DESIGNATION- LECTURER IN ZOOLOGY
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SEMESTER—3RD

SELF- STUDY MATERIAL

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TOPIC- AMPHIBIA & ORIGIN OF TETRAPODA

PAPER- DSC-H-ZOO-V

UNIT--2

TOPIC---Amphibia:Origin of Tetrapods
&
Metamorphosis

CLASSIFICATION

Phylum: Chordata

Subphylum:Vertebrata

Superclass:Ganthostomata

Class: Amphibia

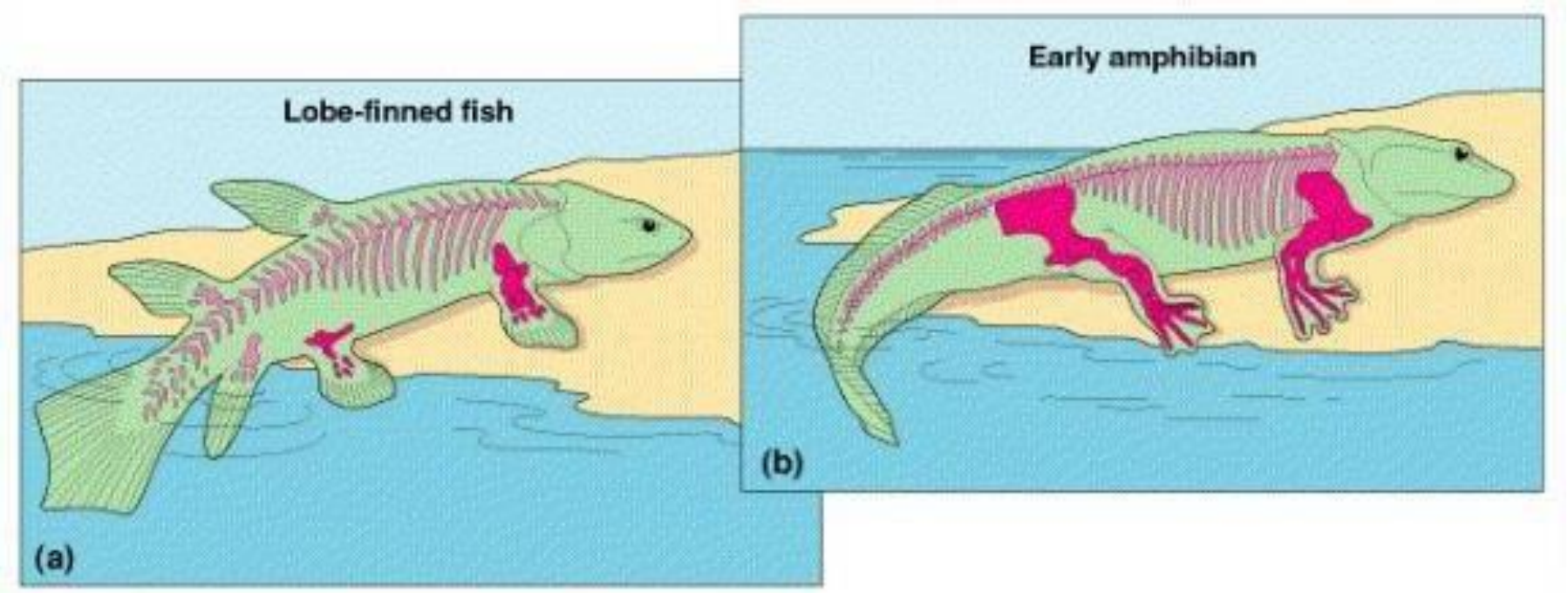
Order:

1. Anurans: frogs and toads
2. Urodeles: salamanders and newts
3. Caecilians: legless, fossorial amphibians

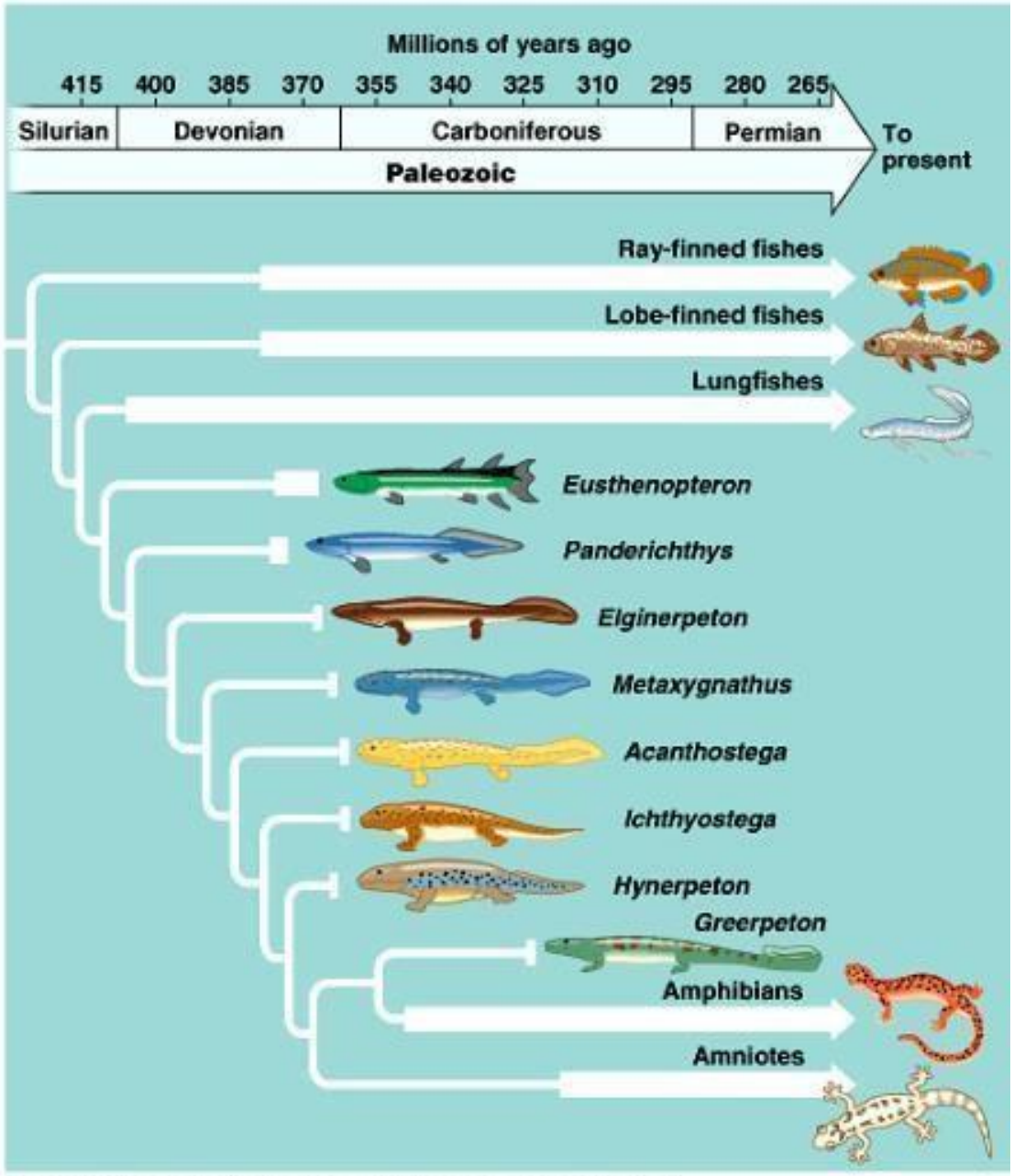
❖ Characteristics

- ➢ tetrapods (4 limbs)- terrestrial movement
- ➢ aquatic larval stage
- ➢ moist, permeable skin

The first tetrapods were amphibians that evolved from the Devonian crossopterygian fishes which lived in shallow marshy locations and already possessed lungs for respiration and lobed fins to support their bodies on muddy banks of ponds, rivers and marshland.



Origin of Tetrapods

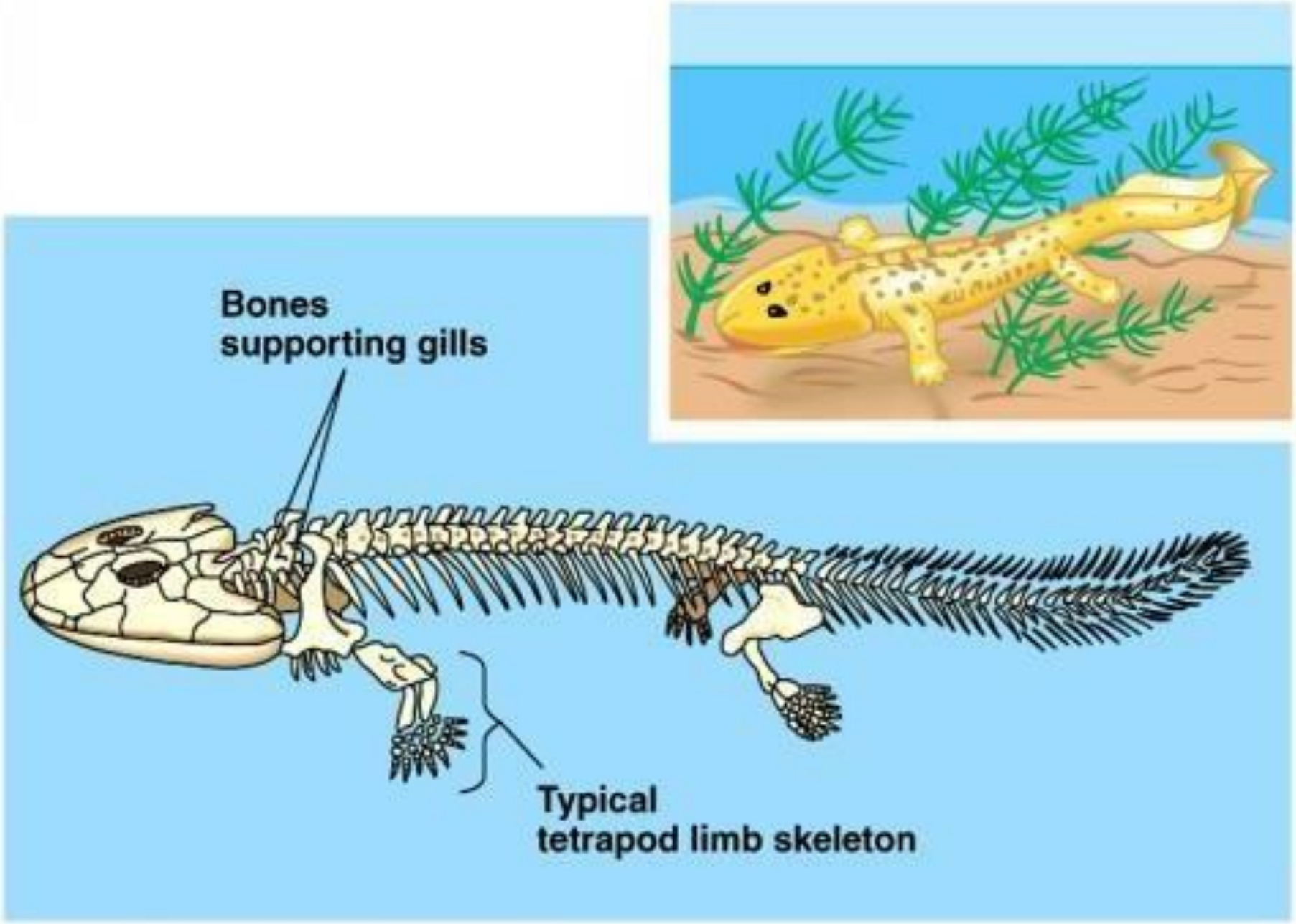


The anatomical changes that took place during transformation from fishes to amphibia were as follows:

- A tetrapod limb evolved to support the body out of water as on land the entire body weight fell on the four limbs, whereas in fishes body weight is supported by water and fins have to just propel it forward.

- Gills were lost in the adult stage as lungs became more and more efficient air breathing organs and air contained more oxygen as compared to water.

- The hyomandibular bone of the second visceral arch transformed into columella to transmit sound vibrations from air to the inner ear.



❖Loss of scales permitted cutaneous respiration which evolved as an alternative method of respiration in the absence of gills while the animal lived and swam in water.

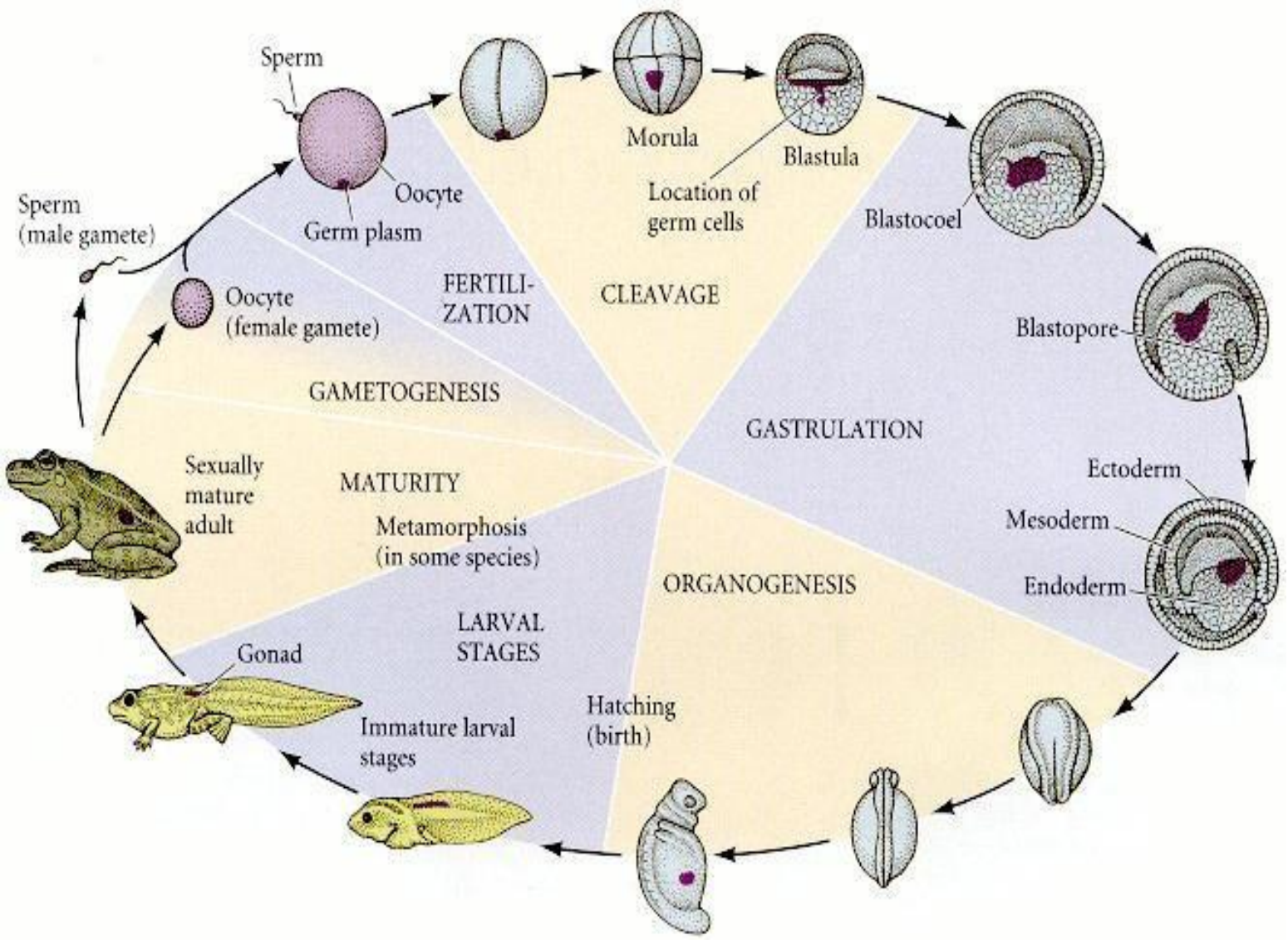
❖The skull developed two occipital condyles that fitted in an atlas vertebra so that skull could move upward and downward for locomotion as well as for better visibility.

❖In terrestrial environment vertebral column must be strong to support the body weight and hence centra of vertebrae transformed from amphicoelous to procoelous type.

❖The lateral line system that was not useful in terrestrial environment simply disappeared.

❖Adipose tissue that stores fat and provides insulation developed under the skin to stop loss of water by evaporation on land.

Amphibian Metamorphosis



❖ Metamorphosis is a biological developmental process by which an animal physically develops after birth or hatching, involving a noticeable and relative rapid change in the animal's body structure through cell growth and differentiation.

❖ Anurans (frog, toad) metamorphic changes are more remarkable, with almost every organ subject to modification.

❖ It is initiated by thyroid hormone (T3 & T4). These hormone/s reach each and every organs of larvae with blood and dramatic modifications (Growth, death, remodeling and respecification) of organs take place.

Amphibian metamorphosis is associated with morphological changes that prepare an aquatic organism for terrestrial existence. Morphological changes are associated with:

- Growth of new structures
- Cell death during metamorphosis
- Remodeling during metamorphosis
- Biochemical respecification in the liver

Growth of new structures

The changes in amphibian metamorphosis are initiated by Thyroid hormones- Triiodothyroxine (T3) Thyroxine (T4)

T3 induces :

- Emergence of limbs on metamorphosing tadpole;
- In the eyes, eyelids and nictitating membranes emerge.
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- Proliferation and differentiation of new neurons-to form limb musculature (Blocking T3 activity prevents limb neurons formations and development causes paralysis of limbs)

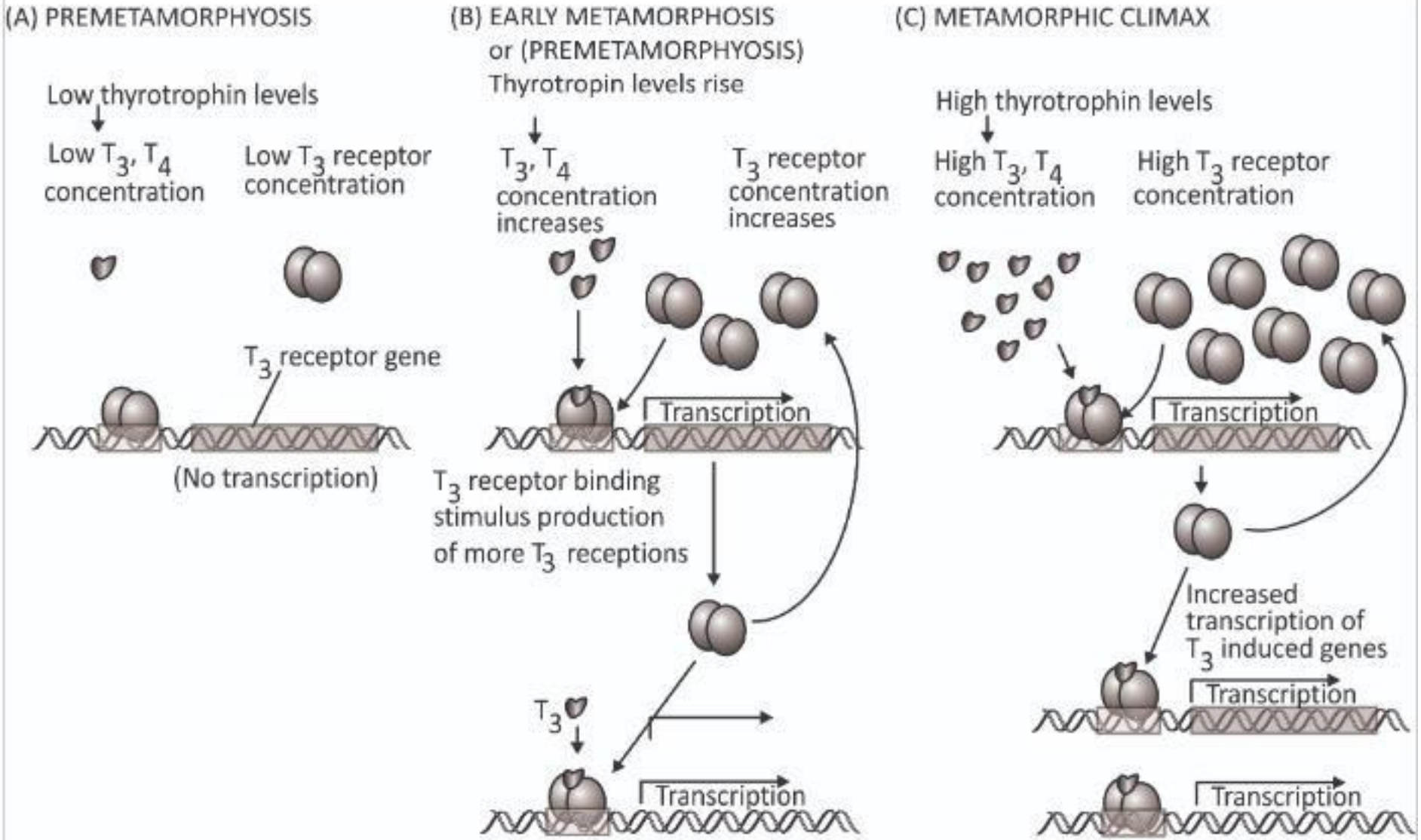


Fig. : Stages of metamorphosis under influenced of T_3/T_4

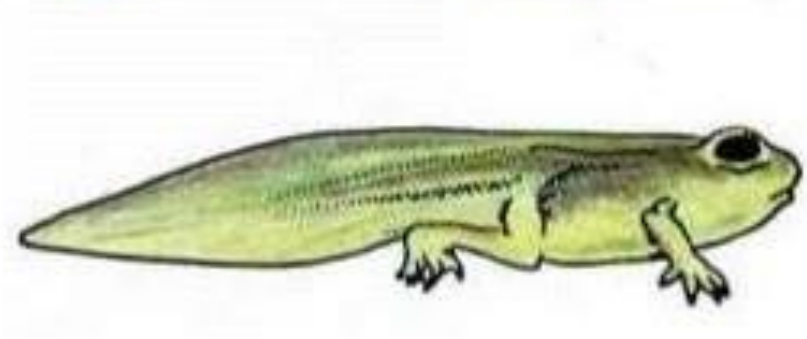
Cell death during metamorphosis

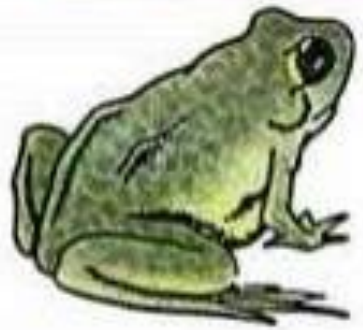
- T3 causes degeneration of tail and gills, that were important for larval (but not adult) movement and respiration.

- The first part of tail resorption is caused by suicide, and later part of tail muscles are eaten by macrophages.

- Tadpole RBCs are digested by macrophages of liver and spleen.

- Tadpole Hb replaced by adult Hb (binds oxygen slowly , releases more rapidly and different in shape).





Apoptosis during the metamorphosis of a tadpole into a frog

Remodeling during metamorphosis

- Development of the lungs and the disappearance of the gills and gill pouch
- The lower jaw transforms into the big mandible of the carnivorous adult
- The long, spiral gut of the herbivorous tadpole is replaced by the typical short gut of a carnivorous predator
- Nervous system becomes adapted for hearing and stereoscopic vision and for new methods of locomotion
- Eyes are repositioned higher up on the head with eyelids and associated glands formed.
- Eardrum, middle ear, and inner ear are developed
- Skin becomes thicker and tougher

Biochemical respecification in the liver

Tadpoles (Ammonotellic)  Adult (Urea)

T3 may regulate this changes by inducing a set of transcription factors that specifically activates expression of urea cycle genes and suppressing the genes responsible for ammonia synthesis.

❖ In tadpoles (as in freshwater fishes), the major retinal photopigment is porphyropsin. During metamorphosis, the pigment changes to rhodopsin, the characteristic photopigment of terrestrial and marine vertebrates .

❖ Tadpole hemoglobin is changed into an adult hemoglobin that binds oxygen more slowly and releases it more rapidly.

The liver enzymes also change, reflecting the change in habitat.

❖ Tadpoles, like most freshwater fishes, are ammonotelic;

❖ Many adult frogs (such as the genus Rana) are ureotelic, excreting urea, like most terrestrial vertebrates, which requires less water than excreting ammonia.

❖ During metamorphosis, the liver begins to synthesize the urea cycle enzymes necessary to create urea from carbon dioxide and ammonia

Hormonal Control of Amphibian Metamorphosis

❖ Gudernatsch (1912) demonstrated the control of metamorphosis by thyroid hormones, who discovered that tadpoles metamorphosed prematurely when fed powdered sheep thyroid gland.

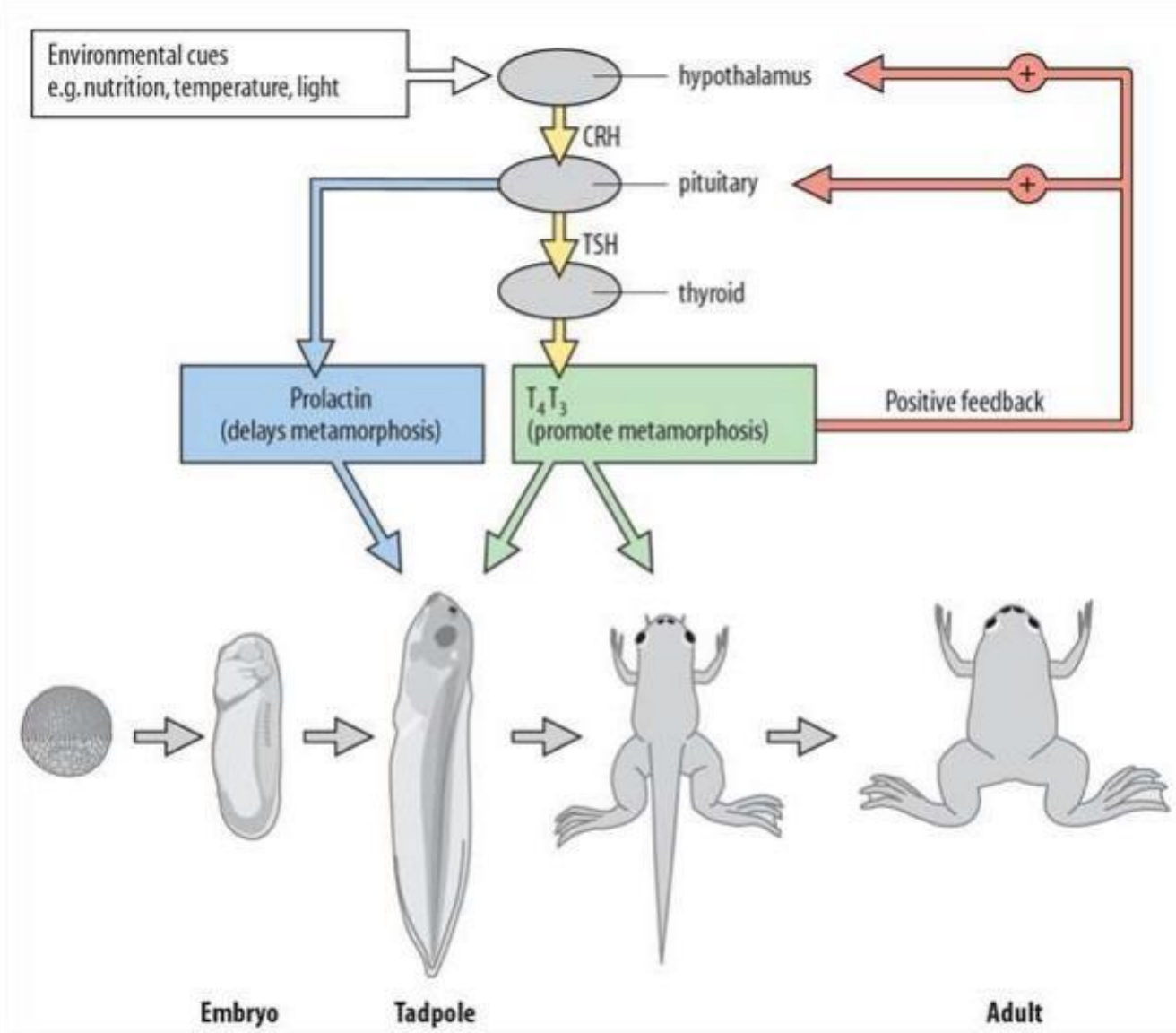
❖ However, Bennet Allen (1916) found that when he removed or destroyed the thyroid rudiment from early tadpoles (thus performing a thyroidectomy), the larvae never metamorphosed, instead becoming giant tadpoles.

Three Stages of Metamorphosis in Frog and Control of hormones

a. **Pre-metamorphosis**

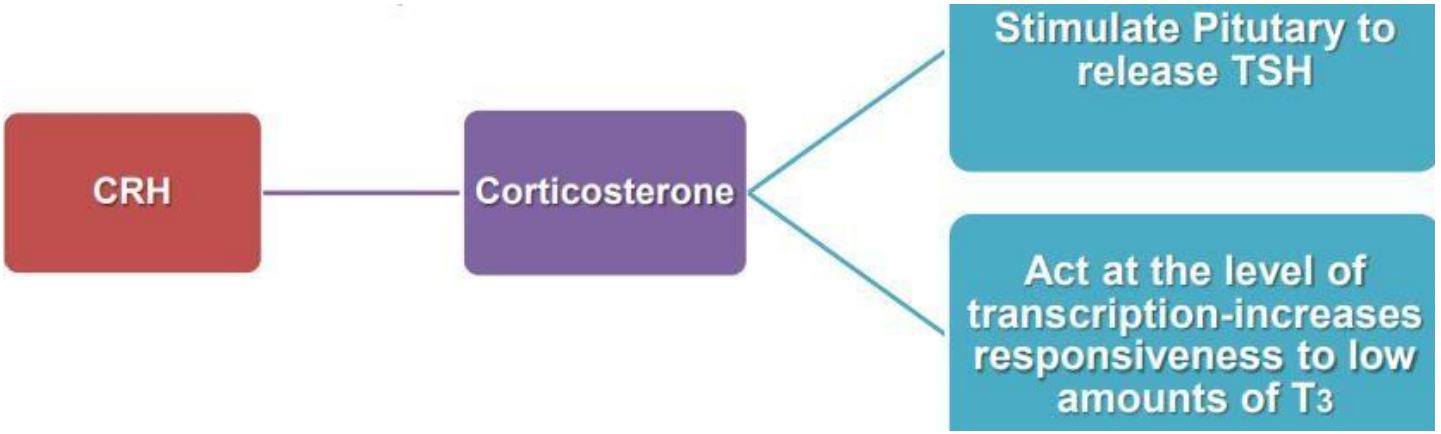
b. **Pro-metamorphosis**

a. **Metamorphic climax**



Pre-Metamorphosis

- In pre metamorphosis, T3 and T4 levels are very low
- CRH causes for initiation of T4 secretion
- Leg growth initiation starts from limb rudiments by using thyroid hormone
- Tissues that respond earliest to the thyroid hormones are those that express high levels of deiodinase II; can convert T4 directly to T3. Eg; Limb rudiments



Pro-Metamorphosis

- The concentration of T4 increases dramatically and TR β levels increase, leading to tail resorption.

- TR β is the principal receptor that mediates metamorphic climax. In this way the tail undergoes resorption only after legs are functional.

- The wisdom of the frog is simple: “Never get rid of your tail before your legs are functional”

- Some tissues are not responsive to thyroid hormones, e.g., dorsal retina.

Metamorphic Climax

❖The frog's brain down regulates metamorphosis once metamorphic climax has been reached.

❖Thyroid hormones induce a negative feedback loop, shutting down pituitary cells which causes thyroid to secrete them.

❖T3 is found in the anterior pituitary at metamorphic climax. This inhibits transcription of Thyrotrophin gene and thereby initiates a negative feedback loop

Summary of some metamorphic changes in anurans

System	Larva	Adult
Locomotory	Aquatic; tail fins	Terrestrial; tailless tetrapod
Respiratory	Gills, skin, lungs; larval hemoglobins	Skin, lungs; adult hemoglobins
Circulatory	Aortic arches; aorta; anterior, posterior, and common jugular veins	Carotid arch; systemic arch; cardinal veins
Nutritional	Herbivorous: long spiral gut; intestinal symbionts; small mouth, horny jaws, labial teeth	Carnivorous: Short gut; proteases; large mouth with long tongue
Nervous	Lack of nictitating membrane; porphyropsin, lateral line system, Mauthner's neurons	Development of ocular muscles, nictitating membrane, rhodopsin; loss of lateral line system, degeneration of Mauthner's neurons; tympanic membrane
Excretory	Largely ammonia, some urea (ammonotelic)	Largely urea; high activity of enzymes of ornithine-urea cycle (ureotelic)
Integumental	Thin, bilayered epidermis with thin dermis;no mucous glands or granular glands	Stratified squamous epidermis with adult keratins; well-developed dermis contains mucous glands and granular glands secreting antimicrobial peptides

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Thank
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