Neoteny in Amphibians

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Neoteny refers to retention of a larval or embryonic trait in the adult body. It is the failure or delay of larva to metamorphose while becoming sexually mature. Neoteny is characteristic of some amphibians.

In most of the literature on Neoteny and Paedogenesis, both have been considered as synonyms but both are the two different processes. Neoteny is a temporary process and can be reversed while paedogenesis is permanent and irreversible process.

Types of neoteny

- **Partial neoteny:**
  When metamorphosis is delayed due to temporary ecological or physiological changes in environment.t is shown by tadpoles and larvae tiding over winter.

- **Intermediate neoteny:**

  This type shown by Axolotls which also reproduce sexually but undergo metamorphosis in suitable conditions.

- **Total neoteny:**

  Shown by perinnibranchiate salamanders such as Necturus, Siren and Proteus. They remain larval throughout. Even treatment with thyroxine fails to induce metamorphosis.

Factors for Neoteny

The significance and cause of neoteny in Amphibians are not properly understood. Several extrinsic and intrinsic factors are considered to be responsible for such unusual phenomenon.

Extrinsic factors influencing neoteny:

Gadow 1903, advanced the idea that the cause of retention of larval features in axolotl is the abundance of food and other favourable requisites in aquatic life.

According to Shufeldt, deep water and coldness inhibit thyroxine secretion, which are essential for metamorphosis.

Drying up of swamps, lack of adequate food supply and rise in temperature in surrounding water induce metamorphosis. Weissmann again claimed that the retardation of metamorphosis of the axolotls is possibly due to the saline nature of the water of the lakes where they live.

In an investigation to establish the role of physical factors in neoteny, tadpoles were kept in water-holes with high vertical walls, so that they were not allowed to reach the land above the water-holes. It has been observed that this forced and prolonged use of larval gills and tails cause their further development, whereas the growth of limbs and other structures necessary for terrestrial life remained suspended.

Marie Von Chauvin in the University of Freeburg undertook similar experiments with axolotl larvae and also came to the above conclusion. It has further been observed that the axolotls which were not likely to metamorphose in normal habitat could be forced to metamorphose by slowly accustoming them to land-life.

Huxley (1929) undertook an investigation on temperature-coefficient on metamorphosis. Several half-grown anuran tadpoles were cultured in variable temperatures ranging from 3-30°C for same span of time. But the culture solution has same concentration of thyroxine.

The larvae exposed to temperature range below 5°C could not complete their metamorphosis even when exposed to higher temperature. But the larvae exposed to higher temperature from the beginning completed metamorphosis very quickly.

Despite extensive researches on the role of extrinsic factors on metamorphosis, there is no sound reason to believe the exclusive role of the extrinsic factors. It is commonly observed that the neotenic as well as normal over-grown larvae occur side by side in the same habitat having similar environment.

Intrinsic factors:

Different investigators Like Zondeck and Leiter (1923) established that calcium delays metamorphosis in axolotls.

Gressner (1928) also advanced that insulin hormone inhibits metamorphosis.

But recent researches incline to reveal that the metamorphosis is primarily influenced

1. by varying threshold levels of thyroxine and its analogs and

2. by the degree of responsiveness of the larval tissue to hormones.

During early pre-metamorphic stage in amphibian development, the level of thyroxine (T_4) is kept very low in the body by genetic mechanism.

Etkin and his co-workers have also established the role of prolactin on metamorphosis.

They have shown that the level of prolactin which acts as an inhibitor in the overall control of metamorphosis remains high at this time. In the light of modern genetics, it may be suggested that the structural genes guiding the synthesis of thyroxine are ‘switched off’ by some operator genes whereas the genes guiding the formation of prolactin are ‘switched on’.

In such condition the hypothalamus becomes sensitive to the available level of thyroid hormone in the blood stream. The neurosecretory apparatus of the hypothalamus produces a substance, called thyrotropin-releasing factor (TRF). TRF stimulates the anterior lobe of pituitary to produce thyroid-stimulating hormone (TSH) which in turn enhances the rate of thyroid secretion.

As the level of TSH rises during pro-metamorphosis, the level of prolactin suddenly falls. So, the metamorphosis starts. The time of shift in hormone balance is possibly determined by the initiation of positive thyroid feed-back to the hypothalamus. Poor secretion of thyroid glands and the irresponsiveness of the larval tissues to the hormone are responsible for neoteny.

Kuhn (1925) studied the thyroid glands of neotenous larvae of the warty newt and observed that the alveoli which secrete thyroxine remain in undeveloped state (only about half the size of those in normal full- fledged specimens). He has further noted that the axolotls possessing normally developed thyroid glands failed to pour their secretion in the blood stream.

Transplantation of at least two more thyroid glands in addition to the normal glands causes the metamorphosis of axolotls. This result indicated that the thyroid gland of axolotls is able to produce one-third of the required quantity of thyroxine and that the larval tissues are only one-third responsive in contrast to normal specimens.

Bytenski and Saez have experimentally exchanged the pituitary gland between a salamander larva and an axolotl larva and found that axolotl’s pituitary gland is as efficient as that of salamander larva. But the tissues of axolotl failed to respond to the pituitary gland of the salamander. This indicates the irresponsive nature of axolotl's tissues to hormones.

The investigations carried on by Etkin (1968) indicated that 'spacing' of events during metamorphosis depends on thyroxin-concentration, while the 'sequence' of events is inherent in the larval tissues.

In amphibian development the tadpole larva undergoes progressive metamorphosis and transforms into an adult. This is a normal occurrence in amphibians. But deviation from the normal pathway of development is found in the life-cycle of many urodeles. Such deviated pathway of development in axolotls due to extrinsic as well as intrinsic environmental factors may be regarded as 'canalisation', i.e., buffering of development against environmental change.

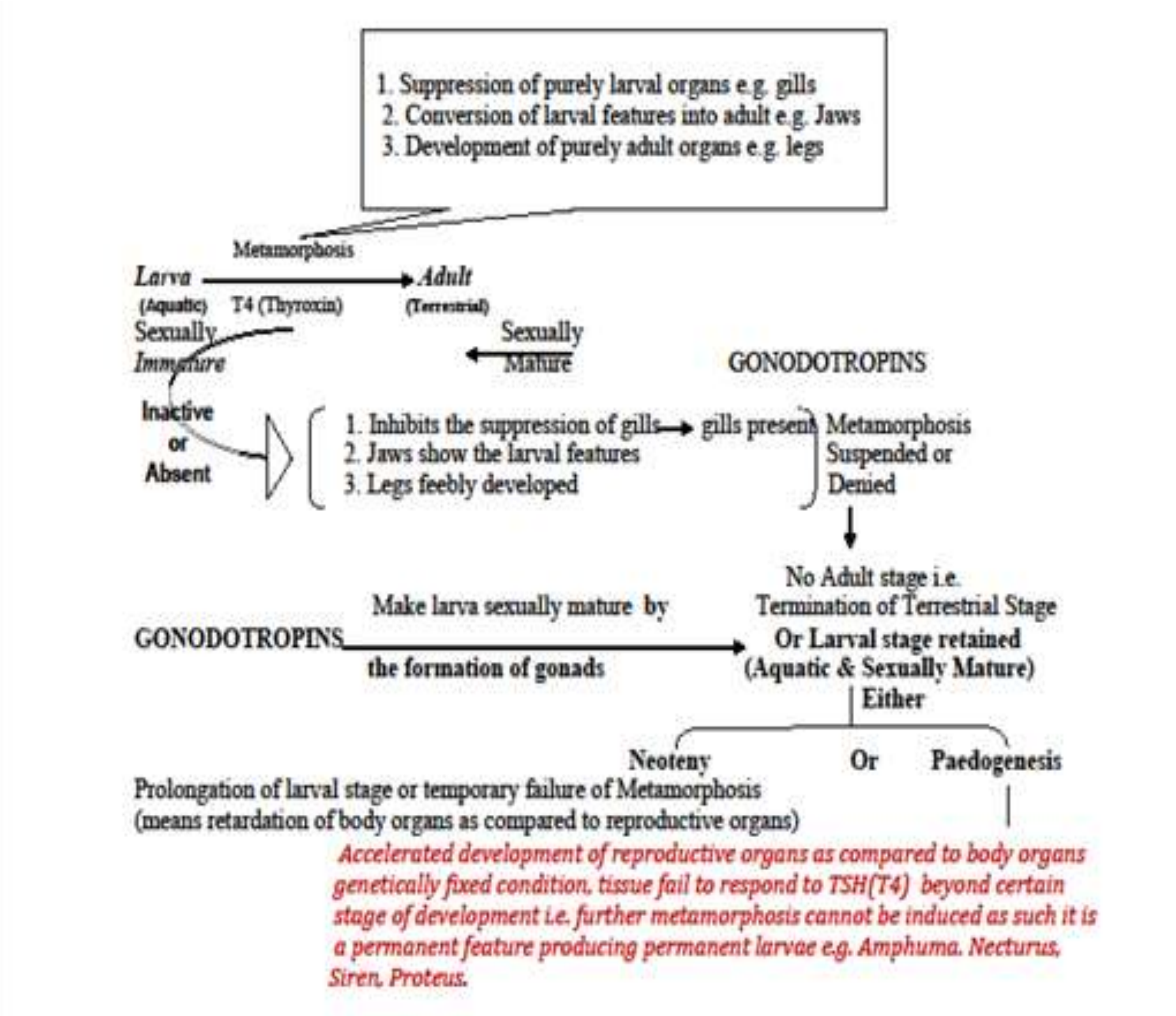
Neoteny is looked upon as a consequence of adaptations to neighbouring environments where retention of larval gills and other larval features may be advantageous.

Significance of neoteny:

According to Weismann (1875) Neoteny is a case of retarded evolution or atavism, that is reversion of ancestral condition.

Now it is regarded as secondary specialization, a physiological adaptation of advantage.

Neoteny and paedogenesis



Source: R.L. Kotpal , Venktesh Shukla former Associate Professor of Zoology (Retired)