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AMPHIBIAN METAMORPHOSIS

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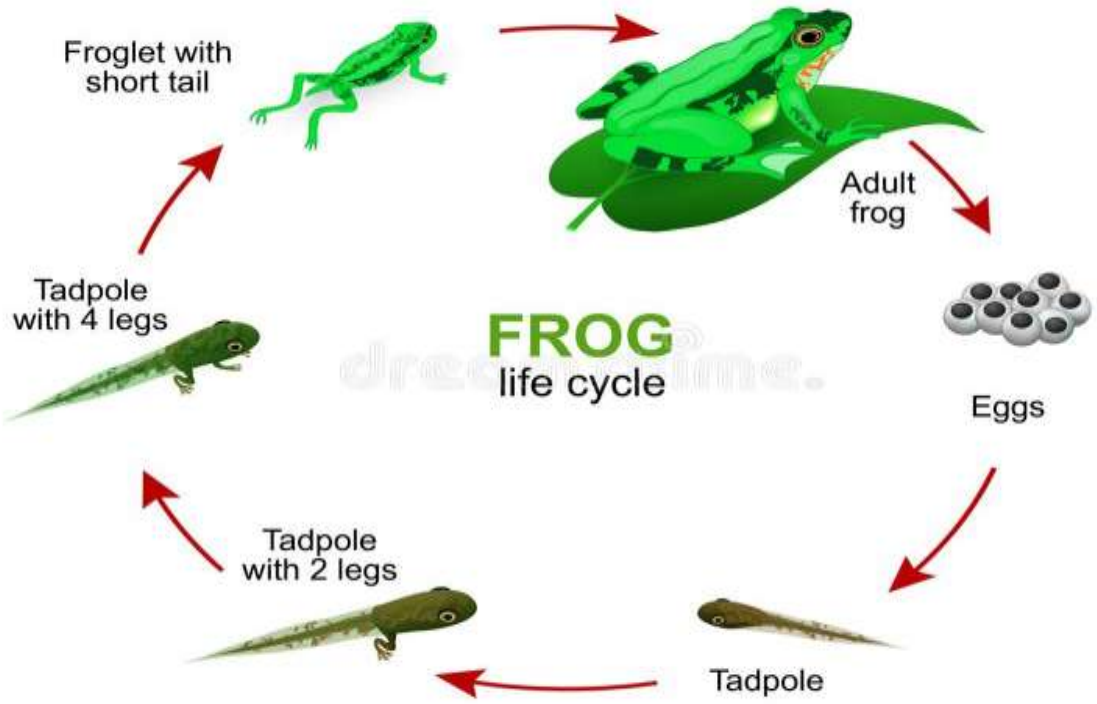
Metamorphosis is a biological process by which animals undergo extreme, rapid physical changes in the body during its life cycle is called metamorphosis. It is a biological process which involves sudden and abrupt changes in the body structure of the animal by cell growth and differentiation.

According to Duellman and Trueb (1986) Metamorphosis can be defined as “a radical transformation from larval life to the adult stage involving structural, physiological, biochemical and behavioural changes”.

Metamorphosis is a remarkable process. The changes leading to metamorphosis are triggered by hormones, which the animal’s body releases as the right conditions for metamorphosis approach. Commonly known examples of metamorphosis include the process undergone by most insects, and the transformation of tadpoles into frogs.



Types of Metamorphosis

Complete Metamorphosis

In complete metamorphosis, a larva completely changes its body plan to become an adult. The most famous example is that of the butterfly, which starts out as a worm-like, leaf-eating caterpillar and transforms into a flying, nectar-drinking creature with an exoskeleton.

Organisms that undergo complete metamorphosis are called “holometabolous,” from the Greek words “holo” for “complete” or “whole,” “meta” for “change,” and the noun “bole” for “to throw.” “Holometabolous,” then, means “completely changing,” or “wholly changing.”

Eg: Butterfly, beetles, flies, moths, ants, and bees.

Incomplete Metamorphosis

In incomplete metamorphosis, only some parts of the animal's body change during metamorphosis. Animals that only partially change their bodies as they mature are called "hemimetabolous," from the Greek words "hemi" for "half," "meta," for "change," and the verb "bole" for "to throw." "Hemimetabolous," then, is a word meaning "half-changing.

Eg : Cockroaches, grasshoppers, and dragonflies.

Process of Metamorphosis

The process of metamorphosis is controlled by hormones such as thyroxine. This hormone is produced by the thyroid gland and its synthesis requires the presence of iodine. Thus, iodine is essential for metamorphosis because it is required for the synthesis of thyroxine hormone. Iodine is essential for the production of thyroxine. Thus, low levels of iodine decreases the level of thyroxine production which in turn delays the metamorphosis of the frog**.**

In amphibians, metamorphosis incorporates ecological, morphological, physiological and biochemical changes.

1. Ecological metamorphic changes:

1. According to the change of environment, from aquatic to terrestrial mode of life, a change in feeding habit occurs in anuran amphibians (frogs and toads).

2. Tadpoles of most frogs and toads feed on vegetable matter, which they scrap off from submerged objects with the help of horny teeth surrounding their mouths.

3. Few anurans are detritus feeders, or plankton feeders (Xenopus). Adult frogs and toads are carnivorous, feeding upon small insects, worms and small vertebrates.

4. In urodele amphibians (salamanders and newts) there is no substantial change of diet, the larvae being as carnivorous as the adults though naturally they feed on smaller animals.

2. Morphological metamorphic changes:

The changes in the organization or morphology of the animal during metamorphosis are in part progressive and in part regressive, and maybe grouped into three categories:

1. Structures or organs necessary during larval life but redundant in the adults are reduced and may disappear completely.

2. Some organs develop and become functional only during and after metamorphosis.

3. Third group of structures, while present and functional both before and after metamorphosis, becomes changed so as to meet the requirements of the adult mode of life.

(a) Regressive metamorphic changes:

(i) The tissues of tail and tailfin are completely absorbed into the body.

(ii) The horny jaws with teeth are shed and mouth becomes a large transverse slit.

(iii) The external gills disappear and the gill slits communicate to the pharyngeal cavity.

(iv) The length of the alimentary canal much reduces.

(v) The changes of the blood vascular system take place and ultimately some blood vessels are reduced.

(vi) The lateral line sense organ disappears.

(vii) Operculum and spiracle disappear.

(b) Progressive metamorphic changes:

(i) The fore and hind limbs increase in size.

(ii) The tongue becomes long and more elastic which is free and bifid posteriorly.

(iii) The eyes become large and prominent and develop eye-lids and nictitating membrane.

(iv) External nostrils communicate with buccal cavity through internal nostrils.

(v) Tympanum and middle ear develop.

(vi) Liver becomes more enlarged.

(vii) Three chambered heart develops from two-chambered heart.

(viii) Pronephros is replaced by mesonephros.

(c) Organs which exist both in larva and adult:

The organs which function both in larva and the adult, but change their differentiation during metamorphosis, are primarily the skin, the intestine and the brain. Skin thickens and becomes more

glandular by possessing multi-cellular mucous and serous glands, attains an outer keratinized layer and acquires a characteristic pattern of pigmentation. Intestine, which is very long in tadpoles, becomes shorter and the coils become straightened out. Brain becomes more highly differentiated.

Cell modifications are evident at the cellular level as in the eye lids, limbs, lungs, eardrum, tongue, skin, operculum, liver, pancreas and intestine. Every cell, tissue or organ of anura gets effected during metamorphosis.

Urodele amphibians undergo less striking ecological and morphological metamorphic changes as the tail is retained and only the fin folds disappear. Branchial apparatus is reduced, the external gills become resorbed and the gill clefts closed.

3. Physiological Changes :

(i) At the beginning of metamorphosis, the pancreas starts to secret insulin and glucagon hormones. This is related to the increased role of the liver.

(ii) During the larval stage, the end product of nitrogen metabolism is ammonia. But after metamorphosis, the toads and frogs excrete most of their nitrogen in the form of urea. This is a shift from ammonotelism to ureotelism with the change of environment from aquatic medium to land.

4. Biochemical Metamorphic Changes:

In frog tadpoles, the endocrine function of the pancreas starts at metamorphosis and this is connected with the increased role of the liver in the turnover of the carbohydrates. In the tadpole, the end product of nitrogen metabolism is ammonia (ammonotelism) which is easily disposed of by diffusion in aquatic medium. Metamorphosed frogs excrete most of their nitrogen in the form of urea (ureotelism).

Shift from ammonotelism to ureotelism, increase in serum albumin and proteins, alterations in the properties and biosynthesis of haemoglobin are the important adaptive changes. Major modifications occur in water balance, visual pigments, pigmentation, and tail metabolism, which aid in adjustment to land.

(i) The concentration of serum protein becomes about double during metamorphosis.

(ii) Biosynthesis and concentration of haemoglobin are greater in adult than in larvae.

(iii) In the liver, DNA synthesis, lipid synthesis, enzymes for ornithine urea cycle increase during adult stage.

iv) Alkaline phosphatase and hydrolase decrease in adult stage of the anurans.

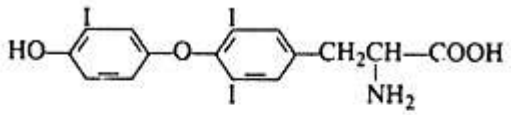
Hormonal Control of Amphibian Metamorphosis:

The amphibian metamorphosis is under neuroendocrine control, involving neurosecretory cells in the brain (the hypothalamus) and two endocrine glands, the pituitary (anterior pituitary) and the thyroid. The trigger to metamorphosis may be an environmental signal affecting the larval brain through the nervous system, or there may be an endogenous 'clock' in the hypothalamus. In a way, hypothalamus integrates the information received from body with the environmental information.

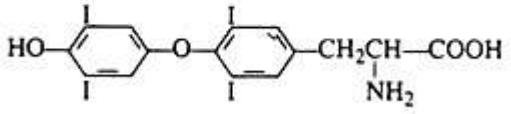
Neurosecretory cells in the hypothalamus are stimulated to produce TRF or thyroid-releasing factor which stimulates the anterior pituitary gland to secrete a TSH or thyroid-stimulating hormone which causes orderly increase of thyroid secretion. Increase in thyroid hormone then trips the orderly sequence of tissue changes that transforms the tadpole larva into the frog.

Two hormones such as Triiodothyronine (T_3) and Tetraiodothyronine (T_4) or thyroxine are necessary for biochemical and morphological changes during anuran metamorphosis. These thyroid hormones are produced by the induction of anterior pituitary lobe or pars distalis when it reaches certain degree of differentiation.

Then it is capable to synthesize a hormone, thyrotropin (Thyroid Stimulating Hormone, TSH) which acts on the thyroid, stimulating the production and secretion of triiodothyronine (T_3) and thyroxine.



3, 5, 3'–Triiodothyronine (T_3)



3, 5, 3'5'–Tetraiodothyronine (Thyroxine)(T_4)

In pre-metamorphic stage the prolactin level is high but levels of thyroid stimulating hormone (TSH) and thyroid hormone (T_3, T_4) are low. The hypothalamus – pituitary link is poorly developed. In pro-metamorphosis, the hypothalamus and pituitary link develops.

Another pituitary hormone, called prolactin is also found to be involved as an inhibitor in the overall control of metamorphosis . The prolactin level is low but the levels of thyroid stimulating hormone (TSH)

and thyroid hormones (T_3, T_4) are high. In metamorphic climax, the prolactin level increases suddenly, then maintains steady low level. The TSH is high until end of climax and the thyroid hormone (T_4) level becomes low.