CHAPTER 3: I

REPRODUCTIVE BIOLOGY
INTRODUCTION

Reproduction is a phenomenon of producing young ones. In invertebrates it occurs by sexual as well as a sexual methods. The sexual method is a most extensive method of reproduction where gamete formation takes place. The process of gamete formation is a "gametogenesis" and it involves the mobilization of nourishment, multiplication and differentiation of cells, gamete accumulation and discharge. It occurs in the reproductive system and the reproductive system comprises of various reproductive organs.

The reproductive system of gastropods show a wide variety of differences in organisation. Many prosobranchs are in general dioecious i.e. the sexes are separate. The sexes often can not be distinguished externally. Sexual differences in prosobranchs may be manifested by the difference in size of the shell or variations in the copulatory organs. In general females have larger shell than males and particularly in Viviparidae in males the right tentacle is a sexual tentacle and it is fused with the penis.
In diecious forms of prosobranchs, females are more numerous than the males (Hyman, 1967). These forms show much variation in the position and arrangement of their genital organs (Fretter and Graham, 1962). Though within the prosobranchs all members of the Diotocardia and the Stenoglossa are dioecious, some members show pseudo-hermaphroditism i.e. in female snails some male characters were also observed. Smith (1971) reported that the female Nassarius obsoletus had one or more male characteristics namely (1) a penis with a duct leading to (II) a vas deferens which passed back to the ventral channel of the capsule gland and (III) convolution of the normally straight gonadal oviduct. He named it as an 'imposex'. A similar pattern has been briefly mentioned by Jenner (1979). Further study of Smith (1980) provided a detailed examination of the reproductive anatomy of normal snails and the imposex snails.

Most of the prosobranch species are hermaphrodite and they may be simultaneous i.e. eggs and sperms mature simultaneously in the same gonad. Among the hermaphrodite species some are protandric hermaphrodites. Pellegrini (1949) and Bacci (1953) have described that Calyptraea chinensis was a balanced protandric hermaphrodite animal. There is no environmental influence on the time of sex
change. Bacci (1951) found that immature gonads of young animals contained both spermatogonia and oogonia. Even while the animal was functioning as a male during the first year, oogenesis was noted to begin. Alonte (1930) reported that *Viviparus angularis* was a simultaneous hermaphrodite animal. Simultaneous maturation of eggs and sperms in the gonads of prosobranchs have been reported in a few species (Fretter, 1948; Dodd, 1956; Ganapati and Rao, 1967). The factors that regulate the development of a gonad into ovary, testis or a hermaphroditic state are not well established in prosobranchs.

Among the gastropods compared to pulmonates, very less work has been done in prosobranch molluscs. However, few workers have studied the reproductive system of various prosobranchs (Drummond, 1903; Greek, 1951; Johansson, 1953; Graham, 1954). A more detailed account of the genital ducts of various British stenoglossans was made by Fretter (1941). Detailed study of the reproductive system of *Melanopsis* and *Zemelanopsis* was made by Bilgin (1973) where as Brink (1973) reviewed the histology and ultrastructure of the reproductive tract of * Biomphalaria glabrata*.

Many tropical invertebrates show synchrony in their reproduction (Webber and Giese, 1969). In most of the prosobranchs gametogenic activity throughout the reproductive
cycle is synchronous in a population. In such type of population three stages are observed in gametogenic cycle; a resting stage, a period of active gametogenesis and a period when the gonad contains fertilizable or apparently mature gametes (Fritchman, 1961, a, b; Feare, 1970). Extensive work has been done about the reproductive cycles, which are determined on the basis of gonad indices, spawning, brooding habits and appearance of mature gametes (Webber and Giese, 1969; Webber, 1970; Lambert and Dehnel, 1974). It is a well known fact that most of the invertebrates are seasonal to their reproduction (Giese, 1959; Kinne, 1963 and Clark, 1965).

Number of methods have been used to determine the annual course of reproduction of marine invertebrates (Giese, 1959). The appearance of ripe gametes in gonads, the brooding of eggs and the relative size of gonads, spawning, number of larvae and other body components have been used by different investigators to define the reproductive seasons. Giese (1969) has reviewed the available literature on the use of body component index to study the seasonal changes in the relative size of the body components and on the biochemical composition of each component of various molluscs. Boolootian et al. (1962) used cross sectional area to follow seasonal changes in the gonad and hepatic indices of two species of abalone,
Haliotis cracheroidii and H. rufescens. They have found an inverse relationship between the seasonal changes in the size of the gonad and the hepatic gland. Webber and Giese (1969) have determined seasonal changes in gonad weight of Haliotis cracheroidii and found a seasonal periodicity in its size. Maximum gonad growth occurs during the summer months just prior to spawning. Lawrence et al. (1965) found a reciprocal relationship between the digestive gland and glandular oviduct indices of the amphineuron, Katherine tunicata. Webber (1970) extended the body component analysis of the Haliotis cracheroidii and found two periods of rapid gonad growth; one prior to spawning and a second just after spawning. Lusis (1961) suggested that the reproductive activity is mainly related to age and body size/weight of the animal. Stickle (1973) has studied the physiology of the reproduction of a intertidal prosobranch, Thais lamellosa with reference to various body component indices. Todd (1978) has clearly shown the relationship between the body size, age, ovotestis and the digestive gland in the marine slug, Onchidora muricata, with a view to their possible ecological significance in relation to reproductive biology.

Little attention has been paid to study the process of gametogenesis in the prosobranchs. In the snail, V. bengalensis,
study on the reproductive biology was furnished by Diwansingh (1974). In the same snail, Raut (1980) has made a preliminary observation on the breeding activity. He has observed that this prosobranch snail reproduces throughout the year but the rate of breeding is variable from season to season. Though some information is available about the reproductive processes of the freshwater prosobranchs, the problem of origin of gametes, their formation, maturation and subsequent degeneration have not been studied in detail. Particularly in the freshwater prosobranch snail, Viviparus bengalensis these aspects are completely ignored.

Gomot (1971) has clearly distinguished three fundamental processes which are involved in the process of gametogenesis. They are the segregation of the germinal cells, entry of the germinal cells into gametogenesis and the orientation of gametogenesis to either spermatogenesis or oogenesis.

For the success of reproduction, various reproductive processes should be well synchronized and be properly coordinated by some control mechanism so as to coincide with favourable season for breeding. In all the animals having a breeding season there must be some means and measures by which all the members of a given population come into breeding condition at a same time.
The reproductive activities progress through a series of events. The major factor in this process is a gametogenic cycle. According to Giese and Pearse (1974) a gametogonial cycle includes following stages:

1. Accumulation of nutrients,
2. Proliferation of gonial cells and their differentiation into mature gametes,
3. Accumulation of mature gametes,
4. Release of mature gemetes (spawning or egg laying or copulatory transfer),
5. A reproductive spent period.

On the basis of commencement of each event they have further divided the reproductive cycle into pre-reproductive, reproductive and post-reproductive periods. It is further stated that it is the time of reproduction which determines the pattern of the breeding cycle i.e. either semi-annual, annual or biannual or a continuous breeding.

In view of the above cited literature, it is clear that, studies on the reproductive patterns and the process of gametogenesis is completely ignored in the freshwater prosobranch molluscs. Thus it is thought worthwhile to study the reproductive activity of a freshwater prosobranch snail, Viviparus bengalensis. This chapter is outlined to give an information regarding the morphology and histology of the reproductive organs, process of gametogenesis and the breeding activity of the snail.
MATERIAL AND METHODS

The freshwater prosobranch snail, *V. bengalensis* were collected from Godavari river at Paithan near Aurangabad, Maharashtra State, India. They were brought to the laboratory and were placed in the glass troughs containing sufficient amount of water. They were fed once in a day on *Hydrilla* plant and algal food material like *Spirogyra*. They were acclimated for 3 - 4 days to the laboratory conditions.

(1) Studies on reproduction

To study the various reproductive organs, mature snails (ranging from 16 - 21 mm in shell length) were selected and from this lot female snails were separated on the basis of the characteristics of the tentacles and shell size. The shells were removed from both the sexes and the animals were dissected in order to study the various reproductive organs and the system.

For the histological study, various parts of the reproductive system were fixed in Bouin's fluid for 24 hrs. This fixation of the reproductive organs was carried out for one year (January to December, 1981). After fixation they were embedded in tissue-mat having 58 - 60°C melting point and then they were sectioned at 6 - 7 μ. After sectioning, they were stained with haematoxylin-eosin stain and histological observations were made at light microscopic level.
(2) **Studies on gametogenesis:**

To study the process of gametogenesis, mature male and female snails were dissected in every month. Their gonads were separated and were fixed in Bouin's fluid for 24 hours. After fixation they were embedded in tissue-mat and processed for histological observations. The observations were made for one year.

The oogonial and spermatogonial stages were divided as follows:

The oogonia as (i) primary oogonia (ii) previtellogenic oocytes (iii) vitellogenic oocytes (iv) postvitellogenic oocytes and (v) the degenerating oocytes. Similarly, the spermatogonial stages were divided as (i) spermatogonia (ii) spermatids and (iii) spermatozoa or sperms.

(3) **Studies on breeding activity:**

To study the breeding activity of the snail *V. bengalensis* mature female snails were dissected and their uterine chambers were examined. The number of snails carrying eggs/young ones were counted separately in each month and this study was made for a period of one year.
RESULTS AND OBSERVATIONS

(1) Reproductive system:

A freshwater prosobranch snail, *Viviparus bengalensis* is a dioecious animal. The sexes are separate and there is a definite sexual dimorphism. The females are larger than the males. In males the right tentacle is modified to serve as a copulatory organ i.e. penis. In general, females are available in large numbers compared to the males.

Morphology and histology of the male reproductive organs:

The male reproductive system of the snail, comprises of following organs (Fig.1).

(1) testis with vasa efferentia,
(2) prostate gland,
(3) the vas deferens and
(4) the penis.

(1) Testis:

The male gonad is a large and massive structure, lying in the upper part of the first three whorls of the shell. It is intermingled in the digestive gland. It is difficult to separate out from the digestive gland. It is brownish or dirty green in colour. It is single and composed of large number of tubules or acini. From the male gonad a tube runs towards the prostate gland, known as vasa efferentia.
Fig. 1: Showing the male reproductive system of the snail, *V. bengalensis*.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>Dig.G.</td>
<td>Digestive gland</td>
</tr>
<tr>
<td>M.G.O.</td>
<td>Male genital opening</td>
</tr>
<tr>
<td>P.</td>
<td>Penis</td>
</tr>
<tr>
<td>PE.G.</td>
<td>Prostate gland</td>
</tr>
<tr>
<td>R.V.D.</td>
<td>Renal vas deferens</td>
</tr>
<tr>
<td>Te</td>
<td>Testis</td>
</tr>
<tr>
<td>V.D.</td>
<td>Vas deferens</td>
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Transverse section of digestive gland shows, the presence of male gonads (Fig. 2). It is located in peripheral region only. An enlarged section of the testis shows the presence of round acini. It was observed that, the size and the number of acini were increased according to the reproductive season. In peak breeding season maximum number of acini were noted. These acini undergo the process of spermatogenesis and give rise to the sperms. However, clear sperms were not observed in the testis.

(2) Prostate gland:

It is a large accessory male reproductive gland. It is a thick and curved structure lying along the top of the last whorl of the shell. It varies from brown to cream in colour and leads into the vas deferens. Histologically, it reveals that, it is lined by a tall epithelial cells, these cells being cuneiform and ciliated (Fig. 3). This gland consists of numerous gland cells and they are filled with secretion spherules. It is observed that, these gland cells are increased in the breeding season. The whole space of the gland cells is filled with the prostatic secretion. This secretion is poured into the canal, known as the prostatic canal. This canal leads into a bigger prostatic duct which ultimately opens into a vas deferens. Spermatophores and the sperms are observed in the prostatic secretion.
Fig. 2: Section of digestive gland showing spermatogonial cells X 150

DG - Digestive gland
SGC - Spermatogonial cells
Fig. 3(a) Photomicrograph showing the structure of prostate gland X 150

Fig. 3(b) Photomicrograph, showing the structure of prostate gland X 400

G.C. - gland cells
S.P. - Sperms
(3) **Vas deferens**:

From the distal end of the prostate gland a long, somewhat coiled tube passes towards the right tentacle known as the vas deferens. It lies on the muscle and connects to the penis. Prostatic duct opens into it. Histological structure of the vas deferens reveals that, it is lined with a columnar ciliated epithelium containing large and centrally placed nucleus. The epithelium is thrown into longitudinal folds. A thicker mass of connective tissue underlines the epithelium. Beyond this connective tissue, a zone of muscular layer is observed (Fig. 4).

(4) **Penis**:

In the male snail, the right tentacle acts as a penis. It is also called as "Verge". It is a thick, swollen and lies in a penis sheath. It is a highly muscular organ being glandular in nature. Because of this nature, it acts as a hold-fast during copulation. Histologically, it consists of circular muscle fibres, connective tissues and blood spaces. It is covered externally by a cuboidal epithelium. The lumen of the penis is very small.
Fig. 4: Photomicrograph, showing the structure of vas deferens X 100

L = Lumen
Morphology and histology of the female reproductive organs

The female reproductive system of the snail, *V. bengalensis* consists of the following organs (i) ovary (ii) oviduct (iii) receptaculum seminis, (iv) albumen gland (v) pallial oviduct or uterus and (vi) a female genital opening. (Fig. 5).

(1) **Ovary**

The ovary is very small and is difficult to locate. It is intermingled in the digestive gland in the visceral mass. In mature snails, it covers a large part of the digestive gland. Between the two digestive glands round follicles are seen. In the follicles oogonial cells are located. In one follicle two or three developing oocytes can be seen. (Fig. 6). The transverse section of the ovary reveals that, it is embedded in the digestive gland. Pyriform or globular oocytes are observed between the two digestive gland or they are observed on the peripheral region of the digestive gland. Oocytes are single, containing large nucleus and small nucleolus. When fully mature the oocytes increase in size.

(2) **Oviduct**

From the ovary a thin walled duct passes, known as the oviduct. It leads forward and ventrally on the right side of the visceral and can be seen through the integument anteriorly. It is very thin, elongated and minute. Some times it can not be seen in the digestive gland.
Fig. 5: Showing the female reproductive system of the snail, *V. bengalensis*

- **B.P.**  Brood pouch
- **C.A.G.**  Capsule albumen gland
- **Dig.G**  Digestive gland
- **Em.**  Embryo
- **F.G.O.**  Female genital opening
- **Pa.OV.D**  Pallial oviduct
- **R.S.**  Receptaculum seminis
- **OV**  Ovary
- **OV.D**  Oviduct
(3) **Receptaculum seminis**:  

The oviduct opens into a big, slightly curved organ known as receptaculum seminis. It is an area near the site of fertilization where the sperms may be stored for a large period, orientated and nourished by the female.

(4) **Albumen gland**:  

It is an accessory reproductive gland. It is large, slightly curved and has smooth surface. During the breeding season it inlarges greatly. It becomes much reduced after the contribution of the albumen to the eggs. Albumen gland secretes the albuminous material that surrounds the eggs.

Histologically, it is formed by a large number of small and elongated vesicles, which are held together by a very narrow and delicate strands of tissues. It is lined by a tall epithelial cells and usually has the structure like capsule gland. Albumen gland contains secreting cells and they secrete the albuminous material. Secretory glands are tubular and they are lined by tall columnar cells. These tubes unite one another forming a tube and act as a duct for albuminous secretion.  

(Fig. 7).
Fig. 6: Photomicrograph, showing oogenial cells (Ovary).
Section of digestive gland X 60

Fig. 7: Photomicrograph, showing the structure of albumen gland X 600

A.G.C. Albumen gland cells
D.G. Digestive gland
OOG Oogonial cells
**Capsule gland:**

The capsule gland has thick lateral walls and thin mid-dorsal and mid-ventral strips. The thick walls consist of numerous invaginated clusters of long-necked gland cells. Tips of the gland cells are reached to the lumen and there they are interspersed with cuneiform ciliated cells. The secretion of the capsule gland solidifies the egg capsule (Fig. 8).

(5) **Pallial oviduct:**

When reaching to the posterior end of the mantle cavity, the oviduct expands greatly which is then called as the pallial oviduct or uterus. It opens into the female gonopore near the anus. In the mature or adult female snails it acts as a brood pouch. It is a single, big sac like structure having a very thin transparent wall. The eggs after fertilization are retained in the uterus and in it they develop into young ones. Histologically it reveals that, this sac is lined by a tall epithelial cells and they are underlined by circular muscles. Epithelial cells are folded to inner side and these folds become extended forming a big lumen, when the uterus is modified into brood pouch (Fig. 9).
Fig. 8: Photomicrograph, showing the structure of capsule albumen gland X 150.

Fig. 9: Photomicrograph, showing the structure of brood pouch (Uterus) X 30

A.L.G. Albumen gland
C.P.G. Capsule gland
U.C. Uterine chamber
(6) **Female genital opening**

The pallial oviduct becomes narrow, forming a small tube and it opens into female gonopore, in the mantle near the anus. This terminal part of the uterus forming vagina is muscular and thick.

**Histomorphology of the female gonads**

Female gonads in the snail, *V. bengalensis* are located in the follicles. These follicles are irregular in shape. The size and arrangement of female gametes changes during the maturation. In this snail development of the female gonad is studied at light microscopic level and it is divided into the following stages:

**Stage - I**

At this stage the follicles have a number of oogonial cells. They are small and rounded. Clear differentiation is not observed at this level (Fig. 6).

**Stage - II**

At this stage in the follicles numerous cells can be observed. The size of the cells is increased. Their round shape is changed into somewhat pyriform. The clear differentiation is seen and one of two developing oocytes are seen in one follicle (Fig. 10).
Oogenesis in the snail, *V. bengalensis*

**Fig. 10**  Showing oogonial cells in the follicle X 400.

**Fig. 11**  Showing formation of previtellogenic oocyte in the follicle X 400

- D.G.  Digestive gland
- F    Follicular layer
- O.O.G.  Oogonial cells or young oocytes
- P.V.  Pre-vitellogenic oocyte
- n    nucleus
Stage - III

Two or three developing oocytes can be located in a follicle and almost all the follicles have developing oocytes. The follicular diameter as well as the diameter of the oocytes are also enlarged. The previtellogenic oocytes also can be clearly seen (Fig. 11).

Stage - IV

At this stage enlarged oocytes are found. Their length is also increased. The diameter of the oocyte is increased and the vitellogenic as well as the post-vitellogenic oocytes are observed. At this stage the gonad has attained full maturity. The number of other cell type like nutritive cells, however, are not seen. (Fig. 12)

Histomorphology of the male gonads:

Male gonad in this snail is single and dispersed in the digestive gland. All developing stages of the male gonad are not observed clearly. However spermatogonia, spermatids and spermatozoa or sperms can be seen.

In the first stage, globular or round acini cells are observed. They are called as spermatogonia or male gonad cells. During the mature period, the size and number
Oogenesis in the snail, V. bengalensis

Fig. 12 Showing vitellogenic oocyte X 400.

Fig. 13 Showing post-vitellogenic oocyte X 400

n nucleus
PVO Post vitellogenic oocyte
VO Vitellogenic oocyte
of these spermatogonial cells increase. These cells undergo mitotic division during the process of spermatogenesis and the formation of sperm takes place. The sperm is short and vermiform. It possesses head which contains round nucleus and a long filament like tail (Fig. 14, 15 and 16).

Oogenesis in the snail, V. bengalensis:

For the clear understanding, the process of oogenesis is divided into two phases (i) The generative phase which includes the proliferation of oogonia and their transformation into pre-vitellogenic oocytes and (ii) the vegetative phase which includes vitellogenesis and the maturation of the pre-vitellogenic oocytes.

(1) The generative phase:

In this stage the oogonial cells develop from the follicular/germinal layer. They are round and less in number. They measure from 3.1 to 3.8 μ in diameter. In a single follicle numerous oogonial cells are observed. In these cells the nucleus is round but however nucleolus cannot be very well seen. These cells undergo cytoplasmic growth during premeiotic division and get transformed into the pre-vitellogenic oocytes (Fig. 10).
Spermatogenesis in the snail, *V. bengalensis*

Fig. 14  Showing spermatocytes.
        Section of digestive gland X 400

Fig. 15  Showing spermatids.
        Section of digestive gland X 400

Fig. 16  Showing sperms.
        Section of digestive gland X 400

D.G.  =  Digestive gland
S.P.C. = Spermatocytes
S.T.  = Spermatids
S.P.  = Sperms
(2) **The vegetative phase:**

With the formation of the previtellogenic oocytes the vegetative phase commences. The previtellogenic oocytes are elliptical or round in shape. The cytoplasm and nucleus are homogenously stained with haematoxylin and are highly basophilic. The nucleolus here can be clearly seen. These oocytes measures from 6.2 to 7.75 μ in diameter. The nuclear diameter is 3.1 to 3.8 μ. (Fig. 11). In this vegetative phase, the previtellogenic oocyte increases in size and then becomes vitellogenic oocyte. It has intense eosinophilic ooplasm which is homogenously stained. The yolk granules are in dispersed condition. These oocytes measure from 9.3 to 10.85 μ in diameter and their nuclear diameter measures 3.1 to 4.0 μ (Fig. 12). In most of these ova nucleoli are invisible. The significant changes can be localized in the nucleus.

The post-vitellogenic oocytes measure 15.5 to 21.7 μ in diameter. They are also called as relict ova. The ooplasm is clumped and formation of net work is seen. This stage can be called as degenerating stage (Fig. 13).
**Spermatogenesis:**

Spermatogonial cells appear at the periphery of the digestive gland. They are called as first or primary spermatocytes (Fig. 14). These are round in shape and their nucleus stains darkly with haematoxylin. They undergo first mitotic division to form secondary spermatocytes. The round shape of spermatocytes changes due to the elongation of the cytoplasm. After the first meiotic division the secondary spermatocytes transform into spermatids (Fig. 15). It is seen that the nuclei are migrated towards the upper side of the cell.

Spermatids undergo spermiogenesis and are converted to spermatozoa. The cytoplasm of the spermatids is drawn out and finally it diminishes in the plume with gets converted into long sperm tail. The process of spermiogenesis is complete with the change of nucleus from a dense round body to a narrow spindal one and it forms the head of the spermatozoa (Fig. 16). The spermatids are thus converted into spermatozoa.

All the stages of spermatogenesis are not clearly observed. However, spermatogonia, spermatids and spermatozoa are observed clearly.

**Breeding activity of the snail, V. bengalensis:**

A preliminary observation on the breeding activity of the snail is made during the year 1981. The freshwater
Table 1

Showing percentage of snails *V. bengalensis* carrying eggs/young ones in their brood pouch during January to December, 1981.

<table>
<thead>
<tr>
<th>Months and Year</th>
<th>Number of snails observed</th>
<th>Percentage of snails carrying eggs/young ones</th>
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<tbody>
<tr>
<td>1981</td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>10</td>
<td>30</td>
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<tr>
<td>February</td>
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<td>50</td>
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<tr>
<td>April</td>
<td>10</td>
<td>70</td>
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<tr>
<td>May</td>
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<tr>
<td>October</td>
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<td>80</td>
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<tr>
<td>November</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>December</td>
<td>10</td>
<td>60</td>
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</table>
snail, *V. bengalensis* is continuous breeder and the female snails carry eggs/young ones in their brood pouch (uterus) throughout the year but the number of female snails carrying eggs/young ones is variable according to season. From the data it is evident that the percentage of the female snails carrying eggs/young ones in their brood pouch is maximum during the rainy season (Table 1). The percentage is declined during the winter and summer season. Thus it can be said that, the rainy season is a peak breeding season of the snail, *V. bengalensis*.

**DISCUSSION**

Among the gastropods, prosobranchs show the greatest diversity in reproduction. Most of the species are dioecious and many forms are protandric hermaphrodite or parthenogenetic. Many species brood their eggs or are viviparous. In the dioecious forms females are more numerous than the males (Hyman, 1967). Differences between male and female of the same species are generally pronounced. In some prosobranchs, internal fertilization occurs and in such type of prosobranchs a penis acts as copulatory organ. It is fused with the right tentacle. Other morphological differences between the sexes are covered by the shell size and shell morphology.
In general females are longer than the males, but Edwards (1968) has found that the males of *Olivella biplicata* were larger than the females. In *Heliotis* no difference was noticed between the average size of males and females (Newman, 1967; Webber and Giese, 1969).

In the freshwater prosobranch snail, *V. bengalensis*, sexes are separate. Female snails are larger in size and they are more numerous than the males. In the family Viviparidae to which this snail belongs, the penis is fused with the right tentacle.

Knowledge of the morphology of the reproductive system of prosobranchs is more extensive than that of any other area of reproductive biology. Reproductive systems of prosobranchs are much complicated. The female reproductive system is highly complicated in relation to the production of egg capsules, whereas the male reproductive system is very much simple. Details of the variability in reproductive anatomy are well reviewed by Fretter and Graham (1962) and Hyman (1967). The anatomical complexity of prosobranch reproductive system reflects the functional spectrum.
In archaeogastropod prosobranchs, simplest type of reproductive system is observed. It is similar in both the sexes and it consists of a single gonad with a gonoduct that leads to the right kidney. Gametes are released into the kidney and then they escape through the renal pore. In some archaeogastropods like Gibbula and Monodonta (Risbec, 1939), the distal portion of the right kidney duct is modified into a glandular region that produces a mucus layer in which eggs are deposited during spawning. In the remaining prosobranchs (i.e., Mesogastropoda and Neogastropoda) the gonadal ducts are separated from the kidney and open separately into the mantle cavity. In general, the male reproductive system consists of a penis and the prostate gland. In most species having internal fertilization, the male gonoduct is elongated at some point to form a prostate gland.

The female reproductive system of prosobranchs which shows internal fertilization is more complicated. It includes gonads, gonadal duct or oviduct, albumen gland, pallial oviduct and female genital opening.

In the snail, V. bengalensis, reproductive system is complicated due to internal fertilization. Male reproductive system comprises of testis, testis duct or vasa efferentia, prostate gland, vas deferens and a penis. The penis is a highly glandular organ and acts as a hold fast.
during copulation. In *Sythinella* an accessory copulatory organ springs from a common base with the penis which might act as a hold fast during copulation (Bregenzer, 1916). In this snail, testis is surrounded by digestive gland completely so that it becomes invisible from the surface region. Similar observations were made in one of the viviparous form *Campeloma* sp. by Van der Schalie (1965). The histological structure of testis shows close resemblance with the testis of *Campeloma* sp. A sperm duct usually after leaving the testis elongates into numerous convolutions which act as seminal vesicles for sperm storage and some part of the sperm duct is altered into a prostate gland. The sperm duct opens into prostate gland and because of this, in spawning period numerous sperms are observed in prostatic secretion. From the prostate gland they pass onwards at the time of copulation.

The enclosure of sperm in spermatophores, probably secreted by the prostate gland are observed in *Goniobasis* (Jewell, 1931) in Neritidae (Andrews, 1937) and in various heteropods (Tesch, 1949).

Two types of sperms (eupyrene and apyrene) are reported in many prosobranchs (Linke, 1934; Neuhaus, 1959). In the snail, *V. bengalensis* sperms are observed but their morphological nature is not seen clearly and due to this it is very difficult to locate different types of sperms.
It needs further observations. A typical type of sperms of Viviparus sp. contribute towards the nutrition of the eypyrene sperm in the duct of the female by dissolving and releasing reserve polysaccharide (Hanson et al. 1952). It has been reported by several workers that the sperm can remain in healthy condition for several weeks and even months. In Viviparus sp., Ankel (1925) found viable sperms in the receptaculum even after five months. Coe (1942) observed in Crepidula that the sperms can remain functional for more than a year.

The female genital tract of the snail, V. bengalensis also shows some resemblance with Campeloma sp. (Van der Schalie, 1965). In the snail, ovary spreads in the digestive gland in the visceral mass. In mature condition it produces eggs and the pallial oviduct is expanded greatly and becomes vase like. It is also called as the uterus. In this uterus the brooding of the eggs occurs. An open pallial oviduct was reported in a freshwater form Fagotia esperi by Soos (1936).

Albumen gland is an accessory reproductive organ. It secretes the albuminous material that directly surrounds the eggs. Fretter (1941) found two or three different kinds of secretory cells in the albumen gland of several prosobranchs. The histological structure of
the albumen gland is similar to that of capsule
gland. In this snail, capsule gland is not reported
(Diwansingh, 1974). But some part of the albumen gland
shows structure like capsule gland and so it may be also
called as the capsule-albumen gland. Capsule gland
secretes the secretion which solidifies the eggs but
its nature is not known because different regions of
the capsule gland stains differently. Creek (1951)
reported three zones in Pomatias and Martaja-Pierson
(1958) in Conus observed seven staining zones. Hence
the nature of the secretion is complicated.

Compared to pulmonates, very less information is
available about the reproductive cycle and reproduction
in the prosobranchs. The problem of origin of gemetes
and gametogenesis are difficult to understand in the
freshwater prosobranchs. It is a well known fact that,
the freshwater prosobranchs are continuous breeders. In
most of the prosobranchs gametogenic activity throughout
the reproductive cycle is synchronous. Most of the
marine prosobranchs are broadcast fertilizers and generally
they have an annual reproductive cycle (Giese, 1959).
The snail, *V. bengalensis* reproduces throughout the year but the rate of breeding is rather variable from season to season. It does not show any particular type of reproductive cycle, but depending upon the environmental condition the rate of reproduction is variable.

The study on the origin of gametes and the process of gametogenesis become very complicated since the animal is throughout breeder. The process of spermatogenesis in prosobranchs received considerable attention, because of the presence of polymorphic spermatozoa in many species (Webber, 1977). Important reviews on spermatogenesis and spermogenesis in prosobranchs are given by Tuzet (1930) Hansen et al. (1952) and Franzen (1955, 1956). The stages of the process of spermatogenesis like, primary spermatocyte, secondary spermatocyte, spermatids and spermatozoa are not observed clearly in this snail. However, some stages like spermatogonia, spermatids and spermatozoa are seen clearly.

In the freshwater prosobranchs oogenesis is a complicated process, but a general pattern can be observed in the snail, *V. bengalensis*. In this snail, oogonial cells are observed in the follicles. These oogonial cells divide mitotically and formation of secondary oogonia or oocyte takes place. These secondary oocytes give rise to
Vitellogenic oocytes. Eggs are released from itellogenic oocytes into the oviduct and pass out for further processes.

Process of oogenesis is studied in number of prosobranchs by Franc (1951), Bacci (1954) and Raven (1961). Franc (1951), described five stages in the nucleus during oocyte formation. However, these five stages of nucleus are not observed clearly in the case of *V. bengalensis*. In this snail, during oogenesis growth of nucleus is observed and at some stages changes in nucleolus are also recorded. As the nucleus increases in size during oogenesis, the cytoplasmic mass also increases. However, the nuclear/cytoplasmic ratio does not remain constant. In *Haliotis* (Bolongari and de Raco, 1956) nuclear and cytoplasmic ratio decreases during oogenesis. In this snail also the growth of cytoplasm and nucleus takes place during oogenesis but the ratio may not be a constant.

Cytoplasmic growth involving the incorporation of surrounding follicle cells has been reported in *Lamellaria perspicua* (Renault, 1965). During oocyte development, before vitellogenesis the membranes of the follicle cells surrounding the oocyte break down and the cytoplasm is incorporated into the developing eggs.
In the prosobranchs time of occurrence of the maturation division of oocytes is not reported. In this snail the time of maturation division of oocyte is not reported. However, such a time a maturation division is observed in the snail, *Campeloma* by Mattox (1937) and he has reported that the first maturation division occurs while the oocytes is still attached to the ovary wall.

It is clearly known that, among the prosobranchs, number of species are dioecious, some are hermaphrodite, some are protandric hermaphrodite and some are synchronous in their reproduction. Because of this, study on the reproductive cycle, the origin of gametes and the process of gametogenesis becomes complicated.

It is a well known fact that the process of gametogenesis/reproductive activity is under the control of environmental factors. Temperature is very important factor in gonadal development (Giese, 1959; Kinne, 1963; Pretter and Graham, 1964; Giese and Pearse, 1974). Nutrition may be another important factor of gametogenic development. Gonad development particularly in the higher zone, was sharply influenced by the pattern of food available (Sutherland, 1970). No evidence of effect of photoperiod on gametogenesis in prosobranch molluscs is reported.
In this snail, active gametogenesis is observed during summer. It may be due to high temperature. Thus, it can be said that, because of some environmental factors, _V. bengalensis_ shows different reproductive activity, though it is a continuous breeder.

An endocrine role in the regulation of gametogenic activity has not been demonstrated in prosobranchs, although some specific observations predict that the role of endocrine might be important (Choquet, 1965, Streiff, 1967 a,b).
SUMMARY

A detailed study on the histomorphology of the various reproductive organs, process of gametogenesis and reproductive cycle has been made in the freshwater prosobranch snail, V. bengalensis.

In this snail the sexes are separate, the females possess larger shell compared to males. The right tentacle in males act as a penis. Male reproductive system comprises of testis, vas efferentia, prostate gland, vas deferens and penis which while in female it comprises of ovary, oviduct, receptaculum seminis, albumen gland, pallial oviduct or uterus and the female genital opening.

Both the gonads (testis, as well as ovary) are single and they are intermingled with the digestive gland in the visceral mass.

The study of the process of gametogenesis is very difficult since the animal is throughout breeder. However, some general pattern can be observed.

Though the animal is continuous breeder, breeding activity varies according to season.
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