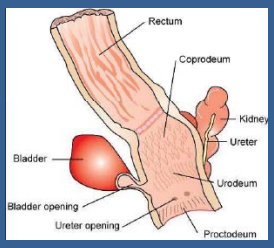
Digestive system

- shortening of the intestine, removal and regeneration of intestinal epithelium, and the appearance of a distinct hindgut that is lined with columnar epithelium and goblet cells
- Esophagus very short and wide, especially in anurans



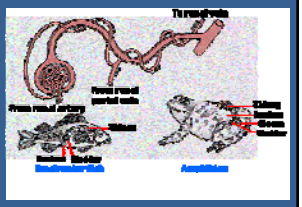
Cloaca

- Common out flow tract for GI and urogenital tracts
- Three chambers: coprodeum, urodeum and proctodeum



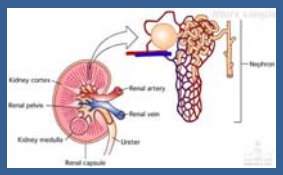
Kidney

- Excreting excess water
- The permeable skin allows fresh water to enter by osmosis.
- The problem is to conserve water, not eliminate it.
- adjust rate of filtration at the glomerulus
- When blood flow through the glomerulus is restricted, a **renal portal** system is present to carry away materials reabsorbed through the tubules.



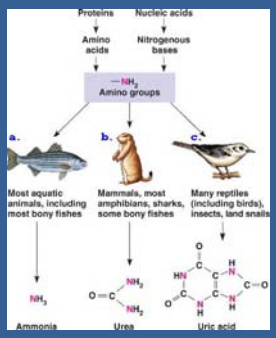
Kidney

- Able to use its urinary bladder to aid water conservation.
- When in water, the frog's bladder quickly fills up with a hypotonic urine.
- On land, this water is reabsorbed into the blood helping to replace water lost through evaporation through the skin.
- The reabsorption is controlled by a hormone similar to mammalian ADH.



Kidney

- Some amphibians excrete ammonia as a nitrogenous waste product; others excrete urea, some excrete uric acid
- No ability to concentrate urine

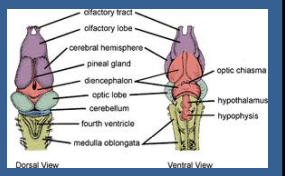


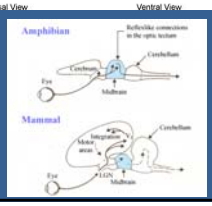
Controlling water loss

- Terrestrial and arboreal frogs have less permeable skin.
  - Some tree frogs spread lipids on skin.
- During dry periods, tree frogs minimize surface area exposed to air.
- All water acquired via skin (no drinking)
  - **water patch:** area of highly vascularized pelvic skin used to absorb water.
- Store water in bladder and reabsorb it during dry periods.

Nervous system

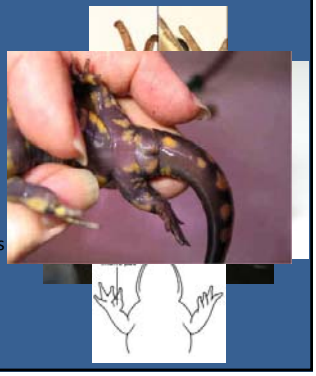
- Brain-well developed for basic functions (sight, olfaction,and movement)
- 10 cranial nerves
- Spinal cord extends to the tip of the tail salamanders and caecilians; ends in lumbar region in frogs and toads
- Animal dependent upon spinal segmental reflexes to control movement





Reproduction

- Sexual dimorphism in some species
  - Size and color
  - Enlarged toe pads
  - Large tympanic membranes
  - Vocal sacs
  - Prominent cloacal glands in male salamanders



Mating tubercles

Smoky jungle frog

Reproduction

- Paired gonads in dorsocaudal coelomic cavity
- Bidder's organs- ovarian remnants near testes in male toads
- Most caecilians are viviparous
- Most anurans and salamanders are oviparous
- Eggs are usually deposited in or near water

salamanders

– **Spermatophore:** large packet of lipid and sperm used for fertilization in various ways:

a. Male pushes spermataphore into female's cloaca.
b. Female picks up spermataphore with cloaca.
c. Female deposits eggs on spermatophore (external fertilization)

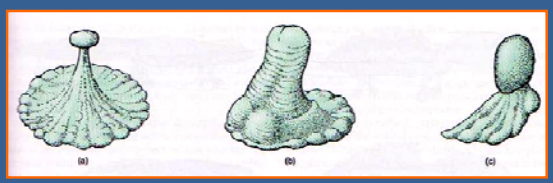
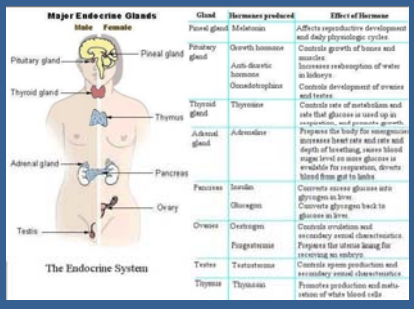


Fig. 10-11

Life cycle

- Larval anurans (tadpoles) have completely aquatic lives prior to metamorphosis
- Tadpole metamorphosis-varies among species
  - Metamorphosis is stimulated by thyroid hormones

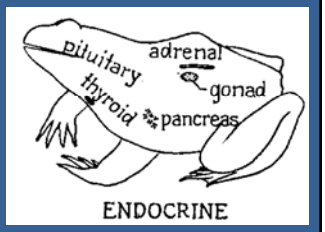
Endocrine system



Gland	Hormones produced	Effect of Hormone
Pineal gland	Melatonin	Affects reproductive development and daily physiologic cycles
Pituitary gland	Growth hormone	Controls growth of bones and muscles
	Anti-diuretic hormone	Increases reabsorption of water in kidneys
	Gonadotrophins	Controls development of ovaries and testes
Thyroid gland	Thyroxine	Controls rate of metabolism and rate that glucose is used up in respiration, and promotes growth
Adrenal gland	Adrenaline	Prepares the body for emergencies: increases heart rate and rate and depth of breathing, raises blood sugar level so more glucose is available for respiration, diverts blood from gut to limbs
Pancreas	Insulin	Converts excess glucose into glycogen in liver
	Glucagon	Converts glycogen back to glucose in liver
Ovaries	Oestrogen	Controls ovulation and secondary sexual characteristics
	Progesterone	Prepares the uterus lining for receiving an embryo
Testes	Testosterone	Controls sperm production and secondary sexual characteristics
Thymus	Thymosin	Promotes production and maturation of white blood cells

Endocrine system

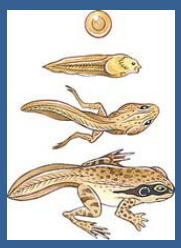
- Single thyroid gland
- Size of thyroid gland varies according to season and metabolic state
- Parathyroid glands and ultimobrachial bodies in cervical region
- Exact location of endocrine organs in amphibians varies



Anuran Metamorphosis

Stages: regulated by **thyroxine** released from thyroid.

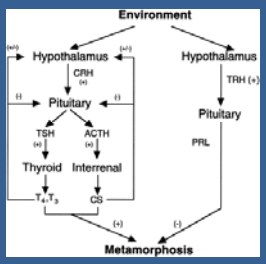
1. **Premetamorphosis:** tadpoles increase in size.
2. **Prometamorphosis:** hind legs appear; slower growth.
3. **Metomorphic climax:** forelegs appear and tail regresses; rapid portion of metamorphosis (when frog is most vulnerable).



Video

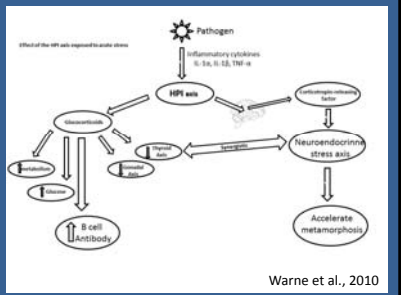
Anuran Metamorphosis

- Stable environment
  - Abundant resources
  - No predators
  - Stable weather conditions



Anuran Metamorphosis

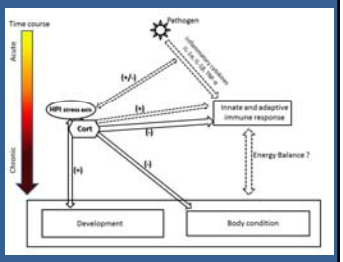
- Hydric stress
- Predation
- Competition
- Diseases



Warne et al., 2010

Stress adaptations

- Speed metamorphosis
- Reduce size
- Cannibalism
- Diseases
- Death



Physiological adaptations

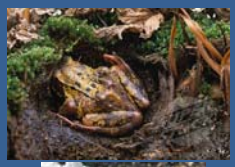
Seasonal changes

Hibernation

- Go dormant during the winter
- Slow metabolism
- Decrease respiration
- In ponds
- Swim to the bottoms and rest on the bottom or partially burrow into the mud.
- must be deep enough that they will not be frozen into solid ice,
- water must have an adequate amount of oxygen.
- Many species can survive underwater for months, their bodies very slowly burning fat stored in their bodies.

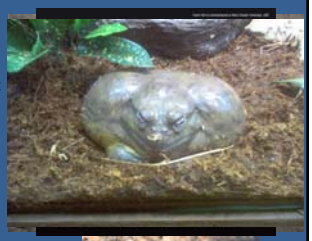
Hibernation

- Dig below the frost line to avoid freezing.
- Salamanders use abandoned burrows or other natural holes.
- Some frogs in the far north can actually freeze solid.
- Reduce water in their bodies (more than half), its veins fill with an antifreeze-like mixture of sugars and sugar alcohols, and freezes.
- While it's frozen, it's hard, and ice forms around the frog's organs. However, the frog's individual cells remain unfrozen and intact.
- When frozen doesn't breathe nor does its heart beat. Brain activity is immeasurable.

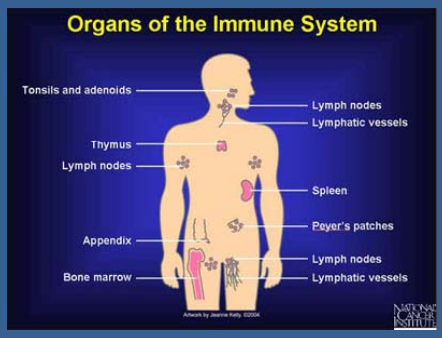


Aestivation

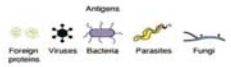
- Hot, dry weather
- Move underground where it is cooler and more humid.
- During estivation breathing, heart rate, and metabolic processes such as digestion all dramatically slow down.
- Decreases the organism's need for water.
- Some frogs and salamanders form a mucus cocoon around themselves to prevent water loss through their skin.
- When rains return, estivating organisms become active again



Immune system



YOUR ACTIVE IMMUNE DEFENSES

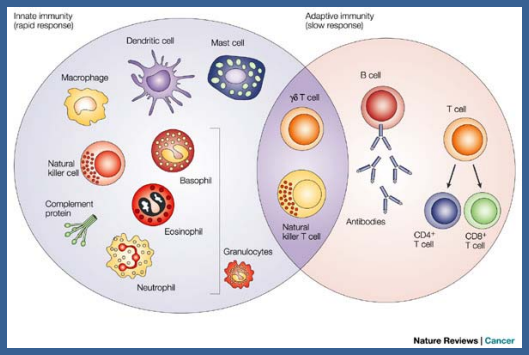


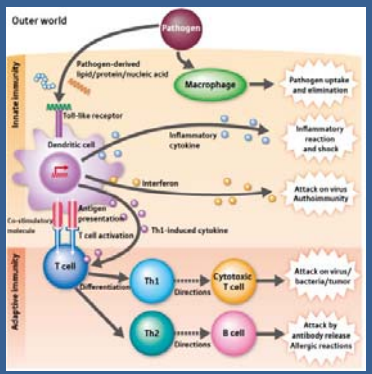
Innate Immunity
- invariant (generalized)
- early, limited specificity
- the first line of defense

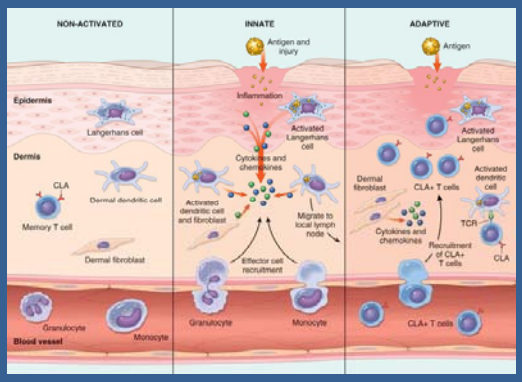
1. Barriers - skin, tears
2. Phagocytes - neutrophils, macrophages
3. NK cells and mast cells
4. Complement and other proteins

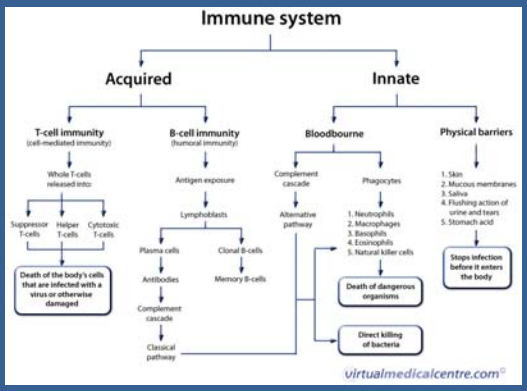
Adaptive Immunity
- variable (custom)
- later, highly specific
- "remembers" infection

1. APCs present Ag to T cells
2. Activated T cells provide help to B cells and kill abnormal and infected cells
3. B cells - produce antibody specific for antigen



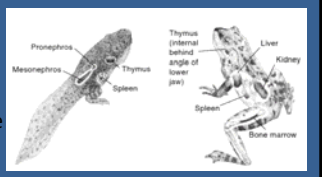


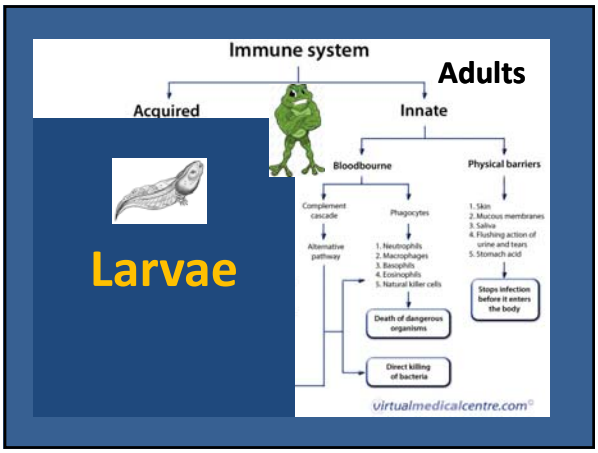




Differences in immune system

- Both have active innate immune system
- Small amount of T cells and B cells in larvae
- NK cells only right before metamorphosis
- Immune system will be complete 2-3 weeks after metamorphosis





Can amphibians fight back diseases?

- Larvae
  - Competent innate system
  - Weak but present adaptive
- Adults
  - Strong innate and adaptive
  - Antimicrobial peptides

Questions

- Are larvae and adults equally susceptible to diseases
- Can disease influence larval stage length
- How does stress affect larval development