Metamorphosis in Frog

To compensate the deficiency of yolk in egg the development is indirect passing through intermediate free living stage i.e. tadpole larva. Precocious 6 mm long tadpole hatches out after about 116 hours of fertilization.

Features of tadpole

Oral-sucker Stage:

- One pair of oral suckers on ventral side of head are the only distinct part which help larva attach to any object for a couple of days.
- No limb buds or tail or other body parts are distinct.
- Does not feed or move.
- External Gill Stage:
- The buds of hind limb come out, and tail start developing with dorsal and ventral fins.
- Three pairs of gills come out on both lateral sides of head called as spiracle.
- Eyes become functional.
- Horny jaws start developing with teeth for herbivorous mode of feeding.
- Grows to 45 – 50 mm size after a free swimming life of about 3 – 4 weeks at 26ºC to 28ºC temperature.

Internal Gill Stage:

- Fish like body with well-developed internal gills covered with operculum with opening spiracle.
- Fish like 2-chambered, venous heart, ammonotelic excretion, nephrostomes connected to nephrons.
- Tail with dorsal and ventral fins.
- Elongated fully formed hind limb.
- Long alimentary canal for herbivorous food habit.
- Eyes, lateral line system changes during metamorphosis from tadpole to adult.

Retrogressive changes

- Disappearance of tail.
- Loss of gills, gill chamber and operculum.
- Loss of lateral line system.
- Horny jaws replaced by bony structures

Progressive change

- Hind limb and pelvic girdle fully formed.
- Formation of forelimb below operculum.
- Lungs are formed.
- Eye balls enlarge and become protrusible, nictitating membrane formed.
- (Both maxillary and vomerine teeth fully formed on upper jaw.
- Middle ear and tympanum fully formed.

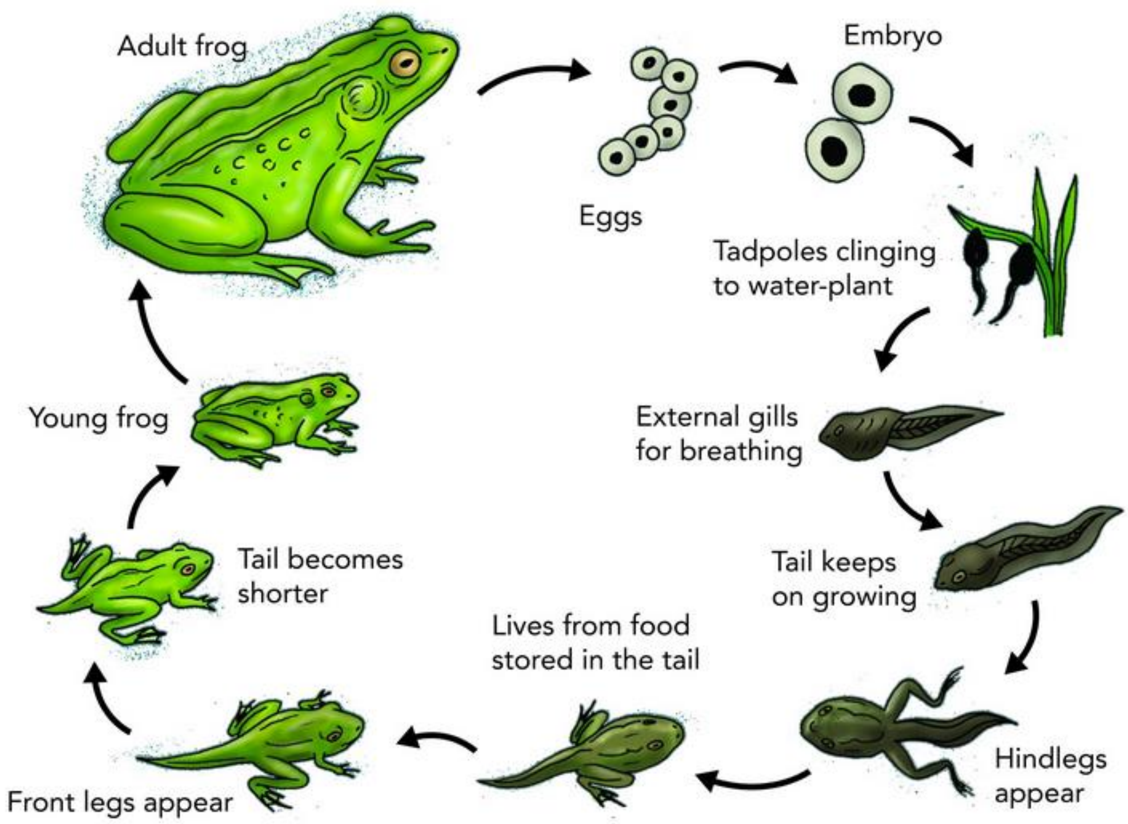
Additional changes

- Shortening of alimentary canal as per change in food habit from herbivores to carnivores.
- Three chambered heart with change in the plan of circulation due to change in mode of respiration.
- Nephrostomes become disconnected from nephrons.
- Shifting from ammonotelic to ureotelic excretion.

Physiological changes

- More functions of liver and increased metabolism of carbohydrate.
- Beginning of endocrine function of pancreas and secretion of insulin.
- Haemoglobin (Hb) changes to adult type.

Fig. Metamorphosis of Frog

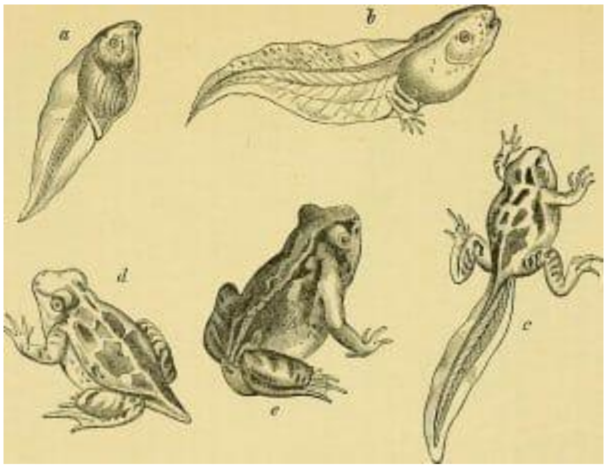


Metamorphosis Definition

Metamorphosis is a process by which animals undergo extreme, rapid physical changes sometime after birth. The result of metamorphosis may be change to the organism's entire body plan, such as a change in the animal's number of legs, its means of eating, or its means of breathing.

In species that use metamorphosis, metamorphosis is also typically required for sexual maturity. Pre-metamorphic members of these species are typically unable to mate or reproduce.

Commonly known examples of metamorphosis include the process undergone by most insects, and the transformation of tadpoles into frogs. The diagram below shows the stages of this change, wherein the small fish-like tadpoles transform into what seems a completely different animal:



Animals that you may not know undergo metamorphosis include fish, mollusks, and many other types of sea creatures which are related to insects, mollusks, or fish. Lobsters, for example, which are closely related to insects, do undergo metamorphosis as part of their life cycle.

Metamorphosis is a remarkable process. The speed and extent of cell growth and differentiation is astonishing. In most species, such rapid growth and such sweeping changes to cell type only happen during embryonic development. Indeed, some scientists believe that the process of metamorphosis involves a sort of re-activating of genes that allow animal cells to change from one cell type to another.

The changes leading to metamorphosis are triggered by hormones, which the animal’s body releases as the right conditions for metamorphosis approach. In some animals a hormone cascade follows, with the trigger hormone causing the release of several other hormones that act on different parts of the animal’s body.

The hormones cause drastic changes to the functioning of cells, and even behavioral changes such as the caterpillar spinning its cocoon.

The effects of hormones on metamorphosis can be studied by artificially administering these hormones to pre-metamorphic animals. Tadpoles, for example, can be triggered to begin losing their tails and growing limbs early by the addition of thyroid hormones to their water supply. Unfortunately this has a detrimental effect on the animal's health.

Function of Metamorphosis

Scientists remain uncertain why metamorphosis evolved. For the animals of today, its purpose is obvious: if metamorphosis did not occur, tadpoles could not become frogs and larvae could not become full-grown adults capable of reproduction. Without reproductively mature members, these species would quickly die off.

But why would these species evolve to need this extra step in the first place? Why not just hatch full-grown butterflies or frogs from eggs?

At least some metamorphosing species did not start out that way: the earliest insects basically did hatch as full-grown adults. But a few hundred million years ago, some species stumbled upon the trick of metamorphosis. It was apparently wildly successful; it is thought that almost two-thirds of species alive today use metamorphosis to accomplish large changes between their adult and juvenile forms.

The benefit of metamorphosis may lie in its ability to reduce competition. Pre-metamorphic animals typically consume completely different resources from their adult forms. Tadpoles live in water, eating algae and plants. Frogs live on land, breathing air and eating insects. Caterpillars eat leaves; butterflies live off of nectar. Etc..

This effectively prevents older members of the species from competing with younger members. This may lead more members of the species to successfully reach sexual maturity, without the risk of being out-competed by older members of their species.

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.”

This transformation is so swift and complete that the caterpillar must spin a cocoon and lie dormant for weeks while its body undergoes these radical changes.

Other animals which transform from a worm-like larval stage into an animal that looks completely different include beetles, flies, moths, ants, and bees.

Some scientists believe that the larval stage of complete metamorphosis may have evolved from insects which hatched from their eggs without developing properly. Some of these embryos may have survived long enough to find food in the outside world; and this may have ended up giving them an advantage, as they would be able to feed longer and gain more strength than their peers before metamorphosing into the adult stage.

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.

Cockroaches, grasshoppers, and dragonflies, for example, hatch from eggs looking a lot like their adult selves. They do acquire wings and functioning reproductive organs as they grow, but they do not completely remake their bodies like their completely metamorphosing cousins do.

Examples of Metamorphosis

Frogs: The metamorphosis of a tadpole into a frog is a little less violent than that of a caterpillar into a butterfly, but the processes share some important common features.

Tadpoles do not dissolve their bodies into mush; but they do "digest" them in a less spectacular way. Using the process of apoptosis – or "programmed cell death" – the tadpoles "order" the cells they don't need anymore to shred their DNA and die. The dead cells are then cannibalized for energy and raw materials to make other cells.

The cells of their tails are broken down and used to make their developing legs; a similar process happens with the gills, which disappear as the tadpole begins to develop air-breathing lungs.

One interesting thing to note is that tadpole metamorphosis and insect metamorphosis likely developed separately; the common ancestor of insects and amphibians diverged long ago, and the ancestors of modern insects are not thought to have used metamorphosis. When the same phenomenon evolves twice in radically different organisms, that's a sure sign that it is a useful adaptation!

Process of Metamorphosis in Amphibians and it's Hormonal Control

Metamorphosis is a post-embryonic extension of the developmental potential and involves dramatic changes in habit, habitat, morphology, physiology and behaviour of larva so that it is transformed into the adult having entirely different habitat and structure.

Metamorphosis is associated with a dramatic change in habitat and consequent way of life. For example, the change from planktonic to benthic existence in the sea urchin, from non-flying to flying mode of life in insects and from aquatic to terrestrial existence in frogs and toads. This wide spread change in environment and activities demand equally rapid transformation of the structure and function of the living machinery.

During the development cycle, metamorphic change is a condensation or acceleration of some basic processes characteristic of most forms of development. It consists of differential destruction of certain tissues, accompanied by an increase in growth and differentiation of other tissues.

Metamorphosis is found in invertebrate phyla and in chordates like Amphibia. Metamorphic morphogenetic processes in different animals differ in the nature of transformation and mode of occurrence of the whole sequence. Amphibians furnish the best example of metamorphosis in vertebrates.

Metamorphosis in Amphibians:

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

1. Ecological metamorphic changes:

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). 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.

Few anurans are detritus feeders, or plankton feeders (Xenopus). Adult frogs and toads are carnivorous, feeding upon small insects, worms and small vertebrates by overpowering then and swallowing the entire animals. 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. Because the degree of difference between anuran larvae and adults is profound, anurans undergo more extensive metamorphic changes in organization.

(a) Regressive metamorphic changes:

Certain adaptive structures formed during embryonic development, namely, the ventral suckers, external gills and larval tail with fin folds of the tadpole larvae are reabsorbed during early functional life. Further, gill clefts are closed, peribranchial cavities disappear, the horny teeth of the peri-oral disc are shed, as well as the horny lining of the jaws.

Shape of the mouth changes, the cloacal tube becomes shortened and reduced, some blood vessels are reduced and the lateral line organs of skin disappear. These are merely resorptions of previously formed structures, which disappear when they have served their purpose.

(b) Progressive metamorphic changes:

The progressive or constructive metamorphic changes involve the progressive development of the limbs, which increase in size and differentiation. The fore-limbs, which in frogs develop under the cover of the opercular membrane, break through to the exterior.

The gill arches become modified into the hyoid apparatus. The middle ear develops in connection with the first pharyngeal pouch. The tympanic membrane develops and is supported by the circular tympanic cartilage. The eyes protrude on the dorsal surface of the head and develop eyelids. The tongue is developed from the floor of the mouth.

(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.

Visceral skeleton becomes greatly reduced. Head changes its shape becoming more oval. Skin becomes cornified and multicellular skin glands become differentiated. Pigmentation of the skin changes. Legs and intestine suffer no change. Larvae of frog and salamanders start coming up to the surface to gulp air into their lungs.

3. Physiological and 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).

This change of ammonotelism is associated with changed function of the liver, which performs the synthesis of urea. Visual pigments of tadpoles are porphyropsin (retinene 2), while during metamorphosis there is a shift to the use of rhodopsin (retinene 1). The reduction of the gills and tail is affected by autolysis of the component tissues of these organs, with active participation of amoeboid macrophages, which phagocytose the debris of the disintegrating cells.

Biochemical metamorphic alterations may be considered to have direct adaptive value or to serve as a basis for morphological, chemical or other changes which have adaptive value relating to the transition from water to land. Shift from ammonotelism to ureotelism, increase in serum albumin and proteins, alterations in the properties and biosynthesis of haemoglobin are the important adaptive changes.

Development of digestive enzymes also contributes to the success of the differentiation. Major modifications occur in water balance, visual pigments, pigmentation, and tail metabolism, which aid in adjustment to land.

Hormonal Control of Amphibian Metamorphosis:

During metamorphosis concurrent changes in all body parts suggest the existence of hormones released in large quantities from the thyroid gland of the animal. This indication was given by Gundernatsch (1912) when he fed some frog tadpoles on dried and powdered sheep thyroid gland and observed their metamorphosis precociously. Thyroid hormone is actually the cause of metamorphosis in normal development was further proved experimentally.

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.

Another pituitary hormone, called prolactin is also found to be involved as an inhibitor in the overall control of metamorphosis. Developmental control is effected by a balance between inhibition and disinhibition rather than stimulation at the level of endocrine action. Thyroid hormones are also known to affect the process of protein synthesis at the levels of transcription and translation and to have a role in cytodifferentiation.