METAMORPHOSIS IN AMPHIBIA

METAMORPHOSIS

- The term metamorphosis customarily denotes the sequences of structural and physiological changes undergone by the larvae to reach the adult stages.
- Metamorphosis is the transformation in the mode of life with radical changes in form, structure and physiology.
- There are broadly two types of metamorphosis:

  A. PROGRESSIVE METAMORPHOSIS

  B. RETROGRESSIVE METAMORPHOSIS

PROGRESSIVE METAMORPHOSIS

IN THIS KIND OF METAMORPHOSIS NEW CHARACTERS ARE ADDED TO THE LARVA WHILE REACHING ADULTHOOD. EXAMPLE: TOAD, FROG

Metamorphosis

- In most species of animals, embryonic development leads to a larval stage with characteristics different from those of adult organisms
- Example: Pleutus larva of Sea Urchin , Caterpillar larva of Butterflies

Metamorphosis is a post embryonic event

- Metamorphosis -transition in multi cellular organisms, from a larval to a juvenile (or adult) stage, accompanied by dramatic morphological, physiological, and ecological changes.

Such changes typically include

- Major restructuring of morphology, and
- Transition from a non-reproductive to a reproductive state,
- Dispersal and settlement to a new habitat, and
- A shift in nutrition and feeding behavior

- The young lacks some adult structures which are developed in late development
- Some structures of young are distinctive and become lost during later development
- The young bears no resemblance to adult

SOME COMMON CHARACTERS OF LARVAL LISSAMPHIBIANS

Larva of all Lissamphibia's present a set of common characteristics:

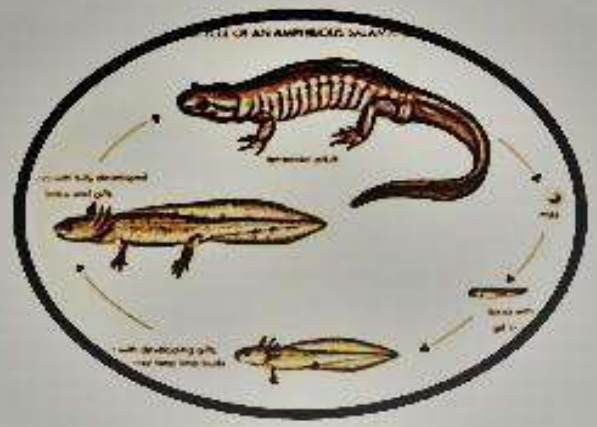
- External gills are held out in the passing current , allowing water to flow across them.
- Absence of eyelids and retinal pigments associated with sight outside water.
- Presence of lateral line or (equivalent) sensorial organ characteristic of fish which allow them to sense vibrations underwater.
- Presence of thinner skin.
- Subaquatic anatomic adaptations present.

METAMORPHOSIS IN FROGS

METAMORPHOSIS IN FROGS IS AN EXCELLENT EXAMPLE OF THE COORDINATION OF A COMPLEX PHYSIOLOGICAL PROCESS INVOLVING NERVOUS, SECRETORY, AND VASCULAR RESPONSES MEDIATED BY THE ENDOCRINE SYSTEMS, AS DISCUSSED IN THE FOLLOWING SLIDES.

A Frog's Life Cycle

- During metamorphosis developmental processes are reactivated by certain hormones
- In Amphibian tadpole, metamorphosis causes the developmental maturation
- Thus metamorphosis is often a time of dramatic developmental change affecting the entire organism



Morphological changes

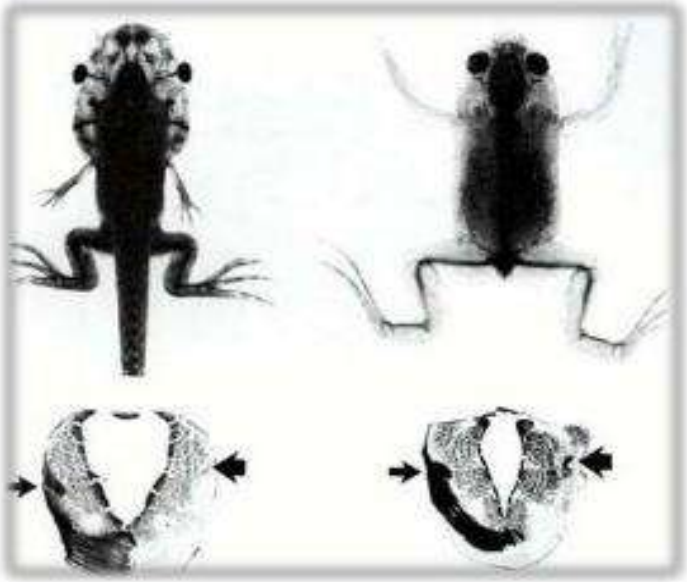
- Here it prepares an aquatic organism for a terrestial exsistence
- In urodeles and anurans
- Regressive changes and constructive process

- Means of locomotion changes as:

  Paddle tail recedes, cartilagenous skull is replaced, horny teeth are replaced, tongue muscle develops
- Large intestine shortens, gills regress, lungs enlarge
- Sensory appendages changes too as the lateral line system of tadpole degenerates and eyes and ear undergo further differentiation
- Middle ear and eyelids develops

Nervous system

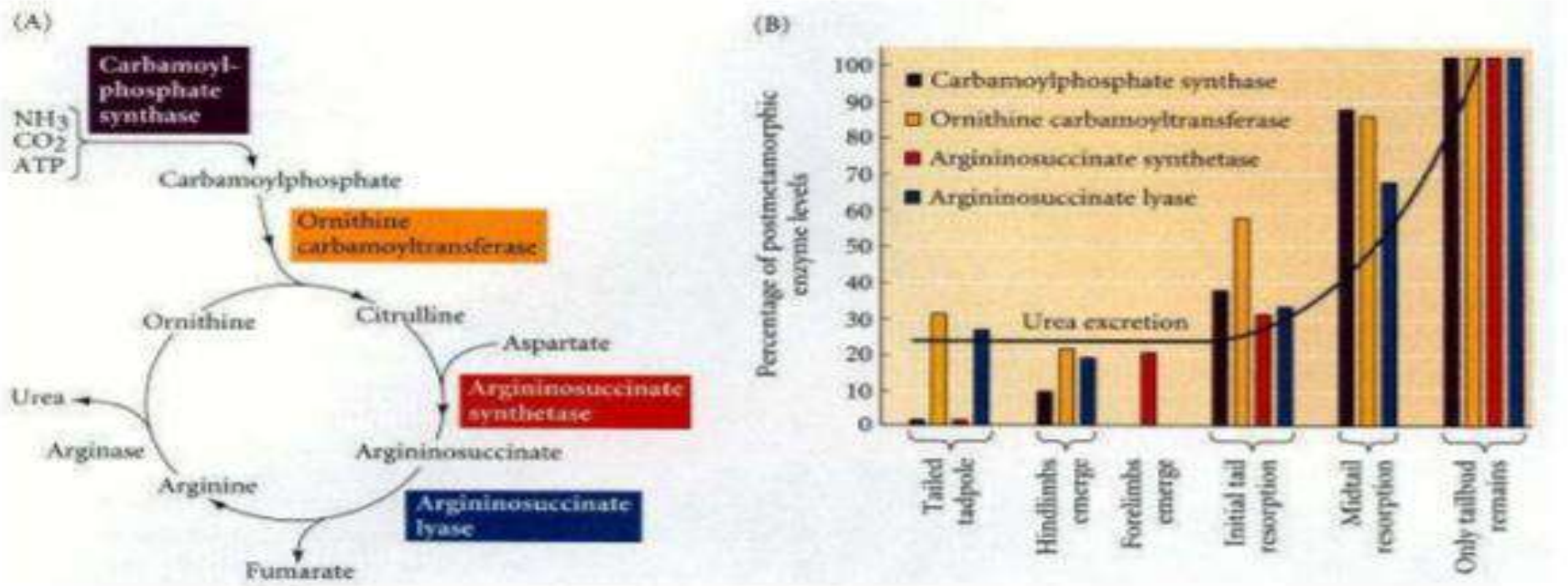
- Nervous system undergoes dramatic changes
- In anuran metamorphosis the movement of eyes forward from their originally lateral position



- Some larval neurons in tadpole jaw, switch their allegiances from larval muscle to newly formed adult muscle
- Other neurons innervating the tongue first form synapse during metamorphosis

Biochemical changes

- Pigment : In tadpoles the major retinal pigment is porphyropsin it changes to rhodopsin
- Haemoglobin : Adult haemoglobin binds oxygen more slowly
- Liver enzymes change
- Tadpoles are amminotelic and adult frogs are ureotelic
- Urea cycle enzymes are synthesized


(A)
Carbamoyl-phosphate synthase
NH_3
CO_2
ATP
Carbamoylphosphate
Ornithine carbamoyltransferase
Ornithine
Citrulline
Aspartate
Argininosuccinate synthetase
Urea
Arginase
Argininosuccinate
Arginine
Argininosuccinate lyase
Fumarate
(B)
Percentage of postmetamorphic enzymic levels
100
90
80
70
60
50
40
30
20
10
0
Carbamoylphosphate synthase
Ornithine carbamoyltransferase
Argininosuccinate synthetase
Argininosuccinate lyase
Urea excretion
Tailed tadpole
Hindlimbs emerge
Forelimbs emerge
Initial tail resorption
Midtail resorption
Only tailbud remains

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

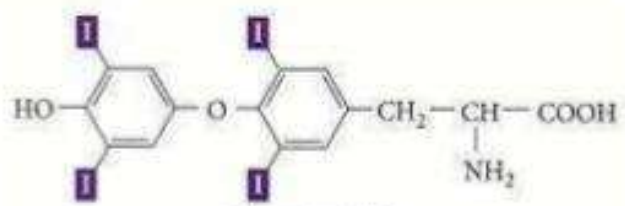
STAGES OF METAMORPHOSIS IN FROGS

The frog tadpole undergoes three developmental stages:

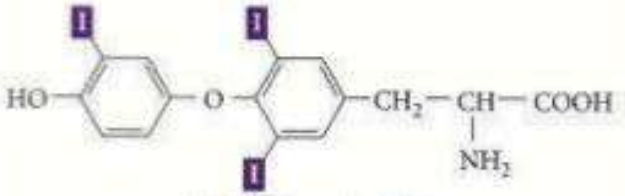
- **PREMETAMORPHOSIS**- This stage is characterized by growth in body size.
- **PROMETAMORPHOSIS**- In this stage the most conspicuous change is development of the hindlimbs, although some growth in body size still continues.
- **METAMORPHIC CLIMAX**- In this stage the tadpole is transformed into the young froglet. The significant changes are:
    1. The forelimbs emerge.
    2. The beak is lost
    3. The mouth widens.
    4. The tail is reabsorbed

HORMONES, DEVELOPMENTAL EVENTS AND THE NERVOUS SYSTEM ARE INVOLVED IN EACH STAGE.

- Metamorphic changes of frog are all brought about by secretion of the hormones Thyroxine(T_4) and Triiodothyronine(T_3)
- T_3 is thought to be the most important hormone



Thyroxine (T_4)



Triiodothyronine (T_3)

HORMONAL INTERPLAY DURING DIFFERENT STAGES OF METAMORPHOSIS

A. PREMETAMORPHOSIS

- During premetamorphosis, the adenohypophysis produces high levels of prolactin, which stimulates growth but inhibits metamorphosis.
- The adenohypophysis also produces small amount of thyroid secreting hormone (TSH) autonomously, without any prompting from the hypothalamus,
- TSH stimulates the thyroid to secrete thyroxine but not in sufficient levels to initiate metamorphosis.
- During this early stage of development, the median eminence of the pituitary does not respond to thyroxine and remains undeveloped.
- Thus during premetamorphosis, the tadpole grows on size but few other changes occur

HORMONAL INTERPLAY DURING DIFFERENT STAGES OF METAMORPHOSIS (continued)

B. PROMETAMORPHOSIS

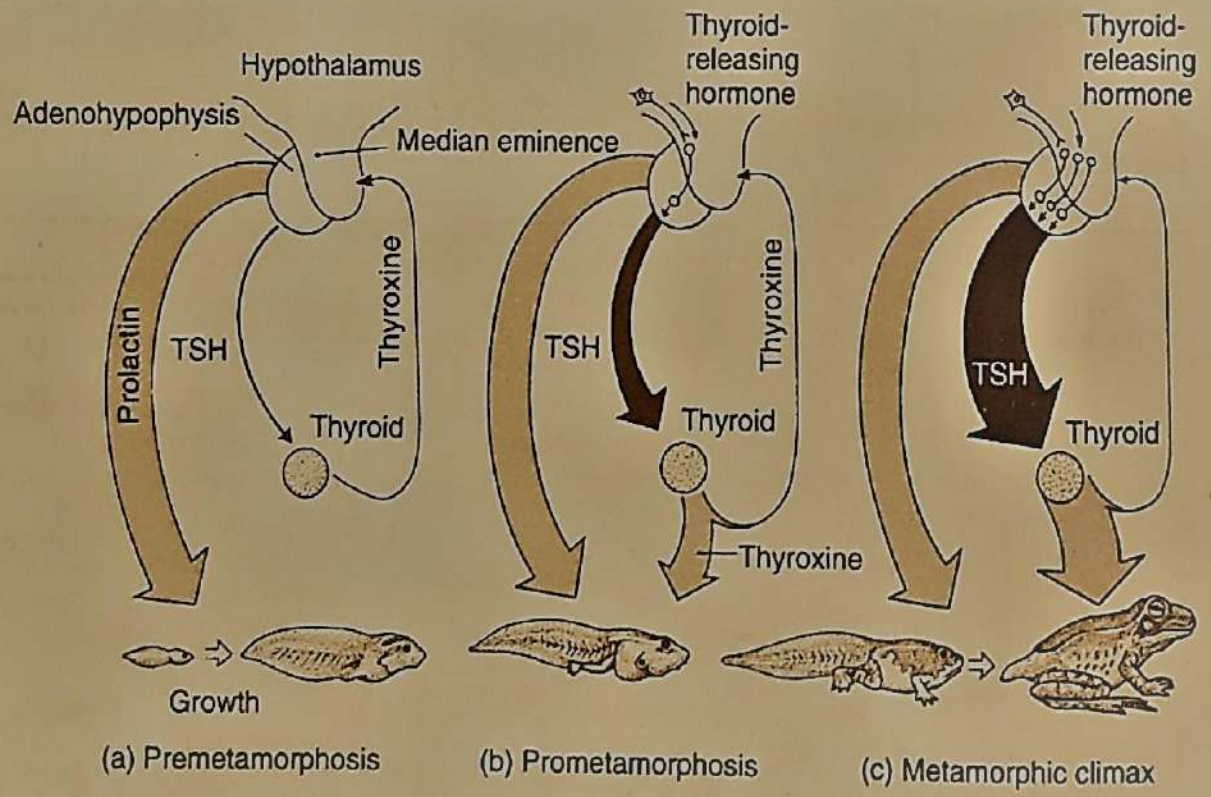
- During prometamorphosis, the median eminence becomes responsive to thyroxine and begins to develop, establishing a complete portal system that allows neurohormones to be transported from the hypothalamus to the adenohypophysis.
- The neurohormone thyrotropin releasing hormone(TRH) stimulates the secretion of increasing amounts of TSH.
- Rising levels of TSH stimulate the thyroid to produce more thyroxine.
- When circulating levels of thyroxine become high enough, hindleg development is initiated.

HORMONAL INTERPLAY DURING DIFFERENT STAGES OF METAMORPHOSIS (continued)

C. METAMORPHIC CLIMAX

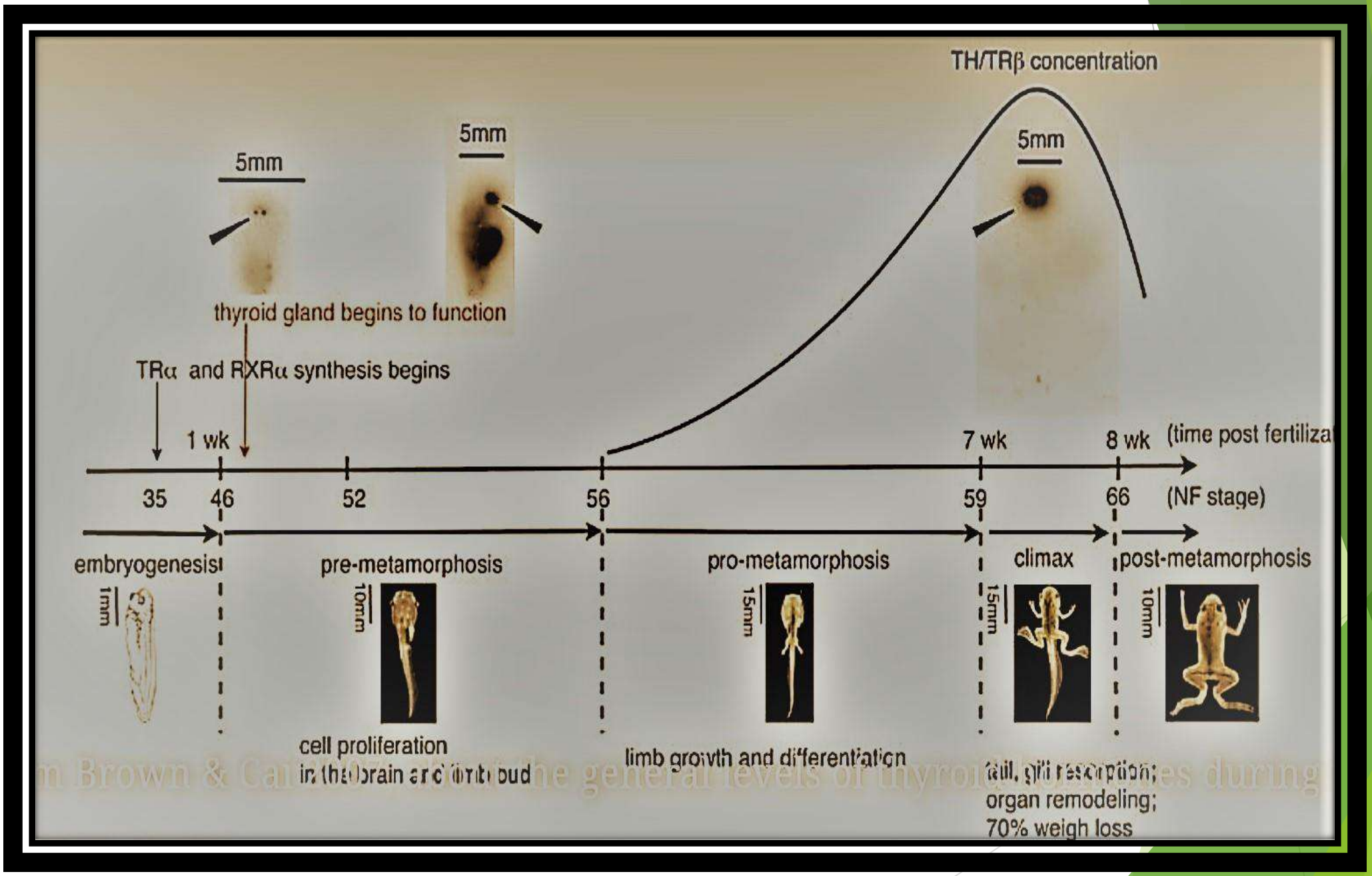
- These events generate a positive feedback system in which rising levels of thyroxine promote the more responsive median eminence to develop a more extensive portal connection so that more TRH is delivered to the adenohypophysis.
- The arrival of TRH stimulates the secretion of even higher levels of TSH and in turn more thyroxine.
- As the events snowball, thyroxine level continue to increase, leading to metamorphic climax.

FIGURE 15.25 Frog metamorphosis. (a) Premetamorphosis is characterized by high levels of prolactin, which promote growth of the tadpole, and low levels of thyroid-stimulating hormone (TSH) and thyroxine. (b) Prometamorphosis includes elaboration of the median eminence and its portal system, which allows the hypothalamus to influence the adenohypophysis. As a result, levels of TSH rise, which promotes rising levels of thyroxine. Thyroxine stimulates hindlimb development. (c) In metamorphic climax, additional vascular routes via the enlarging median eminence stimulate increased secretion of TSH. The resulting elevated level of thyroxine promotes metamorphosis of the tadpole into a froglet.



EFFECT OF PROLACTIN

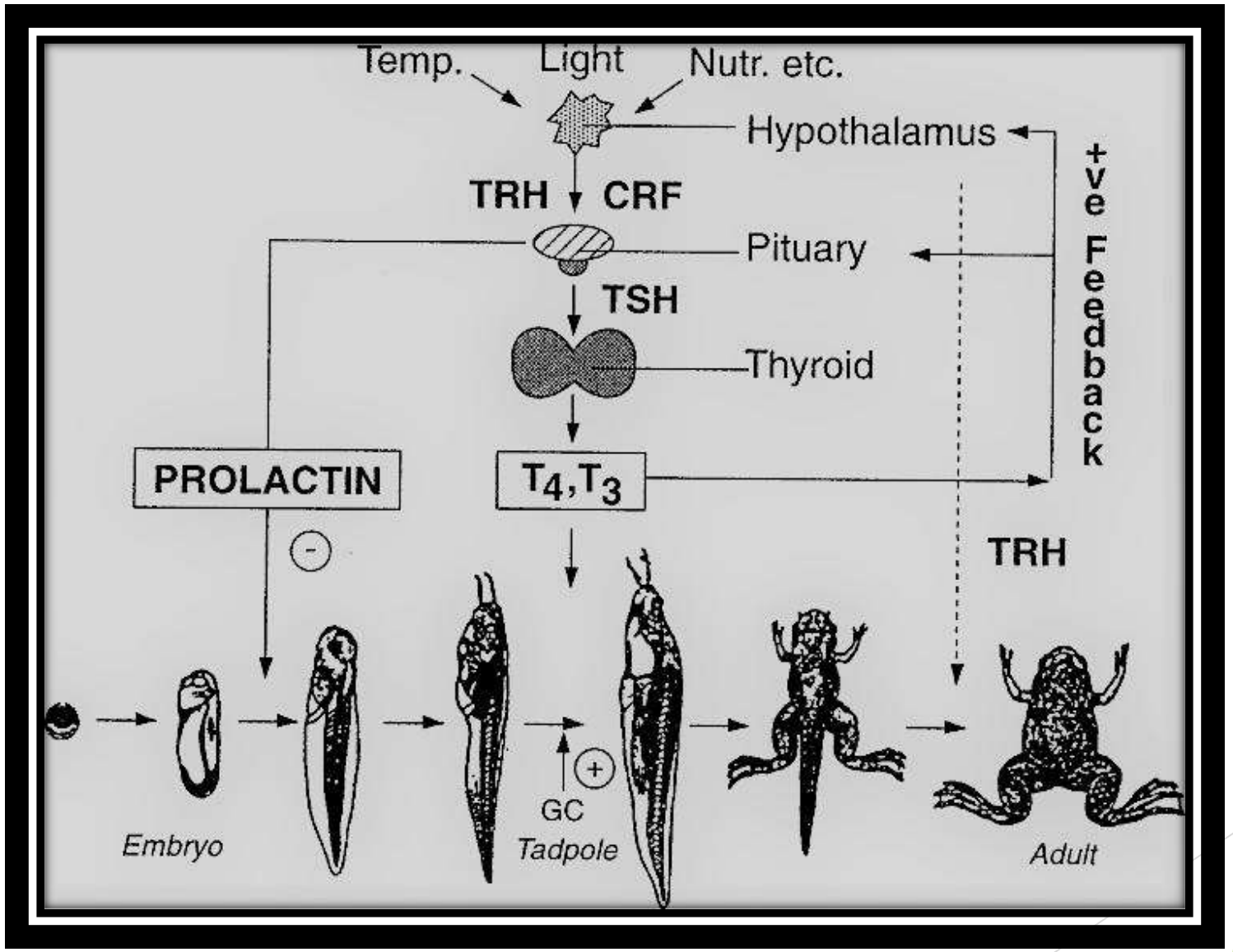
- The polypeptide hormone prolactin plays a part in the control by promotion of larval growth. Prolactin preparations have the capacity to inhibit metamorphic action of thyroid hormones in peripheral tissue level(Turner and Bagnara,1976).
- Early models of endocrine control of frog metamorphosis envisioned levels of prolactin falling as levels of thyroxine rise, but this seems not to be true.
- Levels of prolactin remain high through metamorphic climax, at least in frogs, but its inhibitory effects on metamorphosis are apparently overridden by the rising levels of thyroxine.


TH/TRβ concentration
5mm
5mm
5mm
thyroid gland begins to function
TRα and RXRα synthesis begins
1 wk
7 wk
8 wk
(time post fertiliza
35
46
52
56
59
66
(NF stage)
embryogenesis
pre-metamorphosis
pro-metamorphosis
climax
post-metamorphosis
1mm
10mm
15mm
15mm
10mm
cell proliferation
in the brain and limb bud
limb growth and differentiation
tail, gill resorption;
organ remodeling;
70% weigh loss

FUNDAMENTALS OF HORMONAL CONTROL

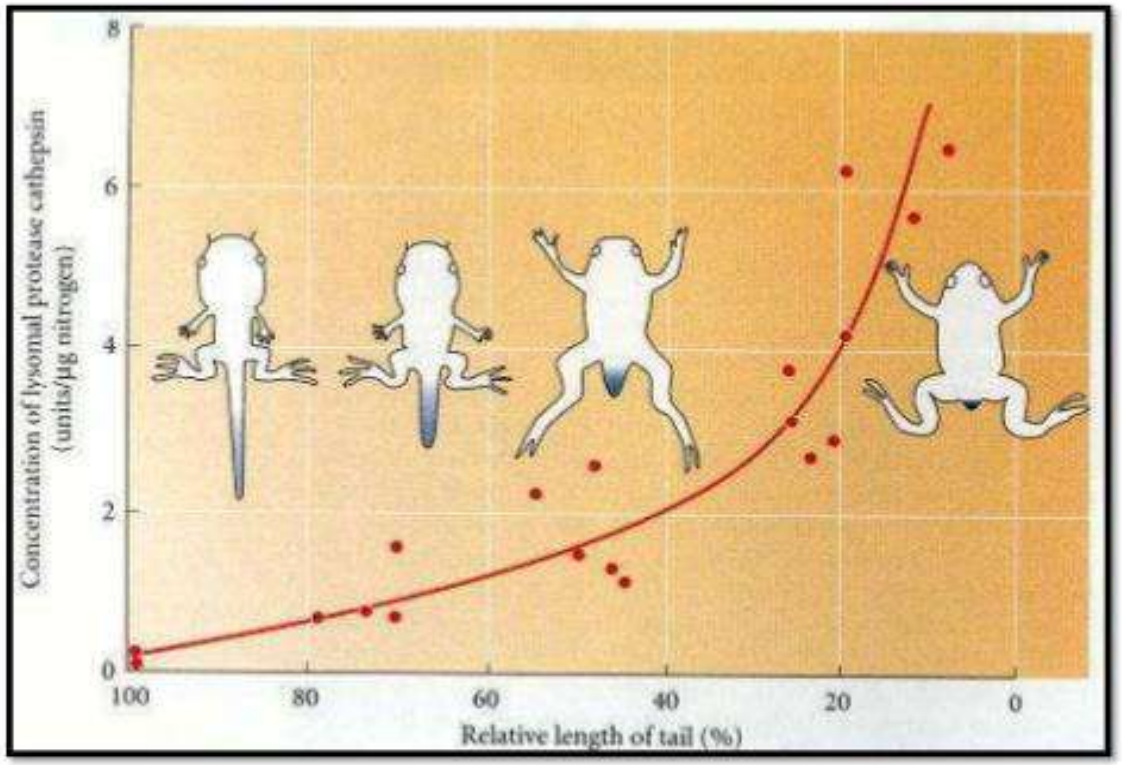
FROG GROWTH AND METAMORPHOSIS HIGHLIGHT SOME BASIC FEATURES OF HORMONAL CONTROL:

- Hormones act not only by exerting a positive influence on target tissue, they also control events by inhibiting target tissues.
- A target tissue, such as median eminence, responds to hormones only after earlier stages of development have been completed.
- Endocrine control is exerted not just on the basis of the presence or absence of a hormone but also on changes in its level.
- The endocrine system is also responsive to environmental conditions and can, within limits, extend or shorten metamorphosis.


Temp.
Light
Nutr. etc.
Hypothalamus
TRH
CRF
Pituary
TSH
Thyroid
PROLACTIN
T4,T3
+ve Feedback
TRH
Embryo
GC
Tadpole
Adult

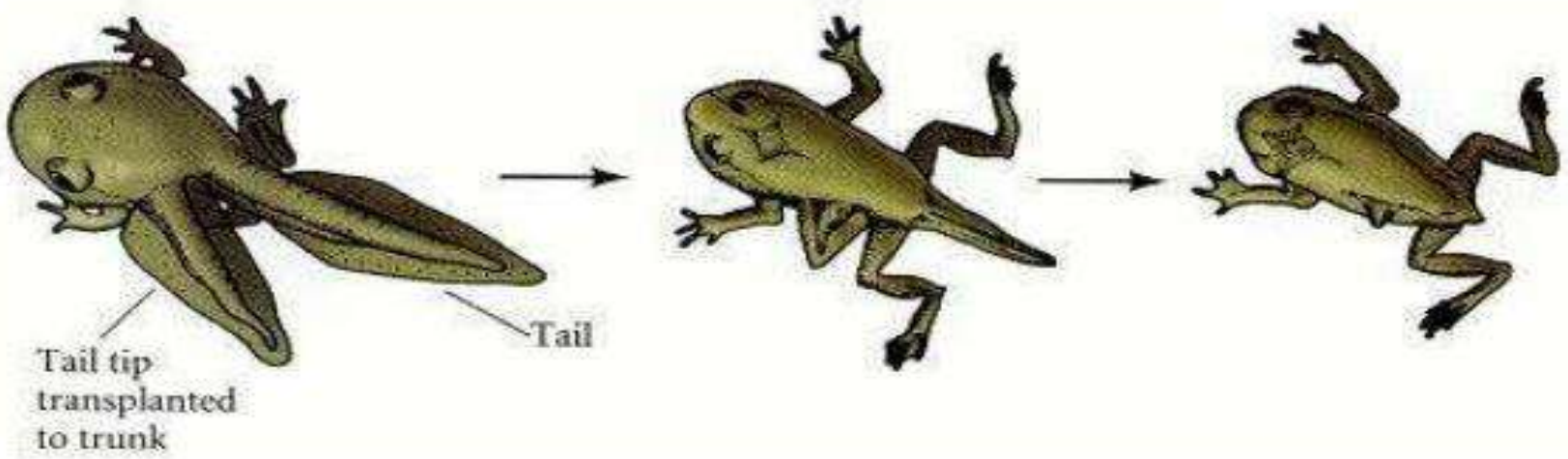
Regionally specific changes

- The various organs of the body respond differently to hormonal stimulation
- Example: Degeneration of tail structure
- The regression of tail is brought about by apoptosis and occurs in 4 stages
  - Protein synthesis decrease
  - Increase in concentration of digestive enzymes
  - Concentration of lysosomal protease rise
  - Cell death occurs



If metalloproteinase inhibitor (TIMP) Is added to the tail, it prevents tail regression

- The response to thyroid hormone is specific to the regions of the body.



Coordination of developmental changes

- Example: Tail should not degenerate until limbs developed
- Model for this is called Threshold concept
- What if tadpoles are deprived of thyroid hormones or given higher concentrations of thyroid hormones?
- Two organs most sensitive to thyroxine are thyroid itself and pituitary gland, which regulates thyroid hormone production