LIFE HISTORY

Life history of anurans has been investigated by many workers in different parts of the world. In this connection the works of Fletcher (1889), Wintrebret (1905), Blues (1907), Tschernoff (1907), Smett and Allen (1919), Noble (1926), Power (1926), De Villiers (1929), Power and Walter Rose (1929), Wright (1929), Etkin (1932), Pollister and Moore (1937), Schrieber (1937), Shumway (1940, 42), Eakin & Harris (1945), Taylor and Kollos (1946), Rugh (1951), Savage (1952), Richards (1953), Gosner (1960) and Akin (1966) deserve special mention.

In attempting to review the literature on life history of Rana cyanophlyctis, nothing more than brief notes on the tadpoles of few anurans of India could be found (Annandale, 1909, 1918; Rao, 1915; McCann, 1933).

The present study deals with the life history of Rana cyanophlyctis up to the completion of metamorphosis as observed in the field and in the laboratory.

Methods of study: - The spawn was collected from Botanical Garden Ponds and tank near Gandhi Bhawan, Panjab University, Chandigarh. The egg masses were divided into small batches of 20 eggs each and kept in glass troughs at room temperature (28°C - 30°C). Measurements of the larvae were taken every 12 to 24 hours. These
stages were preserved in 70% alcohol and were studied under a stereo-binocular dissecting microscope. The length of each tadpole was measured at the start of each new stage. Their mean length is given in Table 19. At least ten larvae were measured from snout to the tip of the tail to the nearest 0.1 mm. Those over 30 mm. were measured to the nearest 0.5 mm. The larvae were examined as soon as they started independent feeding.

The larval stages are divided into four main categories.

1. **Limb bud stages (I to V):** They are characterized by the presence of limb-buds on either side of the tail.

2. **Foot Paddle stages (VI to X):** When each limb bud is transformed into a foot paddle.

3. **Premetamorphic stages (XI to XVII):** They are characterized by the development of hind-limbs and particularly the formation of foot.

4. **Metamorphic stages (XVIII to XXV):** They are initiated by the regression of the cloacal tail pieces and terminate when the resorption of the tail takes place. Stage XXV represents the fully formed Juvenile frog (Fig.33).

Table 19 indicates the mean length of the tadpoles at each stage and time interval between stages. The mean length of tadpoles is plotted against their age in days (Fig.34).
Results of the collections from the Botanical Garden Ponds

The larvae of *Rana cyanophlyctis* were noticed on March 15, 1969. They preferred to remain beneath vegetation. The water of the ponds was clear and they could be spotted out easily. On March 22, the tadpoles were fewer in number but they were quite active feeding mainly on plants. The coiled gut was packed with green bits of algae. On March 28, however, large number of tadpoles had returned to the spawn site and were forming a dense and very active aggregations. In nearby ponds the number of the young larvae was very small. On April 4, very few tadpoles could be observed. On April 11, the tadpoles were rarely seen, but young frogs were skipping among the vegetation. By 20th April majority of the animals had metamorphosed and little young frogs were seen in the neighbouring hedge as well as in the ponds (Fig. 35). There were very few developing tadpoles in the ponds.

The weather during the period of study was hot and dry almost all the time with low rainfall. The level of the water was maintained constant throughout the season.

In 1970 the season was different as compared to 1969 and the ponds contained dense growth of algae and other aquatic plants. Only a few eggs of *Rana cyanophlyctis* were observed near the shallow muddy bottom of the pond on March 2, 1970. Spawning in progress was never observed
but hatching was seen and very young larvae were noticed in March 10, 1970. Tadpoles were comparatively few in number. Reference to Fig. 36 shows that their growth rate was at first slow but later on they became very active and were observed to feed on algae. The entire gut of the tadpoles was impregnated with green material. The mode of feeding resembled that of a herbivorous fish at this stage. On March 19, the tadpoles observed were heavier than those caught on March 12. On March 25, the tadpoles could be spotted in one or two ponds. They were growing rapidly. They were stouter than the tadpoles collected from other places of Chandigah. On April 1, the tadpole population was noticed in different parts of the ponds. Spawn site tadpoles were now the largest and the heaviest in the pond where conditions of life were more favourable. They were less crowded, sunlight was constantly falling on that site and water was renewed at regular intervals. On April 7, in some of the ponds the various developmental stages of *Rana cyanophlyctis* were observed. On April 18, the metamorphosis was almost complete in spawn site pond (Fig. 36). Recently metamorphosed frogs were well built and were as much at home on land as in water. Soon after metamorphosis they were noticed to feed on animal diet. During the day they rarely stayed far from water except during the rain. They were observed
in May and June very actively skipping on the surface of the water. They would leap into the water and skip like the mature frogs along the surface for some distance and then float or dive to the bottom into the mud but their eyes remained above the muddy bottom. After a few minutes they cautiously reappeared on the surface. Their eyes and tips of the snouts first showed themselves above the water and the rest of the body dangled under the surface.

The young tadpoles were not observed in September, 1970.

During 1971 the young tadpoles were observed in September. The condition of life was slightly different from 1969-70. The vegetation was dense, but there was no prominent patches of algae except near the water tap. The water was clear running at intervals into the first pond, interlinked with four ponds. The spawn site was explored in March, July, August and September. The eggs were not seen, but very small sized tadpoles were seen aggregated near the jelly envelopes in September. They were either in limb-bud stages or foot paddle stages, and were growing rapidly as is evident from Fig. 37. Majority of the tadpoles completed the metamorphosis by the second week of October.
A large number of tadpoles of *Rana cyanophlyctis* had just emerged from the egg stage. The larvae hatched out after an interval of 8 days. They came to the surface and rested for a short duration before commencing an active life. The length of the tadpoles was variable. Their average length was 8 mm. A branchial opening was present on either side of the body with external gills protruding out. There were three sets of external gills on either side. Examination of the mouth showed that the beak was feebly horny. There were no horny teeth visible under the binocular. At this stage the tadpoles were overcrowded on the surface of the water and submerged only when disturbed. They kept to the surface of the water and were attached to the water weeds due to the presence of suckers. The feathery external gills were overgrown by the development of the operculum. The external gills were gradually absorbed and new set of internal gills made their appearance (Fig.38).
13-3-1970

The tadpoles were almost in the same condition but they got elongated. Their swimming activity was enhanced. There was increase in their size. The mouth appeared and the tadpole commenced feeding. They entered stage I when their mean length was 10 mm.

14-3-1970

The mean length of the tadpoles was 12 mm. The body and the tail became quite distinct. The eyes were conspicuous. The branchial openings were closed, and the external gills were completely absorbed. A single branchial opening was visible on the left side of the body. The beak became horny. A single marginal upper line of the teeth and two lines of the lower teeth were visible.

15-3-1970

The horny beak became slightly hooked. Three rows of horny teeth were visible one above and two below the upper row extending in a curve across the mouth, the lower rows were short. The length of the body was about half the length of the tail and its breadth 3/5th of its length. The distance between the nostrils was less than 1 mm. The nostrils were 2 mm. away from the extremity of the snout and their distance from the eyes equalled the inter-orbital breadth. The eyes were present on the upper surface of the head and their anterior border was
at a distance from the snout. The distance between eyes and snout was slightly more than that between the nostrils and the snout. The anterior border of the spiraculum was not distinct from the snout. The upper caudal crest of the tail was very deep. It was pigmented with dark granules. The limb-bud was visible as faintly circumscribed elevation in the groove between the base of the tail and the belly wall. The height of the elevation was less than one half the diameter of the disc.

16-3-1970

The limb-buds were visible on either side of the basal part of the tail. The height of the limb-bud elevation was equal to one half of its diameter. The peak was entirely black and hooked. The melanophore patches covered the gill region on either side. The tadpole entered stage II and its mean length was 18.2 mm.

17-3-1970

The body and tail of the tadpole were mottled with pigment spots. There was more concentration of pigment dots on the tail. The greyish pigment of the earlier stages disappeared, a different type of pigmentation appeared. The tail membrane was no longer opaque. Myomeres were quite distinct. The entire region of the tail was clearly marked with pigment spots. The teeth
in the horny jaws became more conspicuous. The lips were well developed. The size of the limb-buds increased.

18-3-1970

More pigment spots appeared all over the body. The beak was almost black and additional rows of teeth developed. A circular horny plate made its appearance on the palate. Limb-buds were clearly visible at the junction of the body and the tail. The length of the limb-bud at this stage was equal to its diameter. This stage was followed by a period in which the limb-bud grew almost equal in diameter and length. The interval between this and the following stages was comparatively long.

19-3-1970

The tail was more acuminate and profusely covered with pigment dots. The limb-buds became more clear. They were visible as conical protuberances at the base of the tail. Teeth became more horny and black. The tadpoles were actively swimming. They were cutting the algae and leaves of the plants with horny teeth and devouring them.

20-3-1970

The tadpoles entered stage III and their mean length was 22.50 mm. The limb-buds were visible at the base of the tail and there was further increase in their size. The intestine was clearly visible. It was greatly
coiled and packed with bits of vegetable matter.

21-3-1970

The tadpoles entered stage IV and their size increased to 33.50 mm. The limb-buds were fully formed. Their size was not more than 2 mm. The tip of the bud became flattened.

22-3-1970

The distal end of the limb-bud was slightly transformed into a foot paddle.

23-3-1970

The fourth and fifth toes prominences were separated by slight indentation of the margin of the foot paddle. They entered stage V and their mean length was 35 mm. There was considerable increase in the activity of the tadpoles, swimming swiftly with the help of foot paddle comprising of indented margin between toes 5-4, 3-2 and 2-1.

24-3-1970

The tadpoles became more active. The margins of the foot paddles became more indented and the web between them was clearly visible. The digits were not formed. They entered stage VI. Their mean length was 39.00 mm.

25-3-1970

There was further increase in their size. The
The web was stretched between 5th and 4th toes, and 4th and 3rd toes. The tadpoles entered stage VII and their mean length was 42 mm.

26-3-1970

The margins of the foot paddles became more indented between them. The tadpoles were moving about with the help of hind limbs. The length of the tadpoles increased further and they attained an average size of 46 mm. The web between the digits became more elongated and the tadpole entered stage VIII.

27-3-1970

The hind limbs increased in size. Pigment free patches appeared at the metatarsal and phalangeal joints. The toe-pads made their appearance as wart-like elevation. The tadpoles entered state IX and their average size was 50 mm.

28-3-1970 & 29-3-1970

The hind limbs increased rapidly in size. The margins of the foot paddles were indented between all the five toes. The inter-digital notch formed by the margin of the web was clear between toes 4 and 5. The tadpoles completed foot paddle stages and their mean length was 52.50 mm.

29-3-1970

The margin of the fifth toe web was directed
towards the third toe. The fourth toe usually had a melanophore streak. They completed stage XI and entered stage XII.

The margins of the 5th toe were more pronounced and the space between the interdigital notch formed by the web became more acute. The hind limbs were fully formed. The forelegs were visible through the branchial chamber.

30-3-1970

They entered stage XIII and their average size was 60 mm. The web between the digits 5th and 4th and 3rd became elongated towards the tips of the digits. After completion of stage XIII, the tadpoles entered stage XIV when pigment free patches appeared at metatarsal and phalangeal joints. The brow spot also appeared at about this time. The average size of the tadpole was 62 mm. The mouth was furnished with labial fringes and the horny beak.

31-3-1970

The tadpoles entered stage XV and their average size increased to 63.40 mm. The proximal toe-pads appeared as wart-like elevation which developed on the ventral surface of the toes at the metatarsophalangeal joint. After completion of this stage, the tadpoles entered stage XVI, when the middle toe pads appeared. They
constituted the first interphalangeal joint on toes 3rd, 4th and 5th. The changes in the mouth, pharynx and tail were observed. The angle of mouth extended progressively.

1-4-1970

They completed stage XVI and entered stage XVII when they had distal toe pad at the second interphalangeal joint on toe 4th. The length of the tadpoles increased considerably and their average length was 68.50 mm. They entered next stage i.e. XVIII. The mouth became wider with the indentation of the margin of the upper jaw. The tongue was notched. The vomerine teeth were also formed. The cloacal tail piece had disappeared. They completed premetamorphic stages.

2-4-1970

The tadpoles attained the maximum size and their mean length at stage XIX was 71 mm. The opercular tissue turned dark. The tail assumed a darker and less transparent appearance than in premetamorphic stages. The skin window became clear. The wall of the gill chamber at the point from where the fore-legs later protruded became thin and transparent. The parts of the fore-limbs were clearly visible in the alizerin stained specimens. They were observed to enter stage XX when the forelegs had protruded out. Towards the end of stage XX the horny beak was shed
and resorption of the labial fringe began.

3-4-1970

The length of the tadpoles was reduced to 68 mm. when they entered stage XXI. The angle of the mouth reached a point midway between the nostril and the anterior margin of the eye. The gap of the mouth increased and it widened soon after stage XXI. The labial fringe had totally disappeared. The beginning of the resorption of the gills and the operculum was evidenced by the darkening of the opercular tissue. The tail assumed a darker and less transparent appearance than in stage XX. The length of the tail was reduced. The dorsal and ventral fins were shrunken.

4-4-1970

The tadpoles entered stage XXII and they were reduced in size. The angle of the mouth had reached the level of the middle of the eye. The remains of the operculum were still darker in colour. They completed stage XXII and entered stage XXIII. The tissue of the tail became darker. Dorsal and ventral fins had almost disappeared. The tail was now shorter than the extended hind limbs.

5-4-1970

The opercular patch was further reduced. The angle of the mouth reached the level of the posterior margin of the eye ball when they entered stage XXIV. The opercular patch was considerably reduced. The annular ring of the
tympanic cartilage was perceptible under the skin. There was further reduction in the size of the tail.

6-4-1970

The opercular patch was reduced to dark line running from the tympanic membrane to the base of the forelegs. A stub of the tail persisted which did not protrude beyond the length of the animal.

7-4-1970

The tail was completely absorbed after the completion of stage XXIV. The young frogs when entered stage XXV had ossified skeleton. The resorption of the operculum and the tail was indicated by the disappearance of the dark tissue from the respective region. Their size varied from 22 to 30 mm.

Feeding was suspended for a few days after which they were feeding on small aquatic animals. They remained near the sides of the troughs until they were sufficiently developed to emerge from water.

There is no evidence for any significant difference in general habits between the juvenile frogs and the adults except at the breeding season, when juvenile phase is one of the wide dispersal. For two or three years the young frogs do not make an annual journey to the ponds to breed but they could cross territory
with no ponds and thus populate a new region.

A glance at Table 19 and figure 34 indicates that there is a rapid growth up to stage XIX. After the completion of this stage there is a little fall and from stage XXI to XXV there is a rapid fall indicating that the absorption of tail which starts at stage XX and continues up to XXIV. It reaches its climax at stage XXV when the tail is completely absorbed.

DISCUSSION

*Rana cyanophlyctis* takes 27 days, soon after independent feeding to complete its metamorphosis. This period is at variance in nature. It takes more days to complete its developmental stages in September both in the field and in the laboratory.

There are a number of factors which facilitate or inhibit growth rates. The period of metamorphosis has also been reported to be variable in many species of anurans studied by McCann (1933). It has also been observed in anurans that generally individuals at the same level of morphological development may vary widely in size due to different conditions of feeding and temperature and also due to significant morphological changes which often occur with, but slight accompanying change in absolute or relative measurement. Criteria based
on size alone prove inadequate (Taylor and Kolloros, 1946).

Among the system of stages based on more or less morphological character is that of Wintrebert (1905) who described ten stages for *Rana temporaria* and *R. viridis*. Tschernoff (1907) established a series of eleven stages for the development of the hind limb in *Rana arvalis* (*R. temporaria*) apparently unaware of Wintrebert's work. A series similar to that of Tschernoff's was set up by Emmett and Allen (1919) for *R. pipiens*. Etkin (1932) described sequentially the changes occurring during anuran metamorphosis. Schreiber (1937) studied eight stages in *R. vulgaris*. Eakin and Harris (1945) mention a series of fifteen stages for *Hyla* larva, but they did not describe them.

Taylor and Kolloros (1946) established a set of closely spaced developmental stages for *Rana pipiens* and proposed 25 stages which the larvae complete in 90 days. The limb bud stages start when the larvae attain a size of 12.69 mm. and grow up to 39.19 mm. within 23.16 days; but in *R. cyanophlyctis* the limb bud stages are completed in 10 days. As regards foot paddle stages they are completed in 5 days, and foot stages in 4 days and the metamorphic stages in 8 days. This is in variance with the observations in *R. pipiens*. 
From these observations it appears that *R. cvanophlyctis* larvae take 27 days to complete metamorphosis. This period is sufficiently less as compared with the observations in *R. pipiens*. It may be stated that these differences can be easily attributed to different ecological conditions.

The normal metamorphosis and growth in amphibians are influenced by nutrition, illumination, temperature and crowding etc. These factors responsible for normal growth and development have been studied by Yung (1873), Barfurth (1887), Adler (1916), Adalph (1931), Lynn and Edelman (1936), Gordon and Charipper (1941), Disclos (1959), Rose (1959), Freiden *et al.* (1965) and Akin (1966).

Even though metamorphic reactions are initiated by thyroxin, they may be either facilitated or inhibited by prolactin steroid hormones (Etkin, 1968). Diet, temperature and crowding are the factors whose mode of action in the regulation of normal development is still unknown (Kaltenback, 1968).

In the present state of our knowledge and lack of experimental data nothing definite can be said about the metamorphic reactions in *Rana cvanophlyctis*. But the preliminary studies on the life history of *Rana cvanophlyctis* reveal that factors like nutrition, temperature, crowding etc. are responsible for variation in sizes and weights of tadpoles.
### Table-19

Mean lengths of the larvae at each stage and time interval between stages as observed in *Rana cyanophlyctis*

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<th>Stage</th>
<th>Length in millimetres</th>
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