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Ramakrishna and Tikader

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ROLE OF SPINNING APPARATUS IN NON ORB-WEAVING AND ORB-WEAVING SPIDERS FROM INDIA

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INTRODUCTION

The evolution of food gathering mechanism forms an important aspect in the success and survival of an animal. In nature, interaction between the prey and the predator is quite common, the predator likes to gather the food and the prey likes to escape. Increased predation decreases the prey population and the decreased predation results in the increased prey population, but in nature predator-prey interaction is maintained by its own method, however, with slight variation at regular intervals. Thus the survival of the organism depends upon its adaptability in the environment. In doing so organisms develop certain structural modifications to suit its mode of living. It is an established natural principle that adaptation leads the animal to develop or specialise certain organs due to its constant use and to either lose or degenerate or becoming vestigial due to its non use. Thus natural selection is operating for the survival of an organism, as the environment is highly flexible.

This fact of adaptability by developing various devices for food gathering, predator-prey interaction and modification of certain organs are well represented in spiders. This is achieved by possessing well developed apparatus to spin web which helps not only in catching the prey but also offers protection to their offsprings and often helps in dispersal.

ECOLOGY OF SPIDERS :

Spiders though abundant and widely distributed occupying all ecological niches, prefer an environment for the prey to fall as victim. The habit and habitat mainly depends on the production and utilisation of silk. The secretion of the silk glands harden when exposed to air and in orb weavers a web is built by the precise action of the sensory and motor apparatus. The life of spiders depend upon the silk they produce, as they ensure the catch of insects as food, construction of webs, lining the nest, formation of egg cocoon production of ballooning threads or forming nursery to the spiderlings. The spiders lead lives bristling with difficulties and are always on the horns of dreadful dilemma; no food without webs no webs without food (Peakall 1966).

Of the 35,000 species of spiders so far recorded about 10% construct orb webs. The life of spiders depends on the utilisation of silk or orb

weaving. These spiders (orb weavers) prefer usually herbs, shrubs or occasionally trees, as in the case of *Nephila* sp. Most of the orb weaving spiders build orb webs at dusk and they are either dismantled or the silk is digested before dawn. During the day time, these spiders are present on folded leaves or in the branches away from the web. The precision of the orb weavers with which they spin web is remarkable. Usually, they first lay the drag line, later build the viscid and spiral threads and keep the centre of the hub, either open or closed condition for manoeuvring.

Most of the spiders are nocturnal and mainly live on insects like butterflies, moths, beetles, gryllids, ants, bees, dragonflies etc., but rarely depend upon worms and other animals. After trapping, they bite the victim with fangs of the chelicerae, wrap occasionally with the silk and suck the body fluid as they are unable to digest the food inside their stomach. In most of the cases, vision and legs play an important role in the life of spiders in determining the course of action. Orb weavers not only trap the victims but also make them to struggle to come out of the silk trap. According to Langer (1969), butterflies and moths escape the orb webs, by losing their scales and hence, the incidence of lepidopterans caught in the web are less than the orthopteran and dipteran insects.

Of the 81 families, only 14 families weave orb webs, of which 7 are represented in India viz. Pholicidae, Therididae, Linyphiidae, Araneidae (Argiopidae), Tetragnathidae, Ageliniidae and Hahnidae. Among them, only the family Araneidae and Tetragnathidae are extensively studied for their orb web construction (Tikader 1980).

Among Lycosidae, only *Hippasa* construct funnel like retreat but rest of the spiders are non orb weaving. The webs of *Hippasa* which are usually constructed in open spaces, in large numbers not only protect these spiders but also assist in minimising their water loss. These spiders hide in their retreat waiting for the prey to fall on its web. The spiders of the genus *Lycosa* live on ground, under stones or in the crevices waiting for the prey. Since it does not spin web, it mainly depends on the eye sight and swiftness of the limb for catching the prey. However, *Pardosa* and *Arctosa* abound near humid atmosphere along the bank of ponds, lakes or rivers. Lycosids are unique in carrying their egg cases by attaching them to the spinnerets untill the young ones are ready to hatch and later the spiderip open their egg cases when the spiderlings undergo the first moult inside and take them on their back till they are ready for their activities.

The Gnaphosids like few Lycosids are found under stones or debris of the vegetation. These are usually ground spiders with brown or brownish black colouration. As in other groups, the major food of these spiders consists of various groups of insects and occasionally show cannibalism. These are nocturnal, often chase the prey, inject the poison from the fangs and suck the body fluid. They do not spin web however, build small tubular retreat under stones.

The family Salticidae includes jumping spiders of small or medium size with short body and stout legs having two tarsal claws. These spiders have remarkable eyes in the arrangement of four, two and two, of which the front row is highly enlarged. The tarsus of the leg are provided with brushes of hair and their tips have well developed claw tufts. These are very common in crevices of the house or under barks, spinning a thin or thick silky retreat which acts as a protective space for the adult as well as the young ones. They have both diurnal and nocturnal hunting habit, these spiders often wait for the prey and pounce upon it with great agility whenever they get one. This act is ably assisted by powerful eyes and well developed legs.

The members of the family Thomissidane includes crab like spiders due to their arrangement of legs like those of crabs. These are brightly coloured and more often resembles the sepals and petals. The spiders of this group are comparatively short with a flat body and long legs extending at right angles. Even though they appear small in size, they have powerful venom to kill small insects. In typical crab spiders the legs are of unequal sizes, the first two pair being quite long and robust while the hind pairs are shorter and weaker. The members of the family Thomissidae are often found on tips of flowers and mainly feed on insects which visit the flowers like ants, bees, wasps, butterflies etc. Usually they sit immobile and wait for the prey to visit the flowers for honey.

Various degree of sociality are exhibited by the members of the families : Eresidae, Amaurobidae, Uloboridae, Dictyniidae, Agelinidae. Theridiidae and also by some members of Araneidae. Among these, *Stegodyphus sarasinorum* Karsch (Eresidae) is well studied, among the Indian forms. The members exhibit nocturnal activity regarding feeding, web building dispersal and reproductive behaviour. These spiders are found in abundance during the month of October to March. The web building, feeding and repairing of

the nest are carried out in groups and the number of spiders present varies depending on the size of the nest. The web and nest are more sticky due to the presence of cribellar silk. Among the prey, the orthopterans and odonates predominate than the lepidopterans as their victims in the web.

MORPHOLOGY OF SPIDER :

The body of the spider is divisible into cephalothorax and abdomen connected by a narrow pedicel (figs. 1-3). The cephalothorax forms the composite anterior part of the head and thorax which is covered dorsally by the carapace and ventrally by a sternum with the cephalic region bearing the central nervous system and eight eyes in majority of the cases (arrangement of eyes is of taxonomic importance). On the ventral surface, the sternum is heart shaped and terminates with the labium in front. The mouth parts of spiders consists of i. A pair of endites attached to the coxa of pedipalp above the mouth, on either side of the rostrum with sclerotised and toothed margin, having a few rows of hairs forming the scopula. ii. A median thin triangular plate covering the mouth viz. rostrum. iii. A ventral triangular sclerotised plate, labium and iv. Pharynx formed by a dorsal epipharynx and a ventral hypopharynx.

Six pairs of appendages are present in the cephalothorasic region viz. i. A pair of chelicerae having fang at its apex with denticulate margin at its outer and inner sides. ii. pedipalp made up of six segments viz. coxa, trochanter, femur, patella, tibia, and tarsus. iii. Four pairs of legs are present on either side with seven articulating segments i. e., coxa, trochanter, femur, patella, tibia, metatarsus & tarsus. Legs are clothed with spines, hair and bristles. The tarsus is provided with a pair of large claws and in few cases with an additional median claw which are variously modified (figs. 4, 5, 8).

The abdomen (Opisthosoma) is a sac like structure without any visible external segmentation, covered by sclerotised cuticle with depressions marking the internal attachment of muscles. Usually the abdomen is sac like enclosing most of the organs viz. digestive, circulatory, respiratory, excretory, reproductive, nervous and spinning glands (fig. 11). As mouth parts are not specialised, spiders absorb digested material from the prey, secreting digestive enzymes on it. This is accompanied by the sucking stomach. It has been clearly shown that the silk is swallowed before it is completely digested and this pre digested material enters into the abdomen, where it is finally absorbed in the intestine.

Abdomen, however, retains a few external appendages at its posterior end assisting in the spinning activity. The only abdominal appendage present in the spiders are the spinnerets (fig. 7). These are believed to be derived from the two branched abdominal appendages of the primitive spiders. In few groups, in addition to the usual three pairs of spinnerets, an accessory spinning organ namely cribellum is present and hence, they are cribellate spiders.

The order Araneae is classified into 81 families, of which 43 are represented in India. The characters on which the classification of the Araneae is based are as follows :

i. *The Number of Eyes.* The cephalic region bears eight simple eyes in majority of the cases, but in few members they have only six. A further reduction in the number of eyes is noticed in *Tetrablema*, having only four eyes. A few of the cave dwelling spiders possess degenerated eyes (*Anthrobia* sp.). The eyes are diurnal or nocturnal type and the arrangement of the eyes is in two rows of four each or first row of four followed by two rows of two each. The eyes are either procurved or recurved, depending upon the nature of arrangement (figs. 6, 9). Of the 43 families only 4 families are found to possess six eyes viz. Segestridae, Dysderidae, Oonopidae and Sicariidae and rest of the families have eight eyes.

ii. *Cribellum.* The second character is the presence of absence or a perforated sieve like plate called cribellum, present in front of the spinnerets. This is absent in ecribellate spider families. The cribellar gland produces silk through the pores of the cribellum, producing a broad ribbon of silk having many threads. As many as 8 families among Indian forms viz. Filistatidae, Bresidae, Oecobidae, Dinopidae, Uloboridae, Dictynidae, Amaurobidae and Pseceridae have cribellum and rest of the families are ecribellate spiders.

iii. *Legs and Tarsal Claws.* On the lateral side of the sternum are four pairs of notches into which the coxae of the four pairs of legs fit forming four pairs of appendages, which are usually designated as I, II, III, IV from the front. The legs of Araneae are always eight in number and are with seven segments viz. coxa, trochanter, femur, tibia, metatarsus and tarsus. The tarsus at its extremity possess paired claws and in few cases an additional unpaired claw, below the paired ones are present. Hence, the spiders are classified into three clawed and two clawed hunters. The presence or absence of the third claw and in few cases the occurrence of accessory claws

forms the matter of taxonomic importance. Among Indian forms, eleven families are three clawed hunters.

iv. *Spinnerets*. The number and arrangement of the abdominal appendage viz. spinnerets forms the part of taxonomic importance. Liphistomorphae, a primitive spider, has four pairs of spinnerets occupying the middle of the lower surface. But in rest of the spiders there are only three pairs, an anterior, median and posterior pairs. The length and location of the spinnerets often vary with different groups. In orb weavers, the spinnerets are short and are located more or less on the mid ventral position of the abdomen. In house spiders, which build sheet web the anterior the anterior spinnerets are longest. However, in a closely related family Hahnidae, the spinnerets form a row and not a group at the end. In *Herselia*, the anterior spinnerets are too long and in *Crypothelae* the spinnerets lie in a mammillary hollow, from which they can be withdrawn or extruded. The spiders bearing the spinnerets at the end are recognised as opisthothelae and those bearing on the middle of the ventral surface as mesothelae. The terminal part of each spinneret is provided with spigots and spinning tubes forming the spinning field.

SPINNING GLANDS IN ARTHROPODA

The production of silk is wide spread among animal kingdom but it is particularly associated with the phylum Arthropoda (Lucas and Ruddal 1968). Among them, the lepidopteran insects and arachnids are notable in their silk spinning apparatus. The silk worm, *Bombyx mori*, has been exploited for the production of silk. An outline mechanism on the production of silk in silk worm reveals that they produce silk only once in their life time for the protection of youngones in the form of cocoon and that is the source of commercial silk. The silk is produced by the larvae of the fifth instar by means of the paired labial glands which are the modified salivary glands. In insecta according to Wigglesworth (1965), three main body regions viz. collateral glands, Malpighian tubules and salivary glands produce silk.

The silk of *Bombyx mori* is a type of a protein fibroin synthesised by the anterior region of the gland. This fibroin moves forward to the middle saccular region where the cells synthesise a second protein namely sericin, which accumulates as a seperate layer surrounding the fibroin case. The proteins move forward without mixing into a tapering region. The anterior region empties into a duct lined with cuticle. Just posterior to the spinneret,

the left and right duct join together and the protein at the spinnerets consists of twin cores of fibroin each surrounded by a layer of sericin.

In Pseudoscorpions, the silk glands present in the anterior part of the prosoma and their ducts leading to the chelicerae open at the tip of the movable finger. Pseudoscorpions use silk solely for their own protection, developing eggs or for moulting. They build small nests or retreat for hibernating.

Among Acarina, the spinning activity is possessed by the members of Tetranychidae which live in colonies of trees and plants. In this, the silk is used as a shelter for themselves, eggs and larvae as well as in some cases for dispersal by ballooning. The silk of mites is very fine and single thread is invisible. It is secreted by the prosomatic glands and the ducts open inside the mouth. It is drawn out by the chelicerae to which the pedipalps and stylets assist.

SILK GLANDS IN SPIDERS :

The habit of producing quantities of silk and of spinning this either into a snare for the prey or into a protective cocoon for eggs is one of the most striking peculiarities of spiders in particular and arthropoda in general. The silk glands of spiders form an important object of research as discrete organ having sole production of single protein namely silk. The evolution of spiders to a greater extent depended upon the production and utilisation of silk. It may be mentioned that the silk plays an important role in the life of spider as they are used to ensnare the prey, construction of webs, lining the nest, assisting in the deposition of the seminal fluid into the palpal organs in male or making the egg cocoons to protect the developing young ones. In addition, it helps in the dispersal of the spiders and also act as nursery to the spiderlings.

The silk glands of spiders are located in the opisthosoma and the numerous ducts leading from them open on the surface of the spinnerets by means of spigots and spinning tubes. The number, size and form of the silk glands vary in different groups. Apstein (1889) classified the silk glands into seven major types depending upon the appearance viz. Ampullaceous, Aciniform, Pyriform, Cylindrical, Aggregate, Lobed and Cribellum glands. Though no spider possesses all the seven types but most of the spiders have first four types.

The ampullate or ampullaceous glands are the largest of all the glands and extensively studied. The number varies in different species also at various stages of development. Each ampullate gland has three regions viz. an anterior tubular highly coiled part with a main function of secreting silk. The lumen in this region is very narrow and granules are often found in epithelial cells. The anterior duct enlarges posteriorly into a wide sac forming the ampulla and hence getting the name ampullate or ampullaceous glands. The ampulla is the largest portion storing mainly the silk, in the liquid form. The ampulla leads into a long tubular posterior duct leading to the spigot on the spinneret. The lumen of the duct in this region is very narrow and lined by a layer of thick cuticle. The silk secreted by this gland is used in the formation of dragline of spiders (Fig. 12).

The aciniform glands are present in large numbers in the posterior part of the opisthsoma. These are having a small bulb or acinous ending blindly and appears in the form of a berry and hence getting the name aciniform. The glands are the smallest with a wide lumen. The duct leading from each gland opens on the spinning tubes of the anterior, median and the posterior spinnerets. The secretion of this gland helps for swathing of the prey or wrapping the prey with silk (fig. 14).

The pyriform glands are also found in large numbers, usually occurring in clusters with small anterior projection on the swollen base and appears in the form of a pear and hence the name pyriform. The anterior part of the gland appears in the form of a duct, which varies in different spiders. The posterior duct of all glands are small and opens on the anterior, median and posterior spinnerets. Histologically also, the gland is differentiated into an anterior and posterior region, depending upon the intensity of staining with eosin. As the silk contains more polysaccharides, which appears in the form of a glue, is utilised in the formation of attachment discs and pseudoattachment discs (fig. 13).

The cylindrical glands or tubular glands are tubular in outline having uniform diameter throughout and are often found in small numbers. The morphology of the gland is more clear before the deposition of the eggs by the female and diminishes in size after the cocoon formation. Hence, these are associated with the silk production of the egg cocoon. The posterior duct of these glands open out by means of the spinning tubes on the middle and posterior spinnerets. Histologically, the epithelial layer resembles to the

epithelium of the ampullate gland. These glands are reported only in the female and are absent in male spiders (fig. 16).

The aggregate glands are highly irregular and tree like situated superficially over the ampullate gland. These are highly delicate, transparent and occur in pairs. The duct of this gland is having a very thick cuticle lining the lumen, opens on the posterior spinnerets. These glands are reported only from the family Araneidae and Linyphiidae. The secretions of this gland helps in the formation of the radial and spiral threads of the orb web (fig. 15).

The lobed glands are found only in the family Theridiidae (Savory 1929). These are irregular in shape, highly lobulated and the ducts of this gland opens on the posterior spinnerets. The swathing band of silk is produced by these glands.

The cribellum glands are the smallest of all the glands known in the spiders and occur in large numbers in the members of cribellate spiders. These glands are associated with the cribellum, a sieve like plate present in front of the spinnerets. The epithelium of the glands are small and the secretory product is continuously liberated in to the lumen of the gland. These glands are well developed in female and are atrophied in male. The secretion of this gland is highly sticky and is used in the formation of the hackled band.

REVIEW OF LITERATURE

The natural history of spiders and other related groups may be traced back to the beginning of nineteenth century. It was Lamarck (1815), who distinguished scorpions, spiders and some other Apterans from the Linnean's *Insecta*, based on the natural relationships and diversities. Since then, most of the work which appeared in the literature related to spiders are mainly concerned with taxonomic descriptions and interpretations. Virtually a little work has been done on various biological aspects such as morphology, anatomy, histology, breeding biology, ecology etc. If at all any attempts are made in this direction, they are fragmentary and meagre.

The earliest description of the spinning glands of spiders came from the work of Wasmann (1846), Menge (1866), Meckel (1846), Oefinger (1866) and Brandt and Ratzeburg (1888). It was Apstein (1889), who summarised 22 species belonging to various groups of spiders and classified the silk glands

into seven major types viz. Glandulae ampullaceous, Glandulae aciniformes, Glandulae pyriformes, Glandulae tubiliformes, Glandulae aggregatae, Lobed glands and Cribellum glands. Further investigations on various aspects of spinning glands are carried out by Warburton (1909), Barrows (1915), Millot (1926, 1929, 1930, 1936 and 1949). A new spinning gland in the geometric spider *Araneus ventriculosus* and *Nephila clavata* was described by Sekiguchi (1952, 1955 and 1955a).

Wilson (1962, 1969) worked on *Araneus diadematus* and described a special valve in the duct of ampullate gland and this valve was found to control the output of the drag line. Among the more comprehensive recent studies on various aspects of spinning glands were from Peakall (1964, 1965, 1966 and 1968), Didier (1965), Mullen (1969), Reichter (1970), Foelix (1971), Kovoov and Zylberberg (1972), Lopez (1973), Work (1977).

From the perusal of the literature, our knowledge regarding the investigation carried out on the spinning glands of the Indian spiders is very fragmentary and meagre. The only study pertaining to the spinning apparatus came from the work of Bradoo and Majupuria (1973) and Jackson (1975) on the social spider *Stegodyphus sarasinorum* Karsch (Eresidae) and from the non orb weaving spider viz. *Heteropoda venatoria* Linn, and *Herselia savignyii* Lucas by Mukerji (1972).

The literature available on the morphology of the external spinning apparatus like tarsal claws and spinnerets is very scanty. The description of the tarsal claws is mainly from Nielson (1932), Bluementhol (1935), Kaston (1935), Parray (1959), Walcot (1959), Foelix (1970), and Foelix and Chu Wang (1973). The number and arrangement of spinnerets is mainly from Apstein (1889), Peters (1955), Mikulska (1966 and 1967), Marples (1967), and Wasowska (1967).

The webs are the product of the synchronised act of various silk glands and external spinning structures and hence, the mechanism of web building and web building behaviour were extensively studied by Savory (1928), Comstock (1940), Millot (1949), Phanael (1961), Szleep (1961), Witt (1960, 1962, 1963, and 1968), Witt and Reed (1965), Witt and Tittel (1964), Levi (1978), Eberhard (1978 and 1980), Jackson (1980) and Tikader (1982).

Though the spiders had drawn attention of naturalists as early as the beginning of the nineteenth century, contribution to the knowledge of various aspects of morphology, anatomy, histology, breeding biology, ecology etc. are

incomplete and fragmentary. Most of the earlier workers confined their attention to the taxonomic description only. The present study was undertaken, in view of the above mentioned lacunae in respect of the natural history of spiders and more over a very few forms have been anatomically and histologically examined and also realising the fact that more information is needed for an understanding of the taxonomic relationship and its evolutionary trends operating in this little known group. In addition, the present study in spiders will also help us to understand the role played by the spinning apparatus in habit-habitat selection, predator-prey interaction, behavioural and breeding habit.

MATERIAL AND METHODS :

Spider specimens of *Lycosa nigrotibialis* Simon, *Hippasa pisaurina* Pocock, *Stegodyphus sarasinorum* Karsch, *Neoscona mukerjei* Tikader and *Plexippus paykullii* (Aud.), formed the material for the present investigation. These spiders are collected from the various environs of Pune, Maharashtra, India. Fully developed adult specimens were selected for the study, the male specimens were identified by the development of the palps and the female by the development of the epigyne. As the number of instars were difficult to ascertain in the field, spiderlings were reared in the laboratory to determine the number of instars and the period of growth. In the laboratory, spider specimens were maintained in substantially big glass containers covered with muslin cloth and were fed on fruit flies (*Drosophila* Sp.).

Studies on the morphology of the spinning glands and the ducts were carried out after narcotising the spider specimens in chloroform or ether and dissecting the same in physiological saline as described by Weesner (1965). As the spinning glands are highly delicate, transparant and are associated with haepato-pancreatic mass. immediately after the removal of the epicuticle from the abdomen, spiders were submerged in ten percent formalin and absolute alcohol (Ratio 3 : 1) for a brief period of 2-3 minutes and slightly blowing the air over the haepatopancreatic mass, alcoholic eosin is spilled over it. After 2-3 minutes, excess alcoholic eosin is washed with 70% alcohol. This was found to be advantageous for detecting the glands and also to follow the course of posterior duct leading to the spigot.

Temporary mounts of spigots, spinning tubes on the spinnerets and tarsal claws were prepared in glycerine after adding a few drops of carbolic

acid to enhance the refractive index of the material. Permanant preparations of the external spinning apparatus were made after treating the material with 10% Sodium hydroxide solution (Wasowska 1966). Morphometric measurements were taken with the help of micrometer scale using camera lucida on Carl-Zeiss Technival binocular microscope.

Histological details on various silk glands were studied after fixing the material in varios fixatives. Modified Carnoy's fluid employed was found to be more suitable than the simple Carnoy's fluid as normally the latter causes the shrinkage of the material. The fixatives were prepared as follows :

Absolute alcohol	...	...	60 ml
Formalin (40% Formaldehyde)	...	...	40 ml
Acetic acid			6 ml

The period of fixation was carried out by practice and it was found that the following period was ideal for complete fixation of the material.

Name of the fixative	Period of fixation	Post fixation change
10% Neutral formalin	18-24 hours	Wash in running water over night.
Alcoholic Bouin's fluid	12-18 hours	70% alcohol for 24-36 hours (3-4 changes of 6 hours duration or till the colour of Bouin's fluid stop comming out from the tissue).
Alcohol-Formalin-Acetic acid	10-12 hours or overnight	70% alcohol for 12-18 hours with 3 changes
Susas fixative	24-48 hours	Running water overnight.

Histological studies were carried out by taking serial sections after infiltration and embedding in paraffin wax. Histochemical analysis of the spinning glands regarding proteins, carbohydrates and bound lipids were investigated. For the usual procees of fixation, dehydration, paraffin embedding and histochemical analysis, the method adapted by Pearse (1953), Weesner (1962) and Bancroft (1975) were followed.

MORPHOLOGY OF SPINNING GLANDS

AMPULLATE GLANDS (*GLANDULAE AMPULLACEAE*)

The ampullate glands of *Lycosa* are the largest of all the glands present and are easily divisible into three parts, an anterior long, coiled tubular secretory duct, a median swollen saccular ampulla and a posterior long tubular duct of more or less uniform diameter, opening through the spigot on the spinneret.

The anterior secretory duct of *Lycosa* is long coiled ending blindly in the hepatopancreatic mass. It is more or less straight during the early stages of development and develops loops or coils, thereby increasing the length for the growing need of silk production in this part. The length of the tube justifies the functional significance of the secretory activity of the spider. When stretched, the length in the fully developed female spider varies from 2.5—3.1 mm. A slight difference in the size of the tubule is observed in male and female (fig. 19-23).

The ampulla stores the secretory product in the form of liquid. The shape of the ampulla varies in *Lycosa*, it is swollen at the base and slightly tapers towards the anterior end. The wall of the ampulla is comparatively thin and the lumen is sufficiently large to store the secretion. The colour of the ampulla is slightly different from that of the anterior secretory duct by being yellowish. The ampulla shows slight variation in the size at various stages of development viz. it attains maximum size at the last moulting stage, just before the onset of ovarian development, but regresses at the time of egg laying. Further, a complete reduction in the size of the ampulla is observed after continuous starvation.

The posterior duct arising from the ampulla is not coiled but forms loops, thereby increasing the length to the maximum. The diameter of the duct is found to be uniform throughout. It enters into the spinneret which in turn opens out by means of spigot. The increase in the length of the posterior duct is probably due to the absorption of water from the liquid silk and to undergo transformation or polymerisation and orientation of the silk as suggested by Kovoov and Zylberberg (1972).

In *Lycosa*, ampullate gland consists of three pairs situated in the posterior part of the abdomen (fig. 19). The number of glands varies during the developmental stages. Soon after they hatch and in the third instar,

three pairs of ampullate glands are clearly visible, however, during the later stages of development from fourth instar onwards posterior pair of the ampullate glands regresses, with the result the adult male and female spider possess only two pairs of functional ampullate glands. The third pair of the posterior ampullate gland is represented in the form of a vestigial tubular part attached to the duct of the median ampullate gland. Hence the posterior ampullate gland is devoid of anterior secretory duct with only a small tubular ampulla ending blindly but the posterior duct runs along the duct of the median ampullate gland.

Of the three pairs in *Lycosa nigrotibialis*, two pairs are well developed and are present in the middle of the opisthosoma. The anterior pair of the gland is the largest, most voluminous and easily distinguishable during dissection. The anterior secretory duct runs upto the book lungs and takes a ventral turn, runs posteriorly and are embedded in the haepato pancreatic mass. The posterior duct takes several 'U' turns throughout its length ultimately opening into the anterior spinneret. The entire glands measures 10.0—12.0 mm fully stretched, of which the anterior and posterior duct occupies 6.8—7.0 mm. The ampulla has the diameter of 0.8—1.2 mm at its widest part. However, the volume of the ampulla depends upon the storage of the secretory product (fig. 17).

The median ampullate gland resembles more or less that of the anterior ampullate gland except that it is smaller in size and volume (fig. 18). The ampulla tapers towards the anterior end. The colour of the ampulla as in the previous one is yellow. In matured female ampullate gland measures 8.0—10.0 mm of which 6.5—7.0 mm is occupied by the anterior and posterior duct. The diameter of the ampulla is 0.6—0.9 mm at its widest part. The posterior duct after forming 'U' turns open on the spigot of the median spinneret.

Hippasa though belongs to the same family of Lycosidae is a web weaver but does not differ much in morphology and number of spinning glands as that of *Lycosa*. Here the secretion of the gland is utilised in the construction of a snare in the form of a funnel web, which is lacking in *Lycosa*. The ampullate glands are situated on the dorsal part of the opisthosoma, embedded in the haepato pancreatic mass (fig- 26). In mature female two pairs of well developed ampullate glands are present and the third pair is represented in the form of a vestige attached to the median ampullate gland as in *Lycosa*.

Of the two functional pair in the adult, the anterior one is the largest superficially located in the opisthosoma (fig. 24). The median pair is slightly smaller in size but runs along with the anterior ampullate gland (fig. 25). The anterior secretory duct is coiled taking the turn in the region of the book lungs running posteriorly and ends in the region of the pyriform glands. The secretory tube is much coiled and the lumen appears to be very narrow. The ampulla is more elongated with a few undulations on its ventral side, tapering towards the anterior and posterior side. The anterior pair measures 10.5—12.0 mm while the median pair is 8.0—11.0 mm. The ampulla in the anterior pairs 1.5—2.0 mm where as in the median pair it is 1.2—1.5 mm in length. The posterior duct is the largest in its length and measures 4.0—4.2 mm in anterior ampullate gland and 4.0—4.2 mm in the median ampullate gland.

Morphology of the gland remaining same, the size of the gland varies in mature male spiders. Two pairs of ampullate glands are clearly visible in mature males but the third pair which is present in the form of a vestige in the female is absent in male. Hence, only two pairs of functional ampullate glands are present in the adult stages. It is not clear whether it is totally absent or fails to develop after they hatch from the egg cocoon. In adult stages the anterior ampullate gland is the largest and measures 8.0—8.5 mm while the median pair measures 6.0—7.5 mm. The posterior pair is completely absent in adult stages. Compared with the ampulla of mature females, males possess elongated ampulla measuring 1.4—1.8 mm in the anterior pair and 1.3—1.5 mm in the posterior pair. The posterior duct of the anterior ampullate gland opens on the spigot of the anterior spinneret while the duct from the median ampullate gland opens on the middle spinneret.

The ampullate glands in *Stegodyphus sarasinorum* are well developed occupying most of the abdominal cavity and are grouped into three different types based on their sizes viz., large, medium and small ampullate glands. In addition to the variation in size, the colour of the glands also differ from white to yellow and dark red. As in other species of spiders described earlier, ampullate glands are divisible anterior secretory duct, a middle ampulla and a posterior duct leading to the spigot.

Two pairs of large ampullate glands are present in the anterior region, embedded in the hepatopancreatic mass one pair on each side, of which one pair is red and the other pair is yellow. The two pairs are closely

arranged and the anterior duct of these two pairs extends upto the base of the book lungs. Of the two pairs, yellow ampullate glands are more superficial than the red one. The anterior secretory duct in both the cases is white in appearance, ends blindly and the tube is highly coiled. The coiling of the anterior secretory duct is more intense and when stretched it reaches a length of 3.2—3.6 mm in adult females and 2.6—2.8 mm in adult males. The anterior duct after its origin from the ampulla runs forwards upto the region of the book lungs and takes a ventral turn, runs posteriorly along with the ampulla. Due to the presence of a large number of ampullate glands, the ampulla is more superficial in its location as compared to *Lycosa* and *Hippasa*. The ampulla is broad at its base and tapers anteriorly. The total length in mature female is 8.0—10.0 mm and the same in the mature male is 6.5—8.0 mm. The posterior duct measures 3.5—4.0 mm and the ampulla has a diameter of 0.5—1.0 mm. The posterior duct in male is slightly smaller.

The second pair of yellow ampullate gland is almost equal in size with slight variation. The ampulla is more superficial in its location. The posterior duct of the yellow ampullate gland is longer than that of the red ampullate gland. The yellow ampullate gland opens on the spigot of the median spinneret while the red ampullate gland opens on the spigot of the anterior spinneret (fig. 27).

The median ampullate glands are also similar in their morphology, like that of large ampullate glands except for their size. The anterior secretory duct and the posterior duct is white, while, the ampulla is either red or yellow in colour. Two pairs of median ampullate glands which consists of one pair of red and one pair of yellow ampullate glands and are bilaterally arranged. The anterior secretory duct of median ampullate gland do not show much coiling but are wavy in outline. Externally, the lumen appears narrow. The anterior duct after its origin runs posteriorly very close to the ampulla. The ampulla is more elongated at either ends. The posterior duct leading from the red ampullate gland opens on the anterior spinneret while the duct from the yellow ampullate gland opens on the median spinneret. The total length of the median ampullate gland in mature females is 5.5—6.0 mm and 5.0—5.6 mm in male, of which the anterior secretory duct measures 2.0—2.5 mm, showing no significant difference in both sexes. The ampulla at its widest part measures 0.3—0.5 mm. (fig. 29,30),

Small ampullate glands occur in large number and usually located on either side of the pyriform gland in the form of clusters. In mature female spiders, four pairs of yellow and eight pairs of red ampullate glands are noticed. Of the eight pairs of red ones, four pairs are closely packed on the extreme end of the opisthosoma, in the region of the spinneret. The anterior secretory duct is very small and the coils are closely packed in front of the ampulla. The ampulla is narrow in front and wide at the base. The duct leading from this gland opens on the spigot of the anterior, median and posterior spinneret. The length of the small ampullate gland is 1.5—2.8 mm in mature female and 1.0—1.2 mm in mature male. Further, the number of small ampullate gland is variable viz. in mature males only four pairs of yellow and four pairs of red ampullate glands are present.

Compared with other species, the spinning glands of *Neoscona mukerjei* are well developed as they are more voluminous and clearly distinguishable. *Neoscona* possesses three pairs of well developed ampullate glands which appear as thin transparent whitish organ, of which the anterior pair is the largest and the posterior pair is the smallest. Of the three pairs, anterior and median pair is directed forwards while the posterior pair is directed backwards. The ampullate glands are more ventral in their location and are present below the aggregate glands (fig. 33).

The anterior ampullate gland (fig. 34), is the largest of the three, lies in the middle of the opisthosoma, whose ampulla is prominently visible. The anterior secretory duct after its origin runs upto the book lungs and runs posteriorly on the ventro-lateral side as a whitish thin coiled tube, whose lumen appears to be very narrow. The coils are more pronounced as the spider attains maturity. The ampulla which is more voluminous has a wide base and a tapering anterior end. The outer surface appears smooth whereas the inner surface shows slight constriction dividing the ampulla into an anterior tapering part and a posterior wide sac. The wall of the ampulla appears thin enclosing a lumen containing the silk in the liquid form. The posterior duct arises from the base of the ampulla. In this region, the ampulla is slightly enlarged and forms the bulb with a thick covering. This region is described as "receptor" by Peakall (1966) and is present only in orb weavers. This region forms the most important part of the ampullate gland as it is believed to control the synthesis of silk by relaying the message for the secretion of the silk, when the spider runs short of or exhausts its silk.

The anterior ampullate gland measures 10.5—12.0 mm of which the anterior secretory duct measures 5.0—6.5 mm. The diameter of the anterior duct at the region of its origin is 0.45 mm but gradually tapers to 0.30 mm at its extreme anterior end and ends blindly. The ampulla at its widest part measures 1.0—1.2 mm. The posterior duct of the anterior ampullate gland after arising from the base of the ampulla runs into the spinneret after forming several loops, opens on the spigot of the anterior spinneret. (fig. 34).

The median ampullate gland is similar in structure and is located ventrally to the anterior ampullate gland. The gland is directed anteriorly and the anterior secretory duct is much coiled, whitish in appearance having a central small lumen. The ampulla of the median ampullate gland tapers anteriorly as well as posteriorly. At the junction of the ampulla and the posterior duct, this part gets enlarged in the form of a bulb like that of a anterior ampullate gland forming the "receptor" area. The posterior duct is comparatively longer and forms several loops before opening on the spigot of the median spinneret. The median ampullate gland measures 8.5—10.0 mm and the anterior duct occupies 4.0—5.5 mm. The ampulla which is widest at the centre measures 0.9—1.2 mm like that of anterior ampullate gland.

The posterior ampullate gland (fig. 36) present at the hind end of the opisthosoma with its anterior secretory duct directed posteriorly. The coiling of the anterior secretory duct is more pronounced and the ampulla is small but stout, morphologically similar to that of other two glands, except for its size. The total length of the gland is 6.1—7.3 mm and the anterior duct measures 2.3—2.8 mm. The posterior duct at the region of its origin from the ampulla shows slight dilation similar to that of anterior ampullate gland, confirming the area of receptor.

In *Plexippus paykullii*, the ampullate gland comprises three well developed pairs of glands in both the sexes, however, a marked difference in the size of the gland is observed in adult stages of both male and female spiders (fig. 37). Unlike others, the ampullate glands in *Plexippus* are anastomosed with large number of tracheae ending on the surface of the gland. The tracheae help in gaseous exchange of the spinning gland directly, as the spider trail behind a drag line in their movement, necessitating the production of silk continuously in the gland, which probably may require more energy supplied in the form of oxygen, directly from outside.

All the three pairs of ampullate glands are directed anteriorly (fig. 37). the anterior pair being the largest and the posterior pair is the smallest. The glands arranged bilaterally with the posterior gland lying in the centre and the anterior gland on the lateral side. The ampullate glands show a wide variation in their size and morphology in different sexes. In female, the anterior secretory duct is slightly coiled while the anterior duct of the male is wavy in appearance. The ampulla in female is very well enlarged and shows two constrictions and thus divides the ampulla into three regions. In a few cases, as one of the constriction is very deep, and divides the ampullae into two distinct regions. In male the ampullae appear to be smooth and are without any undulations or constrictions.

The anastomosis of the trachea in the anterior secretory duct and the ampulla is well pronounced in female as compared to male. As a result of this anastomosis, the lumen of the duct and the ampulla is not clearly visible. The anterior duct is shorter in male and occupies only a small portion and ends blindly. The total length of the duct is less than that of the ampulla. In female, the anterior duct is coiled and occupies relatively more space of the body cavity. The anterior ampullate gland in female measures 5.0—6.5 mm and the ampulla at its widest part measures 0.9—1.1 mm. In matured male the gland measures 3.0—4.5 mm and the ampulla measuring 0.4—0.65 mm. The median ampullate gland in mature female measures 4.0—4.5 mm. The posterior ampullate gland is the smallest measuring 2.5—3.2 mm.

Compared with the posterior duct of the ampullate gland of different spider species, *Plexippus* shows no differentiation in the form of coiled tube or 'U' turns but it enters into the spigot on the spinneret after forming a 'S' shaped curvature.

ACINIFORM GLANDS :

The aciniform glands are present in all the spiders with a main function of producing silk for the capture of the prey. These glands are usually white, having a swollen base in the form of a bulb or acinus and hence the name.

In *Lycosa*, aciniform glands occur in the form of clusters of white granular mass at the posterior end of the opisthosoma below the digestive tube. These are small in size and more or less spherical in outline. In a few cases, a small knob like structure is observed. The posterior duct is small,

narrow and opens on the median and posterior spinnerets. The number of such glands usually varies with the age and in fully developed females there are 80 ± 6 glands. These glands are having a diameter of 0.3–0.4 mm and the size of the gland in male spiders is still smaller than that of the female.

In *Hippasa*, aciniform glands are present in the form of cluster with a small base and an anterior tail like prolongation of small size. The posterior ducts arising from each gland also form the cluster and open on the spinning tubes of the median and posterior spinnerets. Compared with *Lycosa*, aciniform glands are less in number, in matured female it is 56 ± 5 and in male it is 32 ± 4 . However, in few instances the number of such glands observed is numerous.

In *Stegodyphus*, the aciniform glands occur in the form of clusters of two groups, at the base of the spinnerets. These are spherical in outline and the duct leading from glands open on the spinning tubes of median and posterior spinnerets. The anterior prolongation found in other spiders is absent in *Stegodyphus*. Each cluster has 46–62 glands and each gland measures 0.3–0.4 mm in diameter in female spiders. In adult males, aciniform glands are very prominent and are enlarged in the last moult.

In *Neoscona*, the aciniform glands, which are the main source of swathing silk, occur in the form of several clusters, at the posterior end of the opisthosoma in the region of the spinnerets. Each cluster possesses 18–22 such glands and the number of such clusters varies from 4–5. As the glands are located very close to the spinnerets, the posterior ducts arising from the gland are very short and these ducts open on the spinning tubes of median and posterior spinnerets. In each cluster the glands can be differentiated into a spherical type with a swollen acinous and the spherical type with an anterior prolongation on the acinous, which however, are comparatively larger in size. The diameter of the former type vary from 0.25–0.45 mm.

In *Plexippus*, the aciniform glands are few in number but larger in size. These are comparatively spherical and occur in two clusters. Each cluster has eighteen glands in female and twelve glands in male. As these glands are located in the region of the last abdominal ganglion below the ampulla, the posterior ducts of these glands are comparatively longer than that of other species of spiders under investigation. The diameter of the gland is 0.45–0.5mm.

PYRIFORM GLANDS :

These glands are also small, connecting the anterior, median and posterior spinnerets and secrete the material for the attachment disc with which the drag line is fastened to the substrates. Externally, pyriform glands has a swollen basal region with a small or long prolongation. These glands are found in all species of spiders under investigation. Since, the swollen basal region appears in the form of a 'pear' and hence gets the name pyriform glands.

In *Lycosa*, the pyriform glands occur in the form of two clusters of whitish mass on the lateral surface of the body cavity below the digestive duct. These are more or less pear shaped with an anterior small duct. In a few cases the anterior prolongation is quite substantial, as they form a small tube of wavy outline, which very easily can be mistaken for a small ampullate gland. It readily reacts with eosin and two regions can be differentiated, based on this reaction into an anterior yellow tubular region and a basal pink region. The posterior ducts of these glands are short and open on the anterior, median and posterior spinneret. The total number of pyriform glands is 150-160 and each cluster in adult female contains 60-82 glands. The total length of the gland is 0.9—1.2mm. However, in male spiders the anterior prolongation is smaller and the total length is 0.6-0.8 mm, while the total number of glands is 110-126.

In *Hippasa* the pyriform glands are found in small number and are ovoid with short spinning ducts. In mature females the glands possess a small anterior prolongation on the swollen basal part. The differentiation of an anterior part having less affinity for eosin and posterior part which is highly eosinophilic is clearly visible. The total number of glands in *Hippasa* is 65-73 in matured females vs 43-48 in adult males.

It has been observed that the number of glands, which are comparatively less during the fourth instar, increases in the last moult viz. seventh instar of male and eighth instar of female. The increase in the number of glands from sixth to seventh instar in male is 6 ± 1 and in females it is as many as 18 ± 3 from the seventh to eighth instar. Further, the size of the gland remains more or less same unlike ampullate glands, when the spider lays eggs. The size of the gland is 0.25-0.3mm.

In *Stegodyphus*, pyriform glands are present on either side in the form of cluster and each cluster has 98-112 glands in matured female, opening on

the spinning tubes of anterior, median and posterior spinnerets. These appear as whitish mass and each gland has swollen base and an anterior short tail. The number and size of the glands are comparatively small and often found in regressed condition in adult males. The total length of the gland is 0.65-1.1 mm in female and 0.4-0.6 mm in males. In females also the pyriform glands reduce in size when the spider lays eggs into the cocoon.

In *Neoscona*, pyriform glands are found in large numbers and are present in the form of four clusters. The glands are having a swollen base with an anterior short tail. The posterior ducts are small in size and open on the anterior, median and posterior spinnerets. The eosinophilic affinity is well marked in the anterior and posterior regions. The number of glands in each cluster varies from 65-86. The number seems to vary at various stages of development, as it is found to possess a few numbers in the beginning but increases as spiders attain maturity.

In *Plexippus*, the number of pyriform glands are limited and also exhibit sexual dimorphism in respect of the total number of glands. These are slightly oval in outline without any anterior tail like region. Unlike others, the duct of these glands open by the spinning tubes of posterior and median spinnerets. There are 12 ± 2 vs 9 ± 2 glands in mature female and male respectively.

CYLINDRICAL (TUBULAR) GLANDS :

These are tubular or cylindrical in outline, found usually in small number and have uniform diameter throughout. These are present only in mature females but regress in size immediately after cocoon formation, indicating that the silk from these glands is utilised for the formation of cocoon. These glands have been observed in all female spiders under investigation, but are lacking in male.

The tubular glands of *Lycosa* are present along with the pyriform gland in the middle of the body cavity. The glands have uniform glandular portion without any distinction into anterior secretory part and a posterior saccular part for storage. These are well developed in female, the size increases with maturity and attains maximum length before cocoon formation. The posterior duct of this gland is very thin and opens on the spinning tubes of median and posterior spinnerets. The glands have good affinity for eosin

similar to pyriform glands. The total length of the glandular portion, just before the cocoon formation is 1.5-2.1 mm. The size reduces after eggs are laid. The total number of glands is eighteen, nine on each side.

In *Hippasa*, the cylindrical glands occupy a major part of the body cavity along with the ampullate gland in matured female. The glands are having uniform diameter throughout and are wavy in outline. Often it can be easily mistaken for a new type of gland. These are slightly yellowish in appearance as compared to white ducts of the ampullate glands. The posterior duct is thin, long and opens directly on the spinning tubes of the median and posterior spinnerets without forming any loops or 'U' turns. The length of each gland varies from 1.8-2.4mm in matured female and the diameter of the gland is 0.2-0.3mm. Twelve such glands are noticed in the female and are bilaterally arranged.

In *Stegodyphus*, the cylindrical glands are comparatively more in number, as they have fifteen pairs. These are brown or brownish red with a cylindrical appearance. The anterior region is slightly narrow than the posterior region. In mature females, the length varies from 2.0-2.2 mm and decreases immediately after cocoon formation, as in other cases.

In *Neoscona*, there are six cylindrical glands arranged in three pairs on either side, of which the first pair opens on the median spinneret and rest of two pairs open on the posterior spinnerets. These appear as slightly coiled cylinders of uniform diameter throughout their length. The gland extends anteriorly along with the ampullate gland. The length of each gland in fully developed female is 1.5-2.3 mm. The glands appear slightly greenish yellow in colour and react intensely with eosin.

The cylindrical glands in *Plexippus* occur in three pairs and appear as white, tubular part on the posterior side of the body cavity. The total length of each gland in fully developed female measures 0.8-1.2 mm which perhaps is the smallest of all the species of spiders under investigation.

CRIBELLUM GLANDS :

The cribellum glands are present only in the cribellate spider i.e. *Stegodyphus* and absent in rest of the species investigated. Here, the glands appear as two whitish mass, at the region of the spinnerets. Due to the microscopic size of the glands and also as they occur in large numbers,

the morphology of the glands is not clear. This whitish mass is well developed in female but in male it is reduced in size. These glands are in close association with the sieve plate namely cribellum. The secretion of this gland is directly ejected on the surface of the cribellum and this secretion is combed out in the form of hackled band by calamistrum. The silk produced in this glands is very sticky.

AGGREGATE GLANDS :

Aggregate glands or the 'Tree shaped' glands is the characteristic feature of the family of orb weavers. During the present investigation they are found only in *Neoscona* and are absent in rest of the specimens examined. These are irregularly lobulated structure found superficially in the body cavity in close association with the hepato-pancreatic mass and the ampullate glands. Aggregate glands are present in three pairs, the first pair being the largest ; present in the antero-lateral side of the body cavity, while the median and posterior pairs are of equal size present in the postero lateral side. These are very transparent membranous, delicate, slimy and without any distinction into ampulla or the anterior secretory duct. The lobules in each gland are many, small and appear as irregularly folded region. Due to its transparent and membranous nature, they can not be distinguished apparently.

From the base of each aggregate gland, a posterior duct arises, which runs in the form of a wavy tube and opens in the spinning duct of the posterior spinneret. The duct of the anterior aggregate gland is the longest while the median and posterior aggregate gland are having ducts of uniform length. This duct is not smooth but shows several 'nodules' along the length. The size and number of such nodules vary in different ducts. These nodules are more crowded at the region of the duct joining the gland and these nodules are believed to be the precursors of the lobes to be formed in the aggregate gland.

Table showing the number of spinning glands in various Spiders (Females only)

Spider	Ampullate glands	Aciniform glands	Pyriform glands	Cylindrical glands	Aggregate glands	Cribellum glands
<i>Lycosa nigrotibialis</i> Simon	2 pairs in adult only	73-89	150-162	18	Absent	Absent
<i>Hippasa pisaurina</i> Pocock	2 pairs in adult only	50-63	65-73	12	Absent	Absent
<i>Stegodyphus sarasinorum</i> Karsch						
Large red ampullate gland	1 pair					
Large yellow ampullate gland	1 pair					
Medium red ampullate gland	1 pair	46-62 in 2 clusters	98-112	30	Absent	Numerous
Medium yellow ampullate gland	1 pair					
Small red ampullate gland	8 pairs					
Small yellow ampullate gland	4 pairs					
<i>Neoscona mukerjei</i> Tikader	3 pairs	4-5 Clusters 18-22 in each Cluster	4 clusters 65-86 in each cluster	6	3 Pairs	Absent
<i>Plexippus paykullii</i> (Aud.)	3 pairs	18	10-14	6	Absent	Absent

Table showing the number of spinning glands in various spiders (Males only)

Spider	Ampullate glands	Aciniform glands	Pyriform glands	Cylindrical glands	Aggregate glands	Cribellum glands
<i>Lycosa nigrotibialis</i> Simon	2 pairs in adult only	62-78	110-126	Absent	Absent	Absent
<i>Hippasa pisaurina</i> Pocock	2 pairs in adult only	28-35	43-48	Absent	Absent	Absent
<i>Stegodyphus sarasinorum</i> Karsch						
Large red ampullate gland	1 pair					
Large Yellow ampullate gland	1 pair					
Medium red ampullate gland	1 pair	38-47 in 2 clusters	48-62	Absent	Absent	Numerous
Medium yellow ampullate gland	1 pair					
Small red ampullate gland	4 pairs					
Small yellow ampullate glands	4 pairs					
<i>Neoscona mokerjei</i> Tikader	3 pairs	4 clusters 16-19 in each cluster	4 cluster 36-42 in each cluster	Absent	3 pairs reduced in adult	Absent
<i>Plexippus paykullii</i> (Aud.)	3 pairs	12	6-11	Absent	Absent	Absent

**Comparative account of the functional morphology of various spinning glands in
Lycosa nigrotibialis Simon. [Female]**

Name of the gland	Number	Size	Spinneret	Spigot/Spinning tube	Function
Anterior ampullate gland	1 pair	10.0-12.0 mm	Anterior	Spigot type-I	Dragline spinning
Median ampullate gland	1 pair	8.0-10.0 mm	Median	Spigot type-I	Dragline spinning
Posterior ampullate gland	1 pair	Reduced in adult	Anterior	Spigot type-II	Not known
Aciniform glands	73-89	0.3-0.4 mm	Anterior, Median & Posterior	Spinning tube type-I	Swathing of prey
Pyriform glands	150-162	0.9-1.2 mm	Anterior, Median & Posterior	Spinning tube type-II	Formation of attachment disc
Cylindrical glands	18	1.5-2.1 mm	Median & Posterior	Not known	Formation of egg cocoon

Comparative account of the functional morphology of various spinning glands in
Lycosa nigrotibialis Simon. (Male)

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Name of the gland	Number	Size	Spinneret	Spigot/Spinning tube	Function
Anterior ampullate gland	1 pair	8.0-11.0 mm	Anterior	Spigot type-I	Dragline spinning
Median ampullate gland	1 pair	7.0-9.5 mm	Median	Spigot type-I	Dragline spinning
Posterior ampullate gland	1 pair	Reduced in adult	Anterior	Spigot type-II	Not known
Aciniform glands	62-78	0.3-0.4 mm	Anterior, Median & Posterior	Spinning tube type-I	Swathing of the prey
Pyriform glands	110-126	0.6-0.8 mm	Anterior, Median & Posterior	Spinning tube type-II	Formation of attach- ment disc+assisting in the deposition of seminal fluid.

Comparative account of the functional morphology of various spinning glands in
Hippasa pisaurina Pocock. (Female)

Name of the gland	Number	Size	Spinneret	Spigot/Spinning tubes	Function
Anterior ampullate gland	1 pair	10.5-12.0 mm	Anterior	Spigot type-I	Dragline spinning
Median ampullate gland	1 pair	8.0-11.0 mm	Median	Spigot type-I	Dragline spinning
Posterior ampullate gland	1 pair	Vestigial	Anterior	Spigot type-III	Not known
Aciniform glands	50-63	0.35-0.4 mm	Anterior, Median & Posterior	Spinning tube type-I	Swathing of prey
Pyriform glands	65-73	0.6-0.8 mm	Anterior, Median & Posterior	Spinning tube type-II	Formation of attachment disc
Cylindrical glands	12	1.8-2.4 mm	Median & Posterior	Not known	Formation of egg cocoon

Comparative account of the functional morphology of various spinning glands of
Hippasa pisaurina Pocock (Male)

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Name of the gland	Number	Size	Spinneret	Spigot/Spinning tube	Function
Anterior ampullate gland	1 pair	8.0-8.5 mm	Anterior	Spigot type-I	Dragline spinning
Median ampullate gland	1 pair	6.0-7.5 mm	Median	Spigot type-I	Dragline spinning
Posterior ampullate gland	Absent in adult		Anterior	Spigot type-III	Not known
Aciniform glands	28-35	0.35-0.4 mm	Anterior, Median & Posterior	Spinning tube type-I	Swathing of prey
Pyriform glands	43-48	0.5-0.8 mm	Anterior, Median & Posterior	Spinning tube type-II	Formation of attachment disc and assisting in the deposition of seminal fluid

**Comparative account of the functional morphology of various spinning glands in
Stegodyphus sarasinorum Karsch (Female)**

Name of the gland	Number	Size	Spinneret	Spigot/Spinning tube	Function
Large red ampullate gland	1 pair	8.0-10.0 mm	Anterior	Spigot type-I	Dragline, Web frame and light aerial threads.
Large yellow ampullate glands	1 pair	7.9-9.8 mm	Median	Spigot type-I	As above
Median red ampullate gland	1 pair	5.5-6.0 mm	Anterior	Spigot type-II	As above
Median yellow ampullate gland	1 pair	5.5-6.0 mm	Median	Spigot type-II	As above
Small red ampullate glands	8 pairs	1.5-2.8 mm	Anterior-4 Median-2 Posterior-2	Spigot type-III	As above
Small yellow ampullate glands	4 pairs	1.4-2.3 mm	Median-2 Posterior-2	Spigot type-III	As above
Aciniform glands	46-62 in 2 clusters	0.3-0.4 mm	Median & Posterior	Spinning tube type-III	Swathing of prey, attachment disc (?) Cribellar threads
Pyriiform glands	98-112	0.65-1.1 mm	Anterior, Median & Posterior	Spinning tube type--II	Attachment disc and formation of egg cocoon
Cylindrical glands	30	1.1-1.3 mm	Anterior	Spinning tube type-I	Formation of egg cocoon
Cribellum glands	Large nos.	Microscopic	Cribellum	Pore of cribellum	Hackled band of sticky cribellar threads

Comparative account of the functional morphology of various spinning glands in
Stegodyphus sarasinorum Karach (Male)

Name of the gland	Number	Size	Spinneret	Spigot/Spinning tube	Function
Large red ampullate gland	1 pair	6.5-8.0 mm	Anterior	Spigot type-I	Drag line, web frame and light aerial threads
Large yellow ampullate gland	1 pair	6.3-7.9 mm	Median	Spigot type-I	As above
Median red ampullate gland	1 pair	5.0-5.6 mm	Anterior	Spigot type-II	As above
Median yellow ampullate gland	1 pair	5.0-5.3 mm	Median	Spigot type-II	As above
Small red ampullate glands	4 pairs	1.0-1.2 mm	Median-2 Posterior-2	Spigot type-III	As above
Small yellow ampullate glands	4 pairs	1.0-1.3 mm	Median-2 Posterior-2	Spigot type-III	As above
Aciniform glands	38-47 in 2 clusters	0.3-0.4 mm	Median & Posterior	Spinning tube type-III	Swathing of prey, attachment disc (?) cribellar threads and sperm threads
Pyriform glands	48-62	0.4-0.6 mm	Anterior. Median & Posterior	Spinning tube type-II	Formation of attach- ment disc
Cribellum glands	Large Nos.	Microscopic	Cribellum	Pores of cribellum	Hackled band of sticky cribellar threads

**Comparative account of the functional morphology of various spinning glands in
Neoscona mukerjei Tikader (Female)**

Name of the gland	Number	Size	Spinneret	Spigot/Spinning tube	Function
Anterior ampullate gland	1 pair	10.5-12.0 mm	Anterior	Spigot type-I	Dragline and outer framework
Median ampullate gland	1 pair	8.5-10.0 mm	Median	Spigot type-I	Dragline, spiral and radial threads
Posterior ampullate gland	1 pair	6.1-7.3 mm	Median	Spigot type-I	Dragline, spiral and radial threads
Aciniform glands	4-5 clusters 18-22 in each cluster	0.25-0.45 mm	Anterior, Median & Posterior	Spinning tube type-III	Swathing of prey
Pyriform glands	4 clusters 65-86 in each cluster	0.3-0.5 mm	Anterior, Median & Posterior	Spinning tube type-II	Formation of attachment discs
Cylindrical glands	6	1.5-2.3 mm	Median and Posterior	Spigot type-II	Formation of egg cocoon
Aggregate glands	6	...	Posterior	Spigot type-II	Viscid silk of the radial threads

Comparative account of the functional morphology of various spinning glands in
Neoscona mukerjei Tikader (Male)

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Name of the gland	Number	Size	Spinneret	Spigot/spinning tube	Function
Anterior ampullate gland	1 pair	6.0-8.0 mm	Anterior	Spigot type-I	Dragline and outer framework
Median ampullate gland	1 pair	5.5-7.2 mm	Median	Spigot type-I	Dragline, spiral and radial threads
Posterior ampullate gland	1 pair	5.1-6.3 mm	Median	Spigot type-I	As above
Aciniform glands	4 clusters 16-19 in each cluster	0.2-0.4 mm	Anterior, Median & Posterior	Spinning tube type-III	Swathing of prey
Pyriform glands	4 clusters 36-42 in each cluster	0.25-0.4 mm	Anterior, Median & Posterior	Spinning tube type-II	Formation of attachment disc
Aggregate glands	6	Reduced in adult	Posterior	Spigot type-II	Viscid silk of radial threads

**Comparative account of the functional morphology of various spinning glands in
Plexippus paykullii (Aud.) Female**

Name of the gland	Number	Size	Spinneret	Spigot/Spinning tube	Function
Anterior ampullate gland	1 pair	5.0-6.5 mm	Anterior	Spigot type-I	Dragline formation
Median ampullate gland	1 pair	4.0-4.5 mm	Anterior	Spigot type-I	Dragline formation
Posterior ampullate gland	1 pair	2.5-3.2 mm	Posterior	Spigot type-I	Dragline formation
Aciniform glands	18	0.4-0.5 mm	Anterior, Median & Posterior	Spinning tube type-II	Swathing of prey
Pyriform glands	10-14	0.65-0.7 mm	Anterior, Median & Posterior	Spinning tube type-III	Formation of attachment disc
Cylindrical glands	6	0.8-1.2 mm	Median & Posterior	Not known	Formation of egg cocoon (?)

Comparative account of the functional morphology of various spinning glands in
Plexippus paykullii (Aud.) Male

Name of the gland	Number	Size	Spinneret	Spigot/spinning tube	Function
Anterior ampullate gland	1 pair	3.0-4.5 mm	Anterior	Spigot type-I	Dragline formation
Median ampullate gland	1 pair	3.6-3.9 mm	Anterior	Spigot type-I	Dragline formation
Posterior ampullate gland	1 pair	2.2-2.8 mm	Posterior	Spigot type-I	Dragline formation
Aciniform glands	12	0.4-0.5 mm	Anterior, Median & Posterior	Spinning tube type-II	Swathing of prey
Pyriform glands	6-11	0.6-0.65 mm	Anterior, Median & Posterior	Spinning tube type-III	Formation of attachment disc.

DISCUSSION

The silk producing phenomenon is well known among the various groups of arthropods, especially lepidopteran insects are the chief source of commercial silk. In silkworm, *Bombyx mori*, the silk is produced by the larvae of the fifth instar for the protection of youngones in the form of cocoon. Here, the labial glands are modified into salivary glands which secrete silk. The silk secreted by these glands is a fibro-protein surrounded by another protein known as sericin and these proteins remain seperate throughout. These glands are endodermal in origin and are not lined by chitinous cuticle. Similarly the endodermal origin of silk glands is reported in Tetranychidae (Acarina), where the silk is produced by the prosomatic gland which opens inside the mouth. However, the spinning glands originate from the ectoderm in Araneae and possess the chitinous cuticle in the ducts of all the silk glands. Further Gertsch (1949) believed that in Araneae, the excretory products produced originally by the coxal glands had evolved during the course of their evolution into a series of abdominal receptacles for protection and storage of distinct types of silk. Hence, it clearly indicates that the spinning glands in various groups of arthropoda are not related to each other and the silk producing habit has evolved independently in various groups.

Most of the silk producing glands in various groups of spiders are mainly tubular, ending blindly inside, with certain modification, to suit the production and storage of different types of silk in liquid form. These glands open outside by means of spigots and spinning tubes present on the spinnerets. It is believed that the production of silk mainly depends upon the available amino acid pool in the haemolymph and hence, the silk when formed will be in the form of a liquid, undergoes transformation or polymerisation and forms the solidified product, which is variously used. The silk produced by different glands in various groups of spiders differ considerably in its structure.

Generally, the silk fibres produced are the polymers of amino acids which are characterised by a high degree of molecular orientation or alignment. It is this alignment which enables the fibres to withstand high tensility or stress without suffering unduly large deformations. This desired orientation is achieved in the ducts of all these spinning glands.

It is most important in the evolution of the spiders, that it has developed various spinning glands, modified their ducts and developed various accessory spinning structures like spinnerets and tarsal claws, but there seems to be a less development of the intrinsic musculature for the easy flow or the control of the silk in the gland or duct. The only musculature worth mentioning in the opisthosoma is the ventral longitudinal muscles running ventrally, ending in the region of spinnerets but has no connection with the gland. Hence, it can be presumed that a different mechanism is operating in the release and silk production of fibres and this mechanism may be neurological or any other type of stimulus, which is not properly understood.

The exploitation of spider for the production of commercial silk is completely ruled out, as the silk contains a sticky substance in addition to the protein part. This sticky substance perhaps is the main impediment in isolating the yarn. And also the maintenance of spiders is extremely difficult, as they are carnivorous and some times cannibalistic and further a large number of such spiders are needed to make a small yarn of silk. Hence, the study of silk glands is restricted to the pharmacological implication on the application of various drugs and to study the organ as a whole in the production of a single protein. As spiders employ various modes of food gathering devices, by utilising the secretion of the silk glands, for capturing the insect population, the predator-prey interaction can be well understood by studying the silk glands.

The study of spinning glands attracted the attention of various scientists, as the product of the gland is utilised in various ways by the spiders. The construction of an orb web by orb weaving spiders with geometrical precision with the assistance of sensory and motor apparatus is the object of research in the present day investigation. This fact is ably supported by the work of Witt (1960, 1961, 1962, 1963 and 1968), Witt and Reed (1965), Witt and Tittel (1964), Peakall (1964, 1965, 1966 and 1969), Eberhard (1977, 1978 and 1980) and others, who investigated the spiders' precision of producing orb web, by using various parametres like drug, prey population, artificial silk etc. This probably pave the way for the pharmacological implication of various drugs.

The silk produced by the various glands differ considerably in their organisation and also in their function. During the movement of the spider, they leave behind or spin a double thread of silk viz, drag line or a

supporting thread, produced by two large ampullate glands of the anterior spinnerets. In a few cases these drag line are further strengthened by another two filaments from the other two ampullate glands of the middle spinneretes. In orb weavers, these fibres from the ampullate glands are utilised in building the frame work and radii of the orb web. The drag lines are anchored to some substrates with the help of attachment discs, which are groups of fine threads coming from several spinning tubes. The attachment discs are produced by the pyriform glands.

As the spider mainly rely on insects for food, various modes of capturing insects are adapted by spiders. These are achieved by producing some sticky threads, which is very well developed in orb weavers. These sticky threads are coming out from the aggregate glands, which are absent in non orb weavers.

Further, when the insects are trapped, they are made to struggle with the silk, which is wrapped around the body of the victim. Thus the silk is utilised in covering the insects which is well known as 'swathig band' and are secreted by the aciniform glands. The success and perpetuation of spiders depend upon the protection offered to the young ones and hence, the egg cocoon is produced from the cylindrical glands or tubular glands. Lastly, several social spiders which are living in the common nest carrying out all activities together, produce hackled band of sticky silk to trap the prey and to construct the nest, which is produced by the cribellum glands.

Though, Apstein (1889) summarised the glands of 22 species belonging to various groups of spiders and classified silk glands into seven major types viz. ampullaceous, aciniform, pyriform, cylindrical, aggregate, lobed and cribellum glands, however, still there exists some confusion since, many new types of glands have described by several workers viz. Tuberoze glands (Brandt and Ratzeburg, 1888), Glandulae flagelliformes (Sekiguchi, 1952) and Conical and Sub-conical glands (Mukerji, 1973). This often made it difficult either to retain or change the system of classification, unless a thorough study is undertaken in various groups of spiders. All these investigators classified the silk glands into various types based on their morphology but Millot (1949) classified the glands into two major types based on their intensity of reaction viz. acidophilic and basophilic glands. The phenomenon of polymorphism in respect of various glands of spiders is also well known which is associated either with sex linked inheritance or with ontogeny.

The identification of various silk glands in *Lycosa nigrotibialis*, *Hippasa pisaurina*, *Stegodyphus sarasinorum*, *Neoscona mokerjei* and *Plexippus paykullii*, investigated during the present studies is mainly after Apstein (1889), Warburton (1909), Savory (1928), Comstock (1940) and Millot (1949). As such six glands viz. ampullate glands, aciniform glands, pyriform glands, cylindrical glands, aggregate glands and the cribellum glands are identified but shows slight variation in morphological details. It also appears, that the first four glands are common but the other two types viz, cribellum glands in *Stegodyphus* and the aggregate glands of *Neoscona* depend upon the manner in which the spiders have evolved and employed silk for their use.

The ampullate glands are the most voluminous glands in the opisthosoma. The number of glands differ in different species and also at various stages of development. These glands are easily distinguishable from the other glands as they are few in number and anatomically well developed. The glands are uniformly present in both the sexes of all the species studied. The number, however, may vary specifically. In *Lycosa* and *Hippasa* the adult spiders possess two pairs of functional ampullate glands, the third pair or the posterior pair is reduced in the form of a vestige in both the sexes of *Lycosa* and absent in the adult male spiders of *Hippasa*. This perhaps appears to be a characteristic feature of the above mentioned two genera in particular and of the family Lycosidae in general. The development of three pairs of glands in the early stages and reduction of the posterior pair at a later stage clearly indicates, that the ampullate glands are originally three pairs but in the course of their evolution they have employed the anterior and median pair, as a result the posterior pair is reduced but still represented in the form of a vestige by a spigot on the anterior spinneret.

The loss or reduction of the ampullate gland has also been reported earlier by Reichter (1970) in *Pardosa amentata* (Lycosidae). According to him, in the sub adult and adult females, two pairs of small and two pairs of large ampullate glands are present, while in case of adult males the two pairs of small ampullate glands are lost in moulting and vestiges of the spigots are present, corresponding to the degenerated gland. Hence, it appears that loss of ampullate gland or reduction in size is a significant feature in the family Lycosidae as it is found in *Lycosa nigrotibialis*, *Hippasa pisaurina* and *Pardosa amentata*.

The ampullate gland produces silk for trailing of drag line or construction of funnel web in *Hippasa*. The development of anterior and median ampullate gland in male and female by increasing the length of the anterior secretory duct and the enlargement of the ampulla and also the development of many 'U' turns in the posterior duct at various stages, signifies the corresponding demand of the silk by the spider. Further, the reduction in size of the gland during the cocoon formation also indicative of the activity of the gland. In *Heteropoda venatoria*, a non orb weaving spider, Mukerji (1972) reported that the ampullate glands also contribute in the cocoon formation. This fact is strengthened by the discovery of the green silk of cocoon of *Tetragnatha* produced by the ampullate gland (Millot, 1949).

Stegodyphus is peculiar in not only having the cribellum glands but also in possession of a large number of ampullate glands. The morphology of the glands was first described by Bradoo and Majupuria (1973). They further classified these glands into five types depending on the size and colour viz. Large red ampullate glands, small red ampullate glands, large yellow ampullate glands small yellow ampullate glands and the smallest yellow ampullate glands. The present investigation, however, reveals that this glands can be conveniently classified into three types instead of five based on their size and each category includes red as well as yellow ampullate glands. Further, the total number recorded in the present investigation is 32 instead of 38 as reported by Bradoo and Majupuria op. cit. and 26 reported by Jackson (1975). In addition, the present investigation also reveals the presence of two median yellow ampullate glands which have not been described hitherto by the earlier workers. However, it is not properly understood whether this difference is due to the geographic distribution or the number described by Jackson op. cit., is a case of sexual dimorphism, as the male spiders have generally less number than the female.

Apstein (1889) described the ampullate gland in *Araneus diadematus* as two pairs one leading to the anterior and the other leading to the median spinnerets, though several earlier workers like Meckel (1846) and Brandt (1881) described the presence of three pairs in these spiders. The presence of two pairs in orb weavers is also confirmed by the work of Warburton (1909), Comstock (1940), Sekiguchi (1952 and 1955), Kaston (1964) and Peakall (1966). But the present investigation in *Neoscona*, though belong to the same orb weaver family, the ampullate glands differ in number. Three pairs of these glands are clearly observed of which two pairs are directed forwards and one pair backwards. The anterior pair opens on the anterior spinneret

while the median and posterior pairs open on the median pair of spinneret. The ampulla-posterior duct joint is slightly enlarged and forms a small bulb confirming the area as "receptor" as described by Peakall (1966), which controls the secretion of the silk production in the ampullate gland.

The ampullate gland in *Plexippus* is well developed and a clear difference in male and female is observed. Both the sexes have well developed three pairs of ampullate glands. In male, ampullate glands are elongate and the ampulla is not swollen. The anterior secretory duct is coiled but wavy in outline and the length of it does not extend more than the ampulla. However, in female, the anterior duct is long, coiled and the length exceeds the length of the ampulla. The ampulla itself is very well enlarged and shows constriction or demarcation into three regions. Unlike other species, the posterior duct of the ampullate gland does not show any 'U' turns but simply it is almost 'S' shaped, opening on the spinnerets. However, in *Philaeus chrysops*, which also belongs to the same family Salticidae, Millot (1935) described two pairs of lateral and two pairs of median glands, the posterior ducts of these glands show several 'U' turns.

In addition to the difference mentioned above, *Plexippus* differs from others under investigation by the possession of a large number of tracheae anastomosing on these glands, helping directly in the gaseous exchange. Further, the presence of silk fully filled in the ampulla at various stages of development signifies that the silk is continuously produced and utilised.

The first description of the aciniform glands comes from the work of Oefinger (1866), he considered the aciniform and pyriform gland as a single type, but a clear distinction of these glands was made by Apstein (1889) based on their shape and characteristic response with the stains and other reagents. Subsequently, these glands are reported in all the species of spiders by Comstock (1940), but the number of these glands vary in different groups. Apstein op. cit. described as many as 400 glands in *Araneus diadematus* appearing in the form of berry and all the glands are grouped together as bundles. Warburton (1909) demonstrated the functional morphology of these glands and stated that aciniform and pyriform glands contribute in the formation of trailing line. But now it has been clearly established that the secretion of aciniform glands help in the production of silk, which is used by spiders for covering the captured prey.

Usually the glands are having the swollen base resembling that of an acinous but in a few species like *Neoscona*, the aciniform glands possesses an

anterior tail like extension which is absent in other spiders. The number usually varies in different spider species and also in different sexes. In *Lycosa*, the fully developed female have 80 such glands as compared to males having 66. Reichter (1970) also noted the variation in respect of the number of aciniform glands associated with the age in male specimens of *Pardosa amentata* without mentioning their functional significance. The growth of the gland during the moulting and reduction in size afterwards, suggest strongly that they produce the foundation lines or threads spun for moulting. It is also not clear whether glands help in the sperm web construction in male. Melchers (1963), reported that the process of sperm web construction in male *Cupiennius salei*, is being carried out by the median and posterior spinnerets. Since the aciniform glands discharge the silk through these spinnerets, he feels that, it is reasonable to conclude that these glands are involved in the sperm web construction. In female spiders under investigation, the reduction in the size during cocoon formation also indicates that these glands are not involved in cocoon formation.

The arrangement and morphology of the aciniform glands does not show much difference in *Hippasa* to that of *Lycosa* except for the number, which is 56 in female vs. 32 in male. The sexual dimorphism in respect of the number of glands and especially less number in male as compared to female also signify that the male employs less effort in hunting the prey and obviously the utilisation of the silk.

In *Stegodyphus*, aciniform glands occur in two clusters and each cluster is having 46-62 glands in matured female and 30-38 in matured male, opening on the median and posterior spinnerets. In adult males, immediately after the last moult these glands are well developed signifying that the secretion of these glands is utilised in the induction of sperm into the palpal organ of the male. Further the glands located, along the middle spinnerets also contribute in the formation of cribellar silk (Jackson, 1973).

Several clusters of aciniform glands each consisting of 18-22 such glands are present in the orb weaver spiders *Neoscona*. Morphologically they are grouped into two types of glands, one with anterior tail like extension on the swollen acinous and the other without the tail but with a swollen acinous. The latter type is more common and only with a few of the former type. A similar observation was made in *Nephila clavipes* and *Araneus sericatus* by Mullen (1969).

In *Plexippus*, two clusters of eighteen glands each in female and twelve in male are observed, which clearly signifies that the silk of the aciniform glands is not much utilised for capturing the prey, as they mainly depend on their powerful fangs and legs. This assertion is supported by the fact that these spiders normally pounce on the victim and bite with the chelicerae and rarely utilising the silk. In *Heteropoda venatoria*, Mukerji (1972), observed that no swathing bands of silk are produced, perhaps the secretions of the aciniform glands is utilised in the formation of egg cocoon in female and sperm webs in male. In *Philaeus chrysops* (Salticidae), according to Millot (1935), the aciniform glands are similar to bi-partite glands and they form three groups, a median composing of six glands and two lateral comprising of twelve glands each.

Pyriform glands are found in large number in almost all groups of spiders with pear shaped body and anterior tail like extension. Externally, by the reaction of eosin staining, two different regions are clearly visible an anterior elongated part and a basal swollen part. The secretion of the pyriform glands is utilised in the formation of attachment discs. The duct of these glands open on the spinning tubes of anterior, median and posterior spinnerets. Similar to aciniform glands the number of pyriform glands vary in different groups. In *Lycosa*, as many as 150-160 glands occur in two clusters where as in *Hippasa*, the number is drastically as low as 65 in females and 43 in males. This difference in number, in the same family is not properly understood but possibly suggest that the secretion of the pyriform glands of *Lycosa* is utilised in the construction of turrets below the stones, as the silk of this gland is utilised in binding the various substrate or solid particles like sand and plant remainings, during the formation of the turret. In *Hippasa*, it clearly employs the the secretion in the formation of attachment disc as they construct the snare in the form of a funnel web.

According to Reichter (1970), the pyriform glands produces attachment discs and 'broad trail' in adult males and pseudo attachment discs in adult females. He further clarified that in adult males an increase in the attachment discs and broad trail occurs during the breeding season and this can be correlated with the gradual growth of this gland found in this period. The glandulae pyriformes in *Lycosa* and *Hippasa* helps in the construction of cocoon confirming the same as found in *Pardosa amentata* that the glands are reduced in size after the cocoon formation. Morpholo-

gically, the Pyriform glands of *Stegodyphus* resembles that of other species investigated but the decrease in the size of the gland after cocoon formation, indicates that these glands are also utilised in the cocoon construction in addition to the formation of attachment disc.

In *Neoscona*, four clusters of large number of pyriform glands are present which exhibit a clear difference in the anterior and posterior half of the gland with eosin. The presence of large number of glands in *Neoscona* clearly indicates that these glands are utilised in the formation of attachment discs as the spider spins an orb web which needs more and firm anchoring threads not only in fixing the solid framework or support but also in the formation of connections with the radial and spiral threads. The phenomenon of the production of attachment disc is clearly seen, when the spiders are kept in small glass containers. The spider normally rub the spinnerets inside the glass tubes and when the silk is examined it reveals that it possess large number of threads which are more or less glue like demonstrating thereby that the attachment discs or anchoring threads released from the spinning tubes are the secretions of pyriform glands.

The cylindrical glands are having short posterior duct and uniform diameter in the anterior secretory part. These glands have been observed in all the species of spiders under investigation and the absence of this gland in males and immature females are confirmed. However, Apstein (1889) reported these glands in the male spiders also. He recognised three pairs of glands both in male and females of *Araneus diadematus*. But in few cases he stated that these were absent in immature females and males of *Argyroneta*, an aquatic spider. Apstein op. cit. further stated "I have found this gland in males but then only in few specimens whereas in females of the same species these number was six times greater" This clearly indicates that this assumption of the presence of cylindrical glands are not uniform. Subsequently, the presence of these glands were confirmed by Comstock (1940), Sekiguchi (1952 and 1955) and Peakall (1966), only in females. The number of glands usually varies. In *Prothesema petrensis*, eight glands are found, five of them opening on the middle spinneret. In *Lycosa amentata*, 25 glands are seen in mature females. Apstein op cit. further described the absence of this gland in *Epiblenum senicum* and *Attus falcatus*.

The development of these glands to the maximum extent in mature females at the time of egg laying and also the secretion which is yellow in colour confirms that these glands are involved in cocoon formation, as the

silk threads of these are yellow in colour in *Hippasa* and *Neoscona*. The absence of these glands in certain species of Salticidae viz. *Segestria* may probably indicate that these spiders do not spin any egg cocoon.

The number of cylindrical glands is species specific, since in *Lycosa*, there are eighteen such glands while in *Hippasa* it is only twelve, but in *Stegodyphus* as many as fifteen pairs are present with slight brownish red colour and correspondingly the egg cocoons are also red. However, in *Neoscona* and *Plexippus* only three pairs are present.

A comparative study on the various spinning glands reveal that the orb weaver spider, *Neoscona* possesses highly elaborated arrangement of spinning glands and the non orb weaver, *Plexippus* has a very simplified arrangement of spinning glands. Members of Lycosidae i. e., *Lycosa* and *Hippasa*, though the general structure of the glands appear to be same but occupies different ecological habitat and thus the utilisation of silk vary. However, *Stegodyphus* deviates substantially in having various types of glands and this may be mainly due to their social life. From the study of the various aspects of the spinning apparatus in spiders, it is seen that the morphological feature such as the shape of the gland is one of the important criterion in the classification of the glands. Further the flagelliform glands, conical and sub conical glands described by various workers are not met in any of the spiders investigated but the 'receptor' area described by Peakall (1966) in the orb weaver spider is clearly located in the ampulla posterior duct joint. In addition, the probable role played by each gland has been investigated.

Finally, by analysing the various aspects of spinning glands, it reveals that the arrangement of the silk glands, production and utilisation of the silk are all related to the food and feeding habit and the type of adaptation they exhibit.

HISTOLOGY OF SPINNING GLANDS

Histologically the ampullate glands are differentiated into three regions viz. an anterior coiled secretory duct, a median saccular ampulla and a posterior tubular duct leading to the spigot. The entire gland, though more or less tubular with closed anterior end, shows variation in the thickness of the epithelial layer, width of the lumen and the secretory product.

AMPULLATE GLANDS :

The ampullate glands in all the species of spiders investigated are invested by a layer of peritonium, which often shows variation in the thickness of different regions. This layer is often known as "tunica externa" or "tunica propria". Inner to this layer is a layer of epithelium resting on the basement membrane. The height of the cells and the secretory product vary at various regions and also under various developmental stages. The innermost layer, is a layer of chitin which, however, is absent in the secretory region. This inner layer of "tunica intima" is well developed in the posterior duct of the ampullate gland leading to the spigot.

The anterior ampullate glands in *Lycosa* comprises of an outer tunica externa or the peritonal layer enclosing the basement membrane in the anterior secretory region. The epithelial layer is uniformly tall throughout with a broad base and a narrow apex. The cells of the epithelial layer at its apex are not uniform but are highly irregular. The cytoplasm is granular and these granules are quite large. The nucleus is oval, located at the base and shows chromatin granules and nucleolus. There appears to be a clear zone without any cytoplasm around the nuclear membrane. The lumen of the duct contains secretion released by the cells and stains pink with eosin. The epithelial cells as they run posteriorly become taller, however, in the region of the ampulla, the epithelial cells are small with broad base and narrow apex. The nucleus is arranged in the middle but in few cases it is situated at the base. The outer connective tissue layer stains blue with haematoxylin. The contents of the lumen stain pink, with differentiation into an inner core of dark pink and an outer core of light pink area. The outer layer of secretion appears in the form of mucilage, which stains positively PAS and Alcian blue. In the anterior secretory duct and the median ampulla the median ampulla the chitinous intima is absent.

The posterior tubular duct is small, covered externally with a layer of peritonium and stains blue with haematoxylin. The basement membrane in this region is very thin but the cells are very tall and the apex of all the cells are arranged in the form of a circle, which is protected by a layer of chitinous intima. The cytoplasm is clear or homogeneous and the nucleus is spindle shaped, located basally. In a few cases, two or three ducts are enclosed by a common sheath, probably representing the bent portion of

of the duct. The number of the cells is comparatively small (26-28) but this number gradually decreases and also the cell size.

The structure of the median ampullate gland in *Lycosa* appears to be same histologically with an outer peritonal membrane, an epithelial layer in the secretory and the ampullar part and an additional layer of chitinous intima in the posterior duct. The secretion in the lumen shows the same differentiation into outer and inner zone.

In *Hippasa*, the anterior secretory duct is invested by a thick layer of tunica externa. This layer encloses ventrally a layer of basement membrane. The epithelium rests on the basement membrane and the cells in the anterior tubular part are roughly polygonal in shape with a centrally located nucleus. The nucleolus is clearly visible. The cells contain numerous vacuoles at stages when the lumen appears to be empty but when the lumen is filled with secretion, the cytoplasm of the cells are granular and these granules are more crowded adjacent to the lumen and show intense reaction with eosin. The lumen appears as a small canal and the secretion in it shows pink colouration with haematoxylin-eosin without any differentiation into an outer and inner zone. The diameter of the lumen increases as it runs posteriorly towards the ampulla, correspondingly the height of the epithelial layer also increases. The cells are tall, columnar with broad base and a narrow anterior end. The basement membrane in this area appears as a thin network or reticulate type. The nucleus is slightly elongated or spindle shaped located at the basal region of the cell. With haematoxylin the nucleus shows dark staining granules of chromatin material and a large vacuolar nucleolus. The cytoplasm appears to be granular and the secretory product is present in large quantity near its apex. as it can be seen with the intensity of the reaction with the stain.

In a few sections the nucleus is rounded, present more or less in the centre without any visible nucleolus and the cytoplasm appears to be homogeneous.

In the ampullar region, the width of the lumen increases gradually in the antero-posterior direction or from top to bottom. The outer peritonal layer is very thin and the basement membrane present inside is often difficult to locate. The cells at the junction of the anterior secretory duct are tall with a broad base and a narrow apex. The spindle shaped nucleus

present in the basal region and cytoplasm is granular. As they proceed posteriorly, the height of the cells gradually decreases, the nucleus is located at the base or in the central region of the cells of the ampulla where the width of the lumen is maximum, the cells are broader than its length, without any differentiation into basal and anterior region.

The lumen width increases in the antero-posterior direction, showing maximum width in the middle region. The secretory product appears in the lumen, which stains deeply with haematoxylin-eosin. In few cases, the lumen appears to be empty in the anterior ampullate gland but filled with secretion in the other ampulla. In the middle and posterior region of the ampulla, the inner secretory product can be differentiated into a central core of dense layer staining deeply with eosin and shows pink colouration and an outer thin layer of less intensity. The differentiation of the secretory product is more clear in the posterior region of the ampulla. This clearly signifies that the second layer is secreted by the cells of the median and posterior ampullar region. The intensity of the staining reaction of the secretory product is entirely different from that of the anterior secretory duct, indicating probably a different chemical composition.

The posterior duct arising from the ampulla shows well defined three layers *viz.* an outer thick layer of peritonium or tunica externa enclosing a layer of basement membrane. The middle region consists of tall columnar cells with a broad base and a narrow apex and the tip of all the cells culminate in the form of a circle. Inner to this layer is a layer of chitinous intima, which arises from the base of the ampulla and runs upto the spigot. This chitinous layer is absent in the anterior secretory part and the lumen. The thickness of this layer increases gradually in the posterior direction thereby reducing the width of the lumen. The epithelial cells are quite tall, with an elongated nucleus present more or less in the centre. The nucleolus and the chromatin granules are not clearly visible. The cytoplasm appears to be homogeneous without any granules. The secretory product, present in the lumen appears as cylindrical core with differentiation into an outer and inner zone.

The structure of the median ampullate gland is similar to the anterior one, with little variation. The cells in the anterior secretory region are rectangular and the cytoplasm appears alveolar or filled with vacuoles. The external layer of connective tissue is very thin in the ampullar region and the basement membrane is less clear. The contents of the ampulla,

though differentiated into outer and inner core, show light staining and often show bluish red tinge in the central core. In a few cases newly secreted layer in the ampullar region stains positively for the mucopolysaccharides by the alcian blue-PAS method and shows purple colour. This may be due to the presence of muco-polysaccharides.

Following cell layers are distinguished in the microtome sections of the ampullate gland of *Stegodyphus sarasinorum* when stained with haematoxylin-eosin. The large red ampullate gland reveals an outer layer of connective tissue membrane which is thin in the region of the anterior secretory duct. The basement membrane is very thick and consists of layers of interstitial cells at the base of the epithelial layer. The cells in the anterior duct are cuboidal and show reticulate arrangement. The nucleus is round in shape, present in the middle of the cell, rarely situated at the base of the cell and stains deep blue. The chromatin granules are not clear and the nucleus has a single large nucleolus. The cytoplasm is granular and uniformly distributed throughout. The epithelial cells at the region of the ampulla are tall with broad base and a narrow apex. The concentration of granules in the cytoplasm is comparatively less. The nucleus is always at the basal region. The lumen of the anterior duct enlarges progressively and contains a homogeneous material, which stains deep pink with eosin.

The middle ampulla has a very thick outer connective tissue and this region is responsible for the colour of the gland. The basement membrane is comparatively thin and interstitial cells are clear. The epithelial cells are broad with a central rounded nucleus. The cytoplasm is homogeneous without any differentiation into granules. The nucleus shows chromatin granules and single large nucleolus. The secretion of the ampulla in the lumen takes deep pink colour with eosin in the central core and it is surrounded by a light pink area. The innermost chitinous layer arises from the base of the ampulla in the form of a funnel.

The posterior tubular duct is characterised by the presence of an external connective tissue membrane, median tall epithelial cells with a basal nucleus and a homogeneous cytoplasm and an innermost layer of chitinous intima. This innermost layer arises from the base of the ampulla and runs upto the spigot. The number of cells in the posterior duct is found to be 36-42 but in few cases this number varies and also the

number of cells in the posterior end of the duct gradually decreases. The lumen of the duct shows pink colour with eosin.

The structure of the yellow large ampullate gland in the region of the tubular duct appears to be same as that of red ones. The connective tissue region in the ampullar region is thin and the interstitial cells which are well represented in the red ampullate glands are absent. The secretion of the ampulla shows less variation into an outer and inner zone. The posterior duct of the ampullate gland is structurally similar but has more number of cells in the beginning of the duct.

The structure of the median and small ampullate glands appear to be same. The connective tissue membrane is very thin in the anterior secretory duct. The secretory cells are small and hexagonal and more crowded. The nucleus is round in shape, the nucleolus and the chromatin granules are difficult to observe. The lumen is always filled with pink coloured secretion. The ampulla shows differentiation into an outer connective tissue layer having a very thin basement membrane. The epithelial cells are elongated with a basal nucleus. The lumen of the ampulla shows no differentiation into an outer zone and an inner central core. Thus the small and median ampullate glands differ from that of the other ampullate glands in having secretion which is found to be chemically different. This fact is supported by the reaction with PAS, as it shows less reactivity to the above stain.

Anterior ampullate gland in *Neoscona* shows the same differentiation into three regions. The anterior secretory duct is lined externally by the connective tissue membrane, which appears as a thin layer. This layer encloses the basement membrane ventrally. In this region, few interstitial cells are present, the sizes of such cells often vary. A oval dark staining nucleus is visible and the cytoplasm does not stain and appears as empty cells or with vacuoles. The epithelial layer resting on this interstitial cells consist of cells which are small and closely arranged. The cells are hexagonal with a central nucleus. The cytoplasm appears empty or vacuolar. But the cells in the posterior region of the secretory duct increase in height, become more prominent and tall. The nucleus which is situated at the base is slightly irregular but in a few cases it is shifted towards the lumen. The nucleolus is single and centrally placed and the nucleoplasm is also granular. The cytoplasm around the nucleus is very clear but towards the lumen contains the globules or droplets of secretion, which at a later

stage diffuses into the lumen. The lumen gradually increases in size and contents of it take deep pink colour with eosin.

The ampulla has thick connective tissue membrane and a very thin layer of basement membrane. The interstitial cells are absent. The epithelial cells are much shorter and the cell membrane is very clear. The nucleus is spindle shaped with chromatin granules and nucleolus. The cytoplasm appears to be uniformly distributed and seems to be more acidic as it takes blue tinge with haematoxylin-eosin. The lumen of the ampulla contains secretory material which takes pink colour. The colouration of the secretion is uniform and is not differentiated into outer and inner zone.

Though the receptor area has been recognised by Peakall (1969), the exact location in the ampullate gland was not clear. In the present investigation, the "receptor" area is clearly distinguishable and it is present at the base of the ampulla as a small bulb like structure.

The receptor area reveals that the connective tissue layer present externally is very prominent and shows lamellar appearance, consisting of several tissue layers enclosing a small basement membrane and the epithelium. The cells are very small with a round nucleus at the base. The cytoplasm in this area appears empty with a few vacuoles. The connective tissue layer present in the receptor area reacts positively with eosin and shows pink colouration. The inner chitinous intima arises from the base of the bulb as a very thin layer and proceeds posteriorly into the duct.

The posterior duct of the ampullate gland, which arises from the base of the bulbous region of the ampulla is invested externally by a layer of connective tissue membrane enclosing a layer of basement membrane inside. The epithelial layer is quite tall with a broad base and a narrow apex. The apices of all the cells culminate ventrally and a circular area is formed which is lined by innermost cuticular ring or lining. The nucleus is elongated and is arranged basally. The cytoplasm is clear and stains uniformly but appears to be empty at the apex of the cells and thus appears as a continuous canal ventral to the chitinous layer. The number of the cells in the duct varies from 28-32 and the height of the cells increases as they move posteriorly, but the lumen width decreases. Similarly the chitinous intima which is very thin in the beginning gradually increases its thickness, making the lumen very narrow. It is quite common that the posterior duct, as they

run back and forth by bending at certain levels or taking 'S' shaped turns, shows the appearance of a triad in the cross section, and are enclosed by a common sheath. The structure of the duct appears to be uniform except that the size of the duct decreases as it enters into the spinneret. The valvular region which is described by Wilson (1962) in the orb weaver spider of *Araneus diadematus* appears to be absent.

The median ampullate gland in *Neoscona* also has more or less the same structure with slight variation. The epithelial cells are tall and columnar in the anterior secretory duct. Nucleus is located in the periphery with a dark staining chromatin granules and single nucleolus. The cytoplasm is granular throughout due to the presence of the secretory material distributed all over and stains uniformly. The epithelial cells in the ampulla are smaller with a broad base and less height, covered by a layer of connective tissue which is more prominent. The secretion of the ampulla stains uniformly with eosin without any differentiation into an outer and inner zone. When compared with the secretion of the anterior ampullate gland it resembles in having an undifferentiated layer of secretion but differs with the intensity of the reaction. The former is more reactive than the contents of the median ampullate gland. When stained with saffranin and fast green, the anterior ampullate gland shows pink colouration in the ampulla and the median glands show violet colour. The structure of the receptor is similar to that of anterior ampullate gland but the thickness of the lamellar region is comparatively less. The posterior tubular duct arising from the bulb is similar in its histological structure as that of anterior ampullate gland.

The posterior ampullate gland is histologically similar to that of the anterior ampullate gland. The contents of the ampulla when stained in saffranin and fast green show blue green colouration. The receptor area situated at the base of the ampulla is small and the lamellar layer is thin.

Of the three ampullate glands in *Plexippus*, the anterior ampullate gland is more prominent in cross section. The external connective tissue layer is very thin throughout in the anterior secretory duct. On the surface of this layer a few thickening has been observed which may probably represent the area containing tracheole end cells. The basement membrane is very thin and the cells of the epithelial layer are tall and columnar throughout in the anterior secretory duct. Rarely the cells are filled with numerous vacuo-

les in this region but in most of the cases the cells are filled with granules. The nucleus is comparatively small and basally located. The lumen in the anterior secretory region is uniform in diameter, containing the secretion or occasionally found empty. The ampulla shows the same differentiation of various layers. The contents of the ampulla stain uniformly without any differentiation. The posterior duct has a distinct outer layer of peritonium, the epithelial layer consists of 18-24 cells which are tall and columnar in the beginning of the duct. The chitinous intima is thin and runs upto the spigot.

The median and posterior ampullate glands are similar in their structure. The tall columnar cells of the anterior duct have a row of centrally placed nuclei. The external connective tissue layer is thick and takes deep colouration with haematoxylin eosin. The secretion stored in the ampulla stain bluish pink uniformly without any differentiation. The duct of the ampullate gland has similar histological details.

ACINIFORM GLANDS :

Aciniform glands are usually small and occur in the form of clusters at the origin of the spinnerets and are oval in appearance. The glands are invested by a layer of peritonium enclosing the basement membrane on which the secretory epithelium rests. In the glandular portion, the inner layer of tunica intima is absent. The posterior ducts of the aciniform glands are similar to the structure of the ampullate gland but are smaller and occur in the form of clusters.

The aciniform glands in *Lycosa* are grouped together in the form of bundles resembling that of a berry. The glands are enveloped by a thin layer of peritonium or tunica externa, enclosing a thin layer of basement membrane which is difficult to visualise. The epithelial layer is quite small and the cells are broad at the base. The nucleus is small and oval situated at the base of the cell. The cytoplasm or the secretory granules are difficult to visualise due to the intense staining. The lumen of the gland is filled with secretion which takes maximum stain and gives intense colouration of dark red. In histological section the glands are recognised by their location i.e. they are situated close to the spinnerets and secondly of the intense reaction with eosin. As the content of the glands are always full in almost all the sections observed it can be inferred that the secretion of silk is continuous. From the base of the gland, lining the lumen, arises a thin chitinous intima which increases in its thickness in posterior duct. The ducts of the aciniform

glands are less conspicuous in having a very thin intima, a thin layer of epithelial cells and rarely distinguishable outer connective tissue membrane.

Aciniform glands in *Hippasa* are characterised by the presence of an external peritonal membrane enclosing the basement membrane. The epithelium, which is devoid of chitinous intima in the glandular part shows slight variation in the structure of the cells.

The columnar cells in the anterior region are small, compactly packed with an oval nucleus in the centre. The chromatin granules and nucleolus are difficult to observe. The cytoplasm is homogeneous and secretory granules are rarely seen and give light pink colour with haematoxylin-eosin. The lumen in this region is completely filled with secretion and stains red. The cells in the basal portion are slightly taller, the cytoplasm shows small granules and the nucleus is irregular in shape. The lumen in this region is filled with secretion and stains intensely dark red with eosin. The base of the lumen has the beginning of the chitinous intima. Thus histologically two regions can be differentiated in the glandular part of the aciniform gland. An anterior part with large cells and slightly irregular nucleus. Further, the secretion in these two glandular parts vary slightly, but compared with the secretion of the other glands by way of staining reaction, aciniform glands stands unique in having a deep staining secretory material and large granular cytoplasm in the basal region. The structure of the posterior tubular duct is similar to that of *Lycosa*. The content of the lumen in the duct stains dark red.

Aciniform glands in *Stegodyphus* are small with a peritonal covering externally. The epithelial cells are present on an inconspicuous basement membrane lining the lumen of the gland. The cells are conical in appearance. The nuclei of the cells are irregular and are arranged in a row at the base of the epithelium often showing chromatin granules and single nucleolus. The contents of the cell are highly granular and granules are often seen discharging into the lumen. The posterior duct which always occurs in the form of clusters are small with a thick chitinous intima. The secretion of the lumen shows intense reaction with eosin but do not show any differentiation in the anterior and posterior part.

Neoscona possesses two distinct types of aciniform glands histologically also. The aciniform glands are spherical in shape, invested by a thin external peritonium enclosing the basement membrane. The epithelial cells are

small and densely packed throughout. The nuclei of the cells are irregular and arranged basally. The cytoplasm is characterised by small granules and appear as pink coloured cells. The lumen of the glands are always full and show an intense reaction with haematoxylin-eosin and stain dark red.

The epithelial cells in other type of aciniform gland are small and densely packed in the anterior region but are quite tall in the posterior region. The nucleus is spindle shaped or slightly irregular and located at the centre. The cytoplasm contains a large number of granules which are substantially bigger in size. The lumen of the gland is always full with secretion which shows gradation in colour from dark red to deep red or greenish red.

The posterior tubular duct is short and the epithelium is small and devoid of any secretory granules. The nucleus is small and distributed irregularly. The peritonal membrane is very thin but the inner chitinous layer is very prominent.

In *Plexippus*, a thin peritonal membrane envelops the aciniform glands. The epithelial layer consists of cells which are taller and the secretory droplets are minute and granular. The nucleus is oval, chromatin, granules and nucleolus are clearly visible. The secretion of lumen stains pink with haematoxylin-eosin. Compared with the other species under investigation, the staining intensity in the aciniform glands of *Plexippus* is very weak.

PYRIFORM GLANDS

These glands are usually present in large numbers and comparatively larger in size than the aciniform glands. Usually the glands have a basal swollen portion and an anterior extension. As the main function of these glands is to secrete attachment disc, the secretion is more glue like or sticky. The glands are covered by peritonium externally with a secretory epithelium inside. The ducts of these glands also run in the form of cluster and are lined by chitinous intima inside.

Glandulae pyriformes in *Lycosa* are the most prominent structure due to the differential staining in the anterior and posterior half of the gland. The glands are enveloped by a layer of connective tissue which is often thin in the anterior portion but prominent in the posterior half of the gland. The cells in the anterior half rest on the rarely distinguishable basement membrane. The epithelium in the anterior half is cuboidal, cytoplasm is homogeneous

and takes uniform stain. The nucleus is spindle shaped with chromatin granules easily recognisable. The lumen of the gland in the anterior half is comparatively smaller and contains secretion which stains light pink.

The epithelial cells of the basal half are larger, tall and rest on the basement membrane. The cytoplasm is granular and the nucleus is slightly oval or spindle shaped, chromatin granules and nucleus is clearly visible. The staining intensity of the lower half is very intense. Similarly, the lumen which is swollen and broad contains secretion staining intensely dark red. Thus a differential staining ability is noticed. But it is not certain whether the secretory product in these two different regions exhibit any chemical difference like that of the ampullate glands of *Neoscona*. The posterior duct of the pyriform glands is having a very thin layer of outer peritonium, a small cuboidal epithelium and an inner chitinous layer.

In *Hippasa*, pyriform glands which occur in the form of cluster show different structure histologically both in the anterior and posterior half of the gland. The peritonal layer delimits the gland externally enclosing the epithelial cells inside. As in *Lycosa*, the cells in the anterior half are cuboidal with a central oval nucleus, a large number of chromatin granules and a single nucleus in it. The cytoplasm is thinly granular and takes very light pink colour and this appears to be same in the secretion of the gland in the anterior half. The cells of the posterior region are large with an oval nucleus and large amount of secretory material in the form of large granules.

The secretion of the lower half stains intensely. The posterior duct which arises from the base of the gland has thick chitinous intima and external peritonium. The epithelial layer are rarely distinguishable. A noteworthy feature of the duct is the presence of secretion which stains deep in the central core and faintly in the outer core. This staining ability of the gland is ably supported by Alcian blue-PAS method which stains the secretion of the gland positively and shows blue colouration indicating the presence of mucopolysaccharides.

Histologically the pyriform glands in *Stegodyphus* are similar to that of *Lycosa* and *Hippasa*. The glands are delimited externally by the peritonal membrane, the epithelial cells in the anterior half are small cuboidal resting on the basement membrane. The cells are having basal nuclei in the anterior cells whereas the cells in the posterior region possess larger nuclei in the centre

and granular nucleoplasm. The lumen which serves as reservoir shows differential staining in anterior and posterior half.

The Pyriform glands in *Neoscona* are well developed and are easily recognisable by their distinct colouration. These glands are invested by a layer of peritonium enclosing the basement membrane on which the epithelial cells are present constituting the silk secreting cells. The epithelial layer is formed by two types of cells, one type in the anterior region and the other in the posterior region of the gland. The cells of the anterior half are small attached to the basement membrane. The nucleus is almost oval and situated at the base of the cell having a single nucleolus. The nucleus stains blue with haematoxylin and chromatin granules are inconspicuous. The cytoplasm of the cells contain minute granules and stains lightly.

The epithelial cells in the distal half are tall columnar with a broad base attached to the basement memberane. The cytoplasm is more granular, the nucleus is large and slightly wavy or irregular, generally located at the base or occassionally in the middle of the cell. It stains deep blue with haematoxylin. The cytoplasm of the cell shows less intensity of staining with eosin and it is usually yellow. In few cases the cells appear to be vacuolated with a clear cytoplasm.

The lumen of the pyriform gland is narrow in the anterior region but enalrges at the basal region which is filled with secretory material. The staining is very intense in the lower half with Alcian blue-PAS stain. The duct of the pyriform gland shows a layer of peritonium, a layer of small epithelial cells and an inner chitinous intima lining the narrow lumen.

The pyriform glands in *Plexippus* can be distinguished into two halves, an anterior region consisting of small epitheial cells and a posterior region of tall columnar cells having larger granules and show pink coluration in the cytoplasm. The lumen of the gland is large and contain the secretion. The secretion shows either deep pink colouration or some times the acidophilic secretion is flanked on sides by basophilic secretion that stains deep blue. The lumen of the duct shows the differentiation of the secretory product clearly.

CYLINDRICAL OR TUBULAR GLANDS :

The cylindrical glands are exclusively present in the female spiders and are mainly associated with the production of the silk for the cocoon. Hence

they are found in mature female spiders before the eggs are laid in to the egg cocoon. The glands are tubular in outline with tall columnar epithelium similar to that of the cells in the secretory region of the ampullate gland. Externally, the glands are delimited by a layer of peritonium. The chitinous intima is absent in the secretory region.

The structure of the cylindrical glands in *Lycosa* appears to be similar to that of the secretory region of the ampullate gland, but the height of the cells in these glands is comparatively more. The entire gland is protected by a layer of peritonal membrane enclosing the basement membrane which appears fibrillar. Above this layer there is a layer of tall columnar epithelium and the cells are very broad at the base. The cytoplasm is thin and homogeneous with a large basal nucleus, Chromatin granules and the nucleolus are clearly visible. The structure of the cells appear to be uniform throughout without any variation in either height or staining. The lumen is narrow and uniform and the secretion when present stains bluish or bluish-red with haematoxylin eosin. The duct which arises from the base of the gland shows the usual three layers, the innermost layer of chitinous intima is prominent and thick.

The epithelial cells in the anterior secretory part of the cylindrical gland in *Hippasa* are slightly cuboidal with oval nucleus in the centre and vacuolar cytoplasm. The lumen is very small and narrow. The cells in the middle and posterior region of the gland are quite tall with a basal nucleus and a thin cytoplasm which stains faintly. The structure of the epithelium in the glands, which is devoid of secretion appears to be small, the cells are having small nucleus, the nucleolus but the presence of chromatin granules are not clear and thus it shows the reduction in the height of the cells and its activity.

The cylindrical gland in *Stegodyphus* are comparatively smaller in size and diameter. The epithelial cells rests on basement membrane protected by a layer of peritonium. The cells are uniform in their height throughout with small lumen. The nucleus is located at the base. Cytoplasm and the content of the lumen stains faintly and shows bluish red colouration with eosin. The structure of the duct is similar to the one described earlier.

The cylindrical glands in *Neoscona* which are six in number consists of a single layer of epithelial cells resting on the basement membrane, having

few interstitial cells. The cells are tall and columnar type, the nucleus is located at the base with a large central nucleolus. The nucleoplasm appears granular. In spiders, before the eggs are laid, the cytoplasm around the nucleus is clear but has large amount of granules at its apex and these granules stain blue. The cell membrane at its apex is very conspicuous and forms a circular lumen. The cells in the anterior region are small and more crowded with clear cytoplasm or occasionally showing few vacuoles. The posterior duct arises from the base of the gland and the chitinous intima is prominent.

The structure of the cylindrical glands in *Plexippus* appears to be very simple. The epithelial layer is very small with a oval nucleus. The lumen of the gland is very narrow and in most of the cases the lumen appears to be empty. Hence it is not certain whether they synthesise protein or the glands have exhausted its silk.

CRIBELLUM GLANDS :

Cribellum glands which are exclusively present in the social spider *Stegodyphus* are small and oval in outline. Histologically, these glands are very small, lined by a thin peritoneal membrane. The basement membrane is rarely visible and the epithelial cells are small and cuboidal with minute nucleus. The cytoplasm, chromatin granules and the nucleolus are rarely visible. The contents of the lumen stain intensely with the haematoxylin-eosin as well as Alcian blue-PAS method. The posterior ducts are minute and directly open on the surface of the cribellum.

AGGREGATE GLANDS :

Aggregate gland consist of numerous lobes of irregular shape connected with a small chitinous duct. The external connective tissue layer is very thin and often found obliterated. The basement membrane eventhough present is not clearly visible. The epithelial cells are tall and columnar and are closely arranged. The proximal part of the cells of the epithelial layer appears uniform or smooth. The nucleus is small, located centrally and often appears diffuse type. The cytoplasm is uniform without any granules and show great affinity for haematoxylin. The lumen of the gland is very large and it is obliterated at various levels due to the irregular lobes. The content of the lumen shows uniformity in staining and appears as thin layer of secretion.

The posterior duct has a very thin layer of peritonium and a layer of cuboidal cells. The basement membrane is difficult to observe. The innermost layer of chitinous intima is most prominent part of the duct. At various levels of the posterior duct, certain enlargements are noticed which are covered by a very thin membrane. These enlargements enclose a cavity containing homogeneous material and stains bluish. These are the external "nodules" which, according to Comstock (1940), are the precursors of the anterior lobes. As these nodules are present outside the duct it was not possible to visualise the mode of secretion of these nodules in the duct through the thick intima. In adult male spiders of *Neoscona*, these glands are found to be small and the epithelial layer is less clear.

DISCUSSION

Histological details of spinning organs are well revealed by Ehrlich's haematoxylin-eosin method with remarkable differentiation of nuclei and cytoplasm. Though various types of haematoxylin has been attempted, but still the method described above with either aqueous or alcoholic eosin is more ideal for the permanency of the slides and for histological and histochemical analysis,

As described earlier, the spinning glands in spiders are numerous in number, less voluminous except ampullate gland and occupies a major part of the opisthosoma. The glandular part of the various spinning glands show good differentiation of the cell layers. Externally, it can be distinguished by the presence of a layer of connective tissue or peritoneal membrane followed by a cellular layer and a layer of basement membrane sandwiched between these two. The lumen of the gland show slight variation in its width and it is filled with a secretory droplets which stains pink or red with haematoxylin-eosin.

The cells lining the lumen of the gland are organised into an anatomically differentiated areas separated by a layer of basement membrane and connective tissue. The secretory products are directly discharged into the lumen and accumulate there without any morphological or histochemical alteration. This accumulation of the secretory product in the lumen of the glands exhibit the glandular nature of the organ. In addition, histochemical investigation carried out reveal the functional significance of the product which help in the determination of the glandular nature of the cells.

The size of the cell normally vary depending upon the nature of secretion. It has been observed that the shape, size of the nucleus and its location vary perhaps due to the synthetic phase of the cell cycle. Normally the nucleus occupies the basal part of the cell with dark staining chromatin granules. The nucleolus inside the nucleus appears to be strongly eosinophilic and varies depending upon the secretory cycle. Abundance of the basophilic substance in the cytoplasm indicates that these are strongly acidic, thereby confirming the protein rich products. Further, this is confirmed by the mercuric bromphenolblue method. The secretory products normally accumulate at the proximal end of the cell and react positively with basic dyes. This accumulation of synthesised product in the cell some time may push the nucleus to the base and hence, the distribution of the synthesised material may not be uniform.

According to Brachet and Mirsky (1942), in many cases the secretory products are discharged into the lumen, soon after they are formed and this pattern is known as "continuous activity", as extrusion of the product, its formation inside the cell, absorption of the material from the environment, all takes place at the same time. However, in case of "rhythmic activity" where the cells exhibit certain differences due to the secretory nature which is separated by time, a period of absorption, intracellular elaboration of the product and accumulation followed by extrusion. In spiders, probably the latter seems to operate during the synthesis of the silk in the gland as quite often the glands seem to be empty and requires sufficient time for filling it up (Peakall, 1965).

Glatz (1972), described two main regions viz. containing strongly acidophilic and basophilic cells in the epithelium of the tubular glands of *Nemesia* and *Atypus*. Due to the presence of both types of cells in the same gland, he described such gland as "bi-partite" and concluded that all spinning glands of spiders have evolved from this separately or together in a single gland. Thus he classified the spinning glands into acidophilic, basophilic or bi partite.

The ampullate glands of all spiders studied are lined externally by a nucleated layer of connective tissue (tunica externa) enclosing the epithelial layer, however. the thickness of this layer vary at different parts of the gland. This layer reacts with PAS and show positive colouration indicating certain amount of carbohydrate or glycogen.

The secretory activity is comparatively more in the anterior part of the gland. The cells contain mainly granular cytoplasm which shows affinity for eosin. As a result of the secretion and accumulation of granules in the cell, the nucleus is pushed to the basal region and in many cases granules are seen crowding at the tip of the cell which ultimately may enter into the lumen.

The work of Peakall (1966) on the regulation of protein production in the silk glands of *Araneus sericatus* by injecting acetyl-choline and following it by autoradiographic method clearly demonstrates the incorporation of protein droplets throughout the epithelium within ten minutes by the resting glands. Afterwards, these droplets move towards the epithelium lumen boundary and within thirty minutes all the droplets are discharged into the lumen. This mode of synthesis appears to be same throughout the gland in the present investigation, which is well represented by the eosinophilic activity of the the cortical cytoplasm of the epithelial cells of the ampullate gland. But the mode of regulation of the silk in the gland is probably controlled by the central nervous system or by external stimuli or any other local character depending upon the amount of secretion present in the lumen.

The regulation of protein in spiders seems to be entirely different from that of *Bombyx mori*, as the similarities of silk spinning glands are only superficial. The silk worm produces cocoon once its life time and the process takes place several weeks whereas the spiders utilise the silk regularly. According to Witt, Reed and Peakall (1968) the regulation of protein in spiders is by cholinergic or emptying the gland or both.

Mullen (1969), while working on *Araneus sericatus*, observed that the secretory droplets of the glandular epithelium are released as discrete droplets into the lumen. It is postulated that the secretory droplets escape through the limiting membrane of epithelial cells into the lumen where they mingle up to form uniform mass. The condition appear to be same in the anterior secretory region, where the secretion released into the lumen stains uniformly with eosin. But there appears to be a difference in the region of the ampulla. In non orb weave spiders of *Lycosa nigrotibialis*, *Hippasa pisaurina* and the large ampullate glands of the social spider *Stegodyphus sarasinorum*, the content of the lumen differs markedly in the central and outer region. In these spiders the secretion is differentiated into a central dark staining area and an outer core of light staining area. This marked difference is mainly due to the additional substance secreted by the epithelial

cells of the ampullar region. The central core reacts strongly with basic dye namely eosin, thus suggesting a strong acidic group namely protein, which is further confirmed by the mercuric bromphenol blue. But the outer core is less acidic and this may be due to the basic secretion of the glandular cells of the ampulla. Further, this outer less stained area reacts positively with PAS and Alcian blue-PAS suggesting a carbohydrate group. If this principle is assumed, each filament of silk consists of a central core of protein supported additionally by the outercase of carbohydrate, which perhaps adds to the stickyness of the fibre.

Having assumed that each filament of fibre of spiders silk consists of a central core of protein covered by a layer of carbohydrate, poses a problem of explaining in the orb weaving spider *Neoscona* and non orb weaving spider *Plexippus*, where the product of secretion is mainly basic without differentiation into outer and inner core of silk. The deviation may be explained as the orb weaver, during the course of evolution have developed an additional gland namely the aggregate gland whose main function is the production of of a sticky substance to reinforce the radial threads of the orb web. This may also be true, in case of *Plexippus*, where the secretion stains uniformly without any differentiation into outer and inner core, as the spider does not utilise the silk from the ampullate gland for catching the prey but utilise only as a life line.

Based on the intensity of the staining reaction, the difference in the glandular secretion of the anterior, median and posterior ampullated gland of *Neoscona*, may also possibly suggest the difference in the chemical composition of the secretion, thereby, they are used differently in the orb web. This can be achieved only by analysing the gland and the various threads of the orb web. Anderson (1970), working on the amino acid of the *Araneus diadematus*, observed that the material from the large and small ampullate glands are clearly different. The large ampullate gland produces proteins which are rich in glycine, proline and glutamic acid where as the material from the small ampullate gland is rich only in glycine and alanine. Since *Neoscona* possesses three pairs of glands which considerably differ in the nature of secretion, the contents of the gland and the product need analysis of its chemical composition.

The occurrence of empty cavities in the ampullate glands may be viewed as the utilisation of the secretion for its web building activity. Further, the presence of secretion only in the lumen of median and posterior ampullate

gland may possibly suggest that the order of emptying of the silk differs considerably depending upon its functional significance. This observation in *Neoscona*, confirms the work of Witt, Reed and Peakall (1968), who have demonstrated histologically that both the web building and reeling of silk effectively empty the ampullate gland.

The present investigation in *Neoscona* and *Hippasa* has revealed that, the cells in the anterior secretory duct can be differentiated into two types. The first type of cells which are situated in the anterior most part of the ampullate gland are small, hexagonal with central nucleus and cytoplasm which appears to be empty or filled with vacuoles. The lumen is absent or small, if present. But the cells of the middle posterior region of the anterior secretory duct are tall with broad base and narrow apex, nucleus, nucleolus and chromatin granules are very clear and the cytoplasm is filled with granules. This difference may be attributed to the fact that the cells in the anterior region acts either as precursors for the cells which are synthesising or act as nurse cells providing necessary requirement for the rest of the secreting cells.

In *Lycosa*, *Stegodyphus* and *Plexippus*, the cells of the secretory region are uniformly tall with a basal nuclei and fine granules of cytoplasm. This may be attributed to the finding of Reichter (1970), who attempted to relate the production of silk threads during the life cycle of *Pardosa amentata* with observed changes in the state of the gland, in relation to the epithelium height, lumen breadth and size and abundance of the granules. According to him, during the first week after moulting the locomotory activity of males and females increase in relation with the feeding and mating, both the sexes produce more drag lines than before and this can be correlated with an increase in the breadth of the glandular epithelium.

Witt and Reed (1965), Witt and Peakall (1968) suggested the control mechanism seems to operate during the web building. Similarly, Peakall (1969), working on *Araneus sericatus*, found a structure in the ampullate gland that differed markedly from the glandular epithelium by having a regular lamellar appearance. This structure was tentatively called "receptor" Foelix (1971) attempted to determine the exact location of the receptor area, histological description and innervation of nerves in the ampullar glands. The present study clearly indicate the presence of "receptor" area, a swollen bulb like structure in the posterior region of the ampulla, where the duct arise.

The receptor is found in all three pairs of ampullate glands of *Neoscona* but are absent in all other species of spiders under investigation. According to Peakall (1968) this receptor area will feed back the information on the amount of protein present in the gland. As this structure is found in the storage region of the gland, where the silk is known to be in liquid form, the striated portion of the lamellae could possibly sense the change in the pressure or tension and the information which could be transmitted via peripheral cells of the nerve fibres to the central nervous system. Foelix (1971) demonstrated the innervation of nerve fibres in the receptor area of *Araneus diadematus* confirming that the feed back mechanism may exist in orb weavers.

The histology of the duct of ampullate gland has been thoroughly worked out by various scientists, to find out the exact location of the transformation of liquid silk into a solid one. The present investigation shows that the structure of the duct in all species of spiders investigated bear similarities with the exception of the length of the duct. The duct is enveloped by an outer connective tissue membrane having a layer of tall columnar epithelium inside. The nucleus is located at the base, the cytoplasm is thin and uniformly distributed. The chitinous intima is more prominent taking intense stain with eosin. This generalised structure appears to be same in all species.

The structure of the duct in various species of spider was first described by Apstein (1889) and he proposed that the transitional region between the gland and duct reveal nicely the beginning of the very strongly thickened intima. According to Peakall (1969), the distal portion of the duct of the ampullaceous glands in *Araneus sericatus* consists of tube of epithelial cells which appear to secrete a substance that forms the tunica intima of the duct wall.

The epithelial cells of the duct are quite unique in having a thin cytoplasm without granules and with a basal nucleus. Bell and Peakall (1969) while making electron microscopic studies of the glands of *Araneus sericatus* revealed that the sole function of the duct was to remove water as well as to deliver protein to the spinnerets. They further opined that the liquid silk loses 30-40% of its weight in the duct and this could be correlated to the lack of Golgi apparatus in the cell. In addition, many of the cytoplasmic organelles like mitochondria and ribosomes are absent,

Kovoor and Zylberberg (1972), working on *Araneus diadematus*, summarised that the ducts of the ampullate glands consisted of three segments surrounded by the same sheath of multilayered connective tissue rich in glycogen. Electron microscopic studies revealed that the epithelial cells are rich in microtubules and microvilli and the cuticular intima consisted of acid muco polysaccharides rich in the sub cuticle. According to these authors, the second and third segments seems to be related to the water absorption in the ducts. The present observation reveals only the PAS positive areas in the cuticular intima of the duct.

Findings of Wilson (1962, 1962a and 1969), working on the major and minor ampullaceous glands of *Araneus diadematus* reveals the presence of valves in the major ampullate gland duct, situated near the base of the spinneret, as thick cuticular lining, in which the inner cuticular lining forms the lips of the valve. These lips can be considered as a ring which can swell up or occlude the duct when the interlamellar spaces are filled with fluid under pressure. However, in orb weaving spider *Neoscona*, in the present investigation the valve, as described by Wilson op. cit. could not be seen even by serial sectioning of the duct. Further, the author is of the opinion that these valves are absent in Dictyniidae, Gnaphosidae, Clubionidae, Sparassidae, Pisauridae and Agelinidae, but present in *Tetragnatha*, *Meta* as well as *Araneus*. The probable explanation lies in fact that the drag line control valves is linked some way to the spinning of the orb webs and is found only in some of the highly evolved families of spiders.

It was Apstein (1889) who distinguished for the first time the aciniform and pyriform glands based on the shape of the gland. Histologically the glands are protected by an external peritonium, which is very thin and delicate and rather difficult to visualise. The epithelial cells possess large amount of cytoplasm filled with secretory granules, the nucleus is normally pushed towards the base. Due to the accumulation of the secretion, the structure of the cells is difficult to visualise, because they stain intensely with haematoxylin-eosin. As in ampullate gland, the secretory region is devoid of chitinous intima. The size of the cell and the lumen of the gland are comparatively small. The secretion of the gland stains intensely with the stain and thus it can be distinguished easily by this reaction.

Histologically two types of aciniform glands were distinguished by Mullen (1969). They are type-A which are round in shape with bright red

protein droplets filling the lumen and the epithelium consists of low columnar cells with large basal nuclei, nucleoli and this epithelium does not continue into the duct. Whereas type-B are generally larger with elongated anterior end. This type appear in the present investigation in the aciniform glands of *Neoscona*, where the former type of glands are more numerous with few of the latter type. Similar type of glands were observed in *Nephila clavipes* by Mullen (1969) and according to him type-B glands are more active in synthesising the silk whereas type-A glands are full and inactive.

Millot (1935) believed the aciniform glands in *Philaeus chrysops* to be similar to bi-partite glands with a small lumen and a posterior canal. According to him, the aciniform glands are structurally similar to the pyriform glands. Glatz (1972) considered the aciniform glands to be exclusively acidophilic and deduced from the basophilic portion of the pseudo aciniform glands. According to him, pseudoacini form glands carry a basal part which gives out acidophilic secretion.

Jackson (1975) presumed that the aciniform glands of the middle spinnerets may be contributing their share for the formation of the cribellar threads in *Stegodyphus*, probably the straight supporting threads of the cribellar thread. He was also of the opinion that the secretions of the aciniform glands in the male were utilised in the construction of sperm threads. Histologically, as it resembles the aciniform glands of Lycosid spiders, it is not certain whether they are actually involving in the formation of cribellar thread or not.

According to Mukerji (1973), the histology of the aciniform glands of non orb weaving spiders of *Heteropoda venatoria* and *Herselia savignyii* and even staining of the glands in these spiders appeared to be similar and acidophilic. In the present investigation, however, a clear difference is noticed in the aciniform glands of orb weavers and non orb weavers. Reichter (1970) while working on *Pardosa amentata* believed that the males show high degree of activity in the cells of the aciniform glands, one week after the final moult, but after construction of the sperm web, the secretion remains in the form of large granules in the gland. It is not known, the same is true in the case of *Lycosa*, and *Hippasa* also, as it needs further investigation, on the structure of the gland at various developmental stages.

In the present investigation, the cells of the aciniform glands are less clear due to the accumulation of the large amount of secretory granules. In a few cases the granules are freshly released into the lumen and they are found to be present in the form of fresh droplets not yet mingled with the previous accumulation. The contents are not demarcated into outer and inner zone similar to that of ampullate gland and we can presume that the content of the aciniform gland is same throughout, but contains more sticky substance for swathing of the prey.

The pyriform glands are enveloped by the peritonium comprising a glandular epithelial layer enclosing the lumen which is not lined by the chitinous intima. The structure of the epithelium is different in the anterior and posterior region and the intensity of the staining reaction differs considerably. The difference in the staining reaction in the anterior and posterior half of the glandular epithelium is probably due to the difference in the secretion of the lower and upper halves having a difference in the chemical composition. The cells of the anterior half are small and stains uniformly throughout, whereas the cells of the posterior half have more amount of secretory granules and thereby a strong affinity for the stain.

Millot (1936) considered these pyriform glands as bi-partite glands and resemble aciniform glands in *Philaeus chrysops* having different glandular cells in the anterior and posterior half. Mullen (1969) differentiated the pyriform glands based on the intensity of staining reaction into anterior and posterior half of the gland. The intensity of staining is more in the posterior region than that of the anterior region. Anderson (1970) believed that the material should be glue like as they are used in the formation of attachment disc with which drag line is fastened to the substrate. The analysis of its chemical composition indicate the same as the amino acid residues having small chains are not very abundant, whereas the polar and charged residues are present in large quantities with significant amount of proline. This composition confirms the analysis of the composition of the attachment disc of *Araneus sericatus* by Peakall (1968). According to Anderson op. cit., secretion of the pyriform gland significantly has excess of basic aminoacids over acidic ones and the secretion of pyriform glands dries up rapidly due to the high concentration of the hygroscopic low molecular weight compounds.

In the present investigation it has been found that the pyriform glands act as dual natured glands, due to the secretion which differs markedly in the anterior and posterior half. In the anterior region the lumen is small and

the basophilic epithelium is strongly developed and consists of cells upto the middle of the gland. In this region the nucleus is slightly irregular due to the accumulation of secretion and is located either in the centre or at the base. The cell boundaries are less clear and rarely recognisable. The cytoplasm appears to be empty some time or filled with small vacuoles. The basal half of the gland contains epithelium having larger granules in the cytoplasm with well defined cell boundary, the secretion of such cells are acidophilic in nature. The gradation from basophilic to acidophilic of the cells showing basophilic and acidophilic nature is obscure.

Glatz (1973) believed that secretion in these glands is composed of three layers, a central acidophilic secretion, external to it is a thin layer of acidophilic secretions of the transitional cells and above all an outer layer of thick basophilic secretion, but the middle layer of acidophilic secretion disappears. However, in the present investigation the three layers proposed by Glatz op. cit. could not be distinguished, however, the secretion shows only two regions.

Increase in the height of the cells in both the regions of the pyriform glands of *Pardosa amentata* from moulting to the cocoon construction was described by Reichter (1970). Further, he described increase in the amount and size of the granules in the cells after cocoon formation and all these granules were released into the lumen. He has also described the marked increase in the number of pyriform glands during the development of the female. The dual natured glands could not be distinguished but becomes more apparent as and when they grow to the adult.

In *Pardosa amentata* the attachment disc and the "broad trail" in the adult males and "Pseudo attachment disc" are generally ascribed to the pyriform glands. Reichter op. cit. is of the opinion that the secretion in male is utilised in the construction of the sperm web, whereas in female the pyriform glands are used in the construction of the silken cell with which cocoon is produced.

Jackson (1975) believed that the pyriform glands may provide the silk used for cocoon construction, as these glands are found degenerating in the non-secretory phase in the mother spiders. Since, the fore and median spinnerts are brought during the formation of attachment discs in *Stegodyphus*, it is probable that the secretion of the pyriform glands and aciniform glands are used in making attachment discs.

The cylindrical glands or tubular glands are found exclusively in female spiders of all species under investigation. The glands which are seen during the non secretory phase or during the immature stages of the female are very small and many times atrophied. Hence, in the sections of immature female or matured males, cylindrical glands are absent. The glandular epithelium of the cylindrical glands in general resembles that of the anterior secretory duct of the ampullate gland. The glands are having uniform diameter throughout with well developed external peritonym. The basement membrane is more clear in the synthetic phase and has oval vacuolar interstitial cells in *Neoscona*. The columnar epithelium are quite tall and the contents of the cell are found homogeneous and stain blue unlike aciniform or pyriform glands. The lumen is uniform throughout and contains secretion which stains more bluish. In many cases and especially in *Plexippus* the lumen of the gland is found to be empty indicating that the secretion has been utilised or represent the non synthetic phase of the gland. The absence of cylindrical glands in certain species of salticidae viz. *Segestria* may probably indicate that these spiders do not spin any egg cocoon.

The presence of such glands only in the adult females and devoid of secretion after cocoon formation clearly indicates that these glands are associated with cocoon construction as described in *Pardosa amentata* by Reichter (1970). According to him, the contents of the gland stains green when they are put in 70% alcohol but after cocoon construction the substance has disappeared in the gland. The green colour also appears in the newly formed cocoons of *Pardosa amentata* when exposed to air. It is suggested that the green colour substance originate from the silk of the glandular epithelium. According to Sekiguchi (1955), the absence of such glands in male spiders emphasises that they are only associated with cocoon construction in female.

Peakall (1965) found that the regulation of the cylindrical gland which are used in the production of silk for the cocoon is completely different from other glands. Uptake of labelled amino acids was not observed even after eight hours, whereas the aggregate and ampullate glands showed maximum incorporation of these contents. Further, the silk being used in the formation of cocoon, the gland does not refill at least within thirty days, according to Peakall (1965). Thus according to him the gland has neither cholinergic nor the local feed back mechanism in it, but that the sole function of the gland is the production of silk for the cocoon and it is likely that the silk production in them is regulated by hormones.

Very little attempts have been made by the earlier workers to study histological structure of the aggregate glands, due to its delicate nature. Apstein (1889) for the first time described these glands in *Epeira diademata*, consisting of several canals, which form together a round lobe. He further elaborated that the different passages are invested by numerous blind sacs which are filled with cell aggregations. These blind sacs were later studied by Mullen (1969) in *Araneus sericatus* and recognised these as "nodules". Thus the study on these glands were restricted to the structure of the duct only. The present investigation reveals the presence of membranous wall protecting the gland and a spacious lumen. The epithelial cells are tall columnar with a round nucleus. The contents of the lumen stain weakly with haematoxylin-eosin. The nodular cells are large and prominent with an oval nucleus and a basophilic cytoplasm. The glandular region is highly elaborate without any apparent division, into sac and tubular part, but has large number of lobules and each lobule has tall layer of columnar epithelium.

Presence of these glands have been established only in orb-weavers by Apstein (1889), Comstock (1940), Sekiguchi (1955) and Witt, Reed and Peakall (1968). These glands are involved in the production of sticky spirals of the orb-web. These are absent in non orb-weavers and in the present investigation it is found only in the *Neoscona mukuljei*. According to Sekiguchi op. cit., after the last moult, when males of *Araneus ventricosus* reach the sexual maturity and maximum weight, it stop building webs and the aggregate glands become vestigial in adult males. Peakall op. cit. has clearly shown that these glands are involved in the formation of catching area of the web. Ramousse (1973), demonstrated that the adult males are unable to spin webs because their aggregate glands are no longer functional. In the present investigation also, the adult males fail to reveal the presence of aggregate glands.

Cribellum glands are exclusively present in the social spider *Stegodyphus sarasinorum*. The structure of the glands has not been so far worked out. The present investigation reveals that the glands are bounded by an outer thin layer of peritonium enclosing the epithelial layer. Due to the tiny nature and the intense reaction of the cells with the stain the structure of these cells are less clear. The lumen of the gland is very small and always filled with secretion. The posterior duct arising from the gland directly open on the cribellum, a small perforated plate made up of two spinning fields. This plate is considered to be the homologue of the anterior median spinneret (Marples, 1967). The spinning field is covered by thousands of tiny openings which

gives a sieve like appearance from which emerges the exceedingly fine threads of viscid silk known as "hackled band" According to Kulmann (1972) and Fredrick and Langer (1969), cribellate sticky thread is different being composed of a cloud of very fine threads about 0.015 μ in diameter. Many authors like Comstock (1940), Gertsch (1949), Bristowe (1959) and Kastner (1969) have used the word viscid to describe the wet sticky silk of cribellate spiders.

The secretion of the ampullate glands is utilised in the formation of drag-line by all spiders. Usually, this supporting thread consists of double filament released by the spigots of the anterior ampullate glands. This drag-line is further strengthened by the additional secretion of the remaining ampullate gland. Thus the silk of the ampullate gland is utilised by spiders as supporting threads, ballooning threads or the outer frame work and the radii of the orb-web. The spiral threads of the orb-web are very sticky and extremely elastic for capturing insects. Usually, these elastic fibres consist of two filaments. It is generally accepted that the aggregate glands contribute to the sticky threads. According to Anderson (1970), the material present in the aggregate gland is not really silk but could function as glue. Hence the viscid fluid is produced by the aggregate glands of orb-weavers. Aciniform glands are assumed to produce the silk used by the spiders for swathing the captured prey and the pyriform glands are supposed to produce the material used for attachment disc with which the drag line is fastened to the substrate. The cylindrical gland, which are present only in the female spiders contribute silk to the construction of cocoon. Finally the cribellum glands secrete hackled band of cribellate silk, which is more sticky.

Despite a specific assignment of each gland and its role of its secretion, variations have been noticed in respect of the functional morphology in various species of spiders as is evident from the foregoing discussion. Therefore, it may be concluded that though the secretion of the gland, normally performs definite function, but on occasions many glands and their secretions may be involved in performing the different life activities. This interchangable ability may be inherent and in-built.

MORPHOLOGY OF THE EXTERNAL SPINNING APPARATUS MORPHOLOGY OF THE SPINNERETS

The external spinning apparatus in spiders consists of spinnerets and tarsal claws. The spinnerets are usually three pairs situated on the ventral surface of the opisthosoma in front of the anus. In few spiders, addition to the spinnerets, a flat spinning organ namely cribellum is present. The spinnerets are provided with spigots for discharging the silk from the ampullate glands and spinning tubes for carrying secretion of the aciniform, pyriform and cylindrical glands. The location and the structure of the spinning field on the spinnerets are very important in the web building activity.

The spinnerets in *Lycosa* are situated at the extreme posterior end of the opisthosoma in front of the anus and consists of three pairs (fig. 41). The anterior spinnerets are tubular, consisting of two segments measuring 0.8-1.2 mm. Of the two segments, the basal segment is the largest having a circular base tapering anteriorly. The upper segment is circular having a chitinous ring at its margin and a row of hair. The chitinous hairs are more crowded at the base and also surrounding the spinning field. The spinning field present at the tip of the spinnerets form a hollow cup at its ventral side. On the spinning field, two spigots, of which one is larger and a smaller one is present. The larger one has a cylindrical base and a small tube, the smaller spigot present adjacent to the larger one has a smaller base and a smaller tube. The spinning field has spinning tubes of type-I in the margin and type-II in the centre.

The median spinnerets, the smallest of the three are unjointed, cylindrical and measures 0.5-0.6 mm. Chitinous hairs are present on the surface of the spinnerets. The terminal part of the spinneret has a spinning field and is without any chitinous ring but has large number of plumose hair. The spinning field is located on an elevated outer border and a narrow ventral margin. The median spinneret has a single spigot of type-I surrounded by spinning tubes. The spinning tubes are comparatively fewer in number and especially in male the number of spinning tubes are very much limited, thus there seems to be a difference in the number of spinning tubes in different sexes.

The hind spinnerets is the largest of the three and is two jointed, connected by arthroidal membrane and measures 1.0-1.3 mm. A ring of chitinous hairs are present in the region of the joint between upper and lower segment.

The basal segment is the largest of the two and measures 0.5-0.6 mm at its outer margin. The posterior spinneret is characterised by the absence of the spigot but has spinning tubes which are directed centrally. The spinning tubes of type-I are at the margin and type-II centrally. Further, variation in the number of spinning tubes are noticed at different stages as well as in different sexes.

The structure of the spinnerets in *Hippasa*, resembles that of *Lycosa* in most of the respects, as both are terrestrial and hunting (fig. 42). But *Hippasa* constructs a funnel web on grass or on open spaces adjoining the shrub. The anterior spinnerets are made up of two segments connected by arthroidal membrane. Large number of plumose hairs are present all over the spinnerets. The anterior chitinous ring has a row of hair. The spinning field is located at the tip of the upper segment and forms a concavity. The number of spinning tubes increases from periphery to the centre, the spinning tubes are directed centrally. The spinning field at its ventral margin shows a small furrow in which two spigots are situated. Of the two, one is larger and the other is smaller. The spinning tubes are type-I and type-II. The latter type of spinning tube are more crowded surrounding the spigot.

The median spinnerets are the smallest, triangular with a broad base facing outwards and a narrow ventral part. The spinnerets are single segmented covered with plumose hairs. A single spigot of type-I is present in its ventral margin and the spinning tubes surrounding it are of type-I and type-II.

The posterior spinnerets are the largest of the three and consists of two segments. The terminal segment is larger than the basal one and has large number of hairs and bristles at its extremity. Unlike the anterior one, the spinning field is located on a small hump which slopes towards the ventral side. Spigots on the posterior spinnerets are absent but has large number of spinning tubes of type-I and type-II. A marked difference in the number of spinning tubes has been observed in different sexes.

The members of Lycosidae exhibit parental care to the maximum extent. Observations on the breeding mechanisms has revealed that the eggs are deposited at night and are not shed to the mercy of nature, rather enclose all of them with a thick tuft of silk forming the egg cocoon. The egg cocoon of *Lycosa nigrotibialis* is white, transparent when laid but becomes dense as spiders spin more silk during the incubation. The egg cocoon consists of two halves connected by a separate band of silk forming the seam. The

spider retains the egg cocoon below the abdomen connected by means of a silk thread to the spinnerets and the spinning activity continue till the emergence of spiderlings. This condition appears to be same in case of *Hippasa pisaurina* also, but the difference being in the number of eggs laid in the cocoon as well as the period of incubation.

The cribellate spider *Stegodyphus sarasinorum*, leading a social life, possesses a flat spinning organ namely the cribellum in front of the anterior pair of spinnerets and the total number of spinnerets are three pairs as in others (fig. 43). The anterior pair is the largest of the three and measures 0.8-1.2 mm in length on its outer margin. These are more or less cylindrical in outline. The anterior pair is three jointed and joints are connected by a thin arthroidal membrane. The terminal part of the spinneret moves freely and at its tip has the spinning field on a slightly elevated part provided with spigots and spinning tubes. The entire spinnerets are clothed with plumose hair and long barbed hairs near the chitinous ring. The spigots in the anterior spinneret is the largest with a swollen basal part and with a small, conical anterior tube. In addition to this a few more spigots of smaller size occurs, leading from the smallest ampullate glands. Each spinneret possesses two large and four small spigots in mature females. The spinning tubes are small with slightly swollen base and a long terminal part and are crowded on the periphery of the spinning field. Associated with this are spinning tubes of type-I and type-II.

The median spinnerets are located in between the anterior and posterior pair of spinnerets and these are the smallest measuring 0.3-0.4 mm at its outer margin. Median spinnerets are made up of a single unjointed segment without any chitinous ring or separate spinning field. The spinning tubes are of type-II and type-III and in addition it has six spigots in matured female.

Compared with the anterior one the posterior spinnerets are smaller in size and has two segments, which are of unequal length. The basal segment is larger than the terminal part but total length of the spinneret is 0.7-0.8 mm. The spinning field is without any chitinous ring, but has long hairs all over. The spigots of type-III are present in the spinning field and they are four in number. The spinning tubes are also of type-III. The posterior spinnerets are characterised by the presence of ducts from the ampullate glands and pyriform glands.

Cribellum present anterior to the first pair of spinnerets as a big transverse plate, divided into two equal halves by a small furrow. It is perforated by large number of minute pores appearing like a sieve and each pore represents the opening of the cribellum gland. The function of this plate is very clear when the spider is spinning. The silk coming out of the glands through the pores form a ribbon and this ribbon of silk is combed out of the cribellum with the help of IV legs and also with the help of Calamistrum situated on the metatarsus of the leg. The silk expelled from this are very sticky assisting the spider in catching the prey forming a net.

The spinnerets of *Neoscona* forms an important part on the ventral surface of the abdomen. Unlike other spiders, the spinnerets are shifted to more anterior part of the ventral surface for the effective spinning of the orb web. Due to its position, these spiders are classified as mesothelae, whereas all other spiders under investigation are recognised as opisthothelae. Further, the spinnerets have achieved the highest degree of mobility by reducing their height and also the development of good musculature inside. The difference in male and female is easily recognisable by the number of spinning tubes. The entire group of spinnerets are located in a small circular area on the ventral surface forming a conical protruberance. *Neoscona* possesses three pairs of spinnerets and the cribellum is absent.

The anterior pair of spinnerets are the largest, tubular with a broad base and a narrow apex. From the top it appears as a conical protruberance. The anterior pair measures 0.7-0.9 mm and consists of three joints connected by the arthroidal membrane. The basal segment is the largest and measures 0.5-0.6 mm and the second segment fits inside it and rarely recognisable. The terminal segment is small, circular moving freely on the second segment. The terminal part of the basal segment, the median segment and the chitinous ring of the upper segment bears a row of hair in the form of circle. The spinning field in *Neoscona* is located on the ventral surface of the terminal segment with a distinct chitinous ridge and a deep furrow on its ventral side. In this furrow two well developed spigots open on a small chitinous protruberance. The spigot has a broad base and an anterior tube and belong to the type-I. The spinning tubes found on the peripheral region of the spinning field has long ducts and are type-II and the spinning tubes of the central area are of type-III.

The median spinnerets are wedged between the anterior and posterior pair and is the smallest, more or less triangular in outline, with a broad base pointing outside and a narrow terminal part ventrally. The spinnerets lack chitinous ring but has spinning field at its outer margin. The middle spinnerets has two spigots with a broad base and a long tube of type-I and of type-III, surrounded by large number of spinning tubes of type-II and type-III. The median spinnerets measure 0.5-0.6 mm at its outer margin.

The posterior spinnerets of *Neoscona* is more or less of the same height that of anterior spinneret, conical in outline measures 0.6-0.8 mm. The posterior spinnerets has two segments, the basal segment is the largest. The terminal part moves freely, has an outer broad edge and an inner narrow edge having field in this depression. The spinning field has five spigots, three larger and two smaller, the former of type-II and latter of type-III. Spinning tubes surrounding the spigots are numerous, marginal one belongs to type-II and the central one are of type-III.

Three pairs of spinnerets have been recorded in *Plexippus* situated in front of the anal opening (fig. 44). The spinnerets are more tubular in outline. In addition to the spinnerets, an additional structure associated with the spinnerets, is the colulus, representing a vestigial structure. The basal surface of the colulus is covered by few hairs and thus the entire structure looks like an onion from the top. Thus *Plexippus* differs from others in having colulus.

The anterior spinnerets are the largest measuring 0.8-1.0 mm with a long basal part and a smaller anterior segment connected by arthroidal membrane. At the junction of two segments a row of chitinous hairs are present. The spinning field located at the tip of the anterior segment is triangular with a deep furrow on its basal region and in this furrow two spigots are present. Surrounding the spigot, the spinning tubes of type-II are present but the spinning tubes of type-III are distributed in the periphery. The spinning tubes of type-III are very small.

The median spinnerets, smallest of the three pairs, are almost rectangular in outline. It consists of a single piece with a flat spinning field. The median spinneret is characterised by the absence of any spigots. The spinning tubes are small and are of type-II and type-III. The median spinnerets measures 0.3-0.5 mm.

The posterior spinnerets, slightly smaller than the anterior one and are made up of two segments and the entire spinnerets measure 0.6-0.7 mm. The terminal part of the posterior spinneret is prominent, elevated and hump like having spinning field at its top. The spinning field does not show any furrow like that of the anterior spinnerets. Unlike the other non orb weaving spiders, the posterior spinneret has a single large spigot of type-I. At the margin of the spinning field a row of long bristles are present. The spinning tubes are of type-II and type-III. A difference in the number of spinning tubes in different sexes has been observed.

HISTOLOGY OF THE SPINNERETS :

The spinnerets are protected externally by the chitinous cuticle and this covering is resistant to many of the reagents and thus offers protection to the spider. In sections treated with Mallory's triple stain, three different layers can be differentiated viz. an outer layer of epicuticle, a median layer of mesocuticle and an inner layer of endocuticle. The colour of the spinneret is mainly due to the pigmentation of the epicuticle. Inner to this layer of cuticle, is a layer of muscles, which of course cannot be differentiated into circular and longitudinal layers.

Of the various spiders under investigation, *Hippasa* appears to possess a very thick cuticle whereas the *Neoscona* is having the thinnest. The segments of the cuticle is connected by a thin membrane, arthroidal membrane, assisting in the mobility of the segment.

The muscular system which is poorly developed in spiders is represented by a longitudinal ventral muscle, running below the internal organs of body cavity, ends up in the spinnerets. This is the only musculature worth mentioning in the opisthosoma and this probably controls the movement of spinnerets. This musculature is very important as the silk glands are not supplied and assisted by any muscle and probably the muscles of the spinnerets control the movement of the silk gland also. The longitudinal muscle running below the nerve cord in the abdominal region divides into two halves in the region of the anterior spinnerets and run on its outer and inner surface. According to Brown (1939), these halves represents the compressor and protractor muscles. These muscle bands run upto the second segment of the spinneret and helps in the elevation and contraction of the upper segment.

The musculature of the median spinneret is poorly developed and does not innervate up to the tip of the spinneret. It is only in *Neoscona*, the median spinneret exhibit a small muscle band at the base. The posterior spinneret is also supplied by the muscles of the longitudinal ventral muscular trunk, which bifurcates at the base of the spinnerets into protractor and retractor muscles. The muscles in the posterior spinneret well developed and run upto the second joint and assist in the backward and outward movement of the spinnerets. In the present investigation, this generalised arrangement of musculature appears to be same in all species, however, the musculature in the spinnerets of *Plexippus* are small and poorly developed.

Associated with the muscle band, cross section of the spinneret reveal large number of posterior ducts of various spinning glands. Among these ducts, the ducts of the ampullate glands and the ducts of aggregate glands in *Neoscona* are very prominent. But the ducts of the aciniform glands, pyriform glands and cylindrical glands are comparatively small and usually occur in the form bundles. These ducts are found to enter into their respective spigots and spinning tubes. In the orb weaver *Neoscona*, fail to reveal any thickening in the cuticular lining of the duct of the ampullate gland. The duct of the ampullate gland is clear with an outer connective tissue layer, a median epithelial layer and an inner layer of chitinous intima enclosing the lumen. The section of the lumen, as it is small and fine, fail to reveal the different layers of silk core but continuity of the silk is maintained throughout. The ducts of the aggregate glands are very prominent by having a thick intima and an outer layer of nodule.

The terminal part of the spinneret bearing the spinning field shows the structure of the spigot and the spinning tubes. Each spigot has a basal swollen part and a long tubular anterior chitinous part. The entire lumen of the spigot is found to enclose secretion. The spigots are surrounded by a prominent base. Except for the difference in the arrangement of spigots and spinning tubes, the structure of the spinnerets in various species appears to be same.

Table showing the number of spigots and spinning tubes in mature female spiders

Spider	Spinneret	Type of spigot			Type of spinning tube		
		Type-I	Type-II	Type-III	Type-I	Type-II	Type-III
<i>Lycosa nigrotibialis</i> Simon	Anterior	1	1	-	14-18	21-33	-
	Median	1	-	-	10-12	22-28	-
	Posterior	-	-	-	11-15	24-32	-
<i>Hippasa pisaurina</i> Pocock	Anterior	1	-	1	9-12	6-12	-
	Median	1	-	-	10-13	15-19	-
	Posterior	-	-	-	15-27	18-25	-
<i>Stegodyphus sarasinorum</i> Karsch	Anterior	1	1	4	15	16-19	15-19
	Median	1	1	4	-	14-22	12-22
	Posterior	-	-	4	-	13-27	18-25
<i>Neoscona mukerjei</i> Tikader	Anterior	2	-	-	-	48-68	13-20
	Median	2	-	1	-	41-63	11-23
	Posterior	-	3	2	-	37-49	15-29
<i>Plexippus paykullii</i> (Aud.)	Anterior	2	-	-	-	4-6	3-5
	Median	-	-	-	-	5-8	2-6
	Posterior	1	-	-	-	4-8	3-5

Table showing the number of spigots and spinning tubes in mature male spiders

Spider	Spinneret	Type of spigot			Type of spinning tube		
		Type-I	Type-II	Type-III	Type-I	Type-II	Type-III
<i>Lycosa nigrotibialis</i> Simon	Anterior	1	1	-	9-12	13-26	-
	Median	1	-	-	13-19	16-20	-
	Posterior	-	-	-	10-16	15-23	-
<i>Hippasa pisaurina</i> Pocock	Anterior	1	-	1	4-10	8-12	-
	Median	1	-	-	3-8	6-13	-
	Posterior	-	-	-	5-11	9-14	-
<i>Stegodyphus sarasinorum</i> Karsch	Anterior	1	1	-	-	8-18	16-19
	Median	1	1	4	-	11-23	9-17
	Posterior	-	-	4	-	7-16	12-18
<i>Neoscona mukerjei</i> Tikader	Anterior	1	-	-	-	23-28	8-12
	Median	2	-	-	-	22-32	10-14
	Posterior	1	3	-	-	28-38	13-23
<i>Plexippus paykullii</i> (Aud.)	Anterior	2	-	-	-	2-3	3-4
	Median	-	-	-	-	2-3	2-4
	Posterior	1	-	-	-	3-5	2-4

DISCUSSION

The only abdominal appendage present in spiders are the spinnerets, which acts as accessory spinning organ. These are usually located at the end of the abdomen on the ventral surface in front of the anus. In few spiders, in addition to this, a flat spinning organ namely cribellum is present. Thus the spiders are classified into cribellates and ecribellates based on the presence or absence of cribellum. In most of the spiders the number of spinnerets are three pairs, however, the number may vary in few species. In addition to this, the relative length of the spinnerets and their location also vary and this seems to be related to the method by which the silk is utilised. The tip of the spinnerets contain the spinning field having spigots and spinning tubes through which the fluid silk is expelled.

The external spinning apparatus consists of usually three pairs of spinnerets at the extreme posterior end of the opisthosoma. Such of those spiders which have this type of arrangement is said to be opisthothelae, to which *Lycosa*, *Hippasa*, *Stegodyphus* and *Plexippus* belong. In orb weaver, *Neoscona*, the spinnerets are shifted on the mid ventral surface close to the book lungs. Such spiders are said to be mesothelae. Further, based on the presence or absence of cribellum, spiders are classified into cribellatae and ecribellatae. *Stegodyphus* belong to the former type where as rest of the spiders are ecribellates.

As a result of terrestrialisation of arachnids, structural modification took place and according to Marples (1967) the spinnerets of spiders are considered to represent the fourth and fifth pair of abdominal legs, which has acquired biramous form at an early embryonic period like primitive appendages of crustacea. Hence, in Liphistomorphae, the primitive number of eight spinnerets are present occupying the middle of the lower surface but only four exopodites are active.

In true spiders, only six spinnerets are present, the four large ones are being derived from the exopodites of the fourth and fifth pair of abdominal appendages, while the middle spinnerets are derived from the endopodites of the fifth pair. In cribellate spiders the anterior pair is still retained as cribellum. According to Gertsch (1949), whether cribellum is a new

development from the antero-median spinneret or represents the ancestral condition of all true spiders, is a debatable question.

Of the three pairs of spinnerets found in various species of spiders, the anterior spinnerets have three segments in *Neoscona* and *Stegodyphus* but in *Lycosa*, *Hippasa* and *Plexippus* have two segments. The segments are interconnected by arthroidal membrane, which is very thin and assisting in the free movement of the segments. The median spinneret is the smallest of the three pairs and are single segmented having the spinning field at its tip. The posterior spinnerets, which are comparatively well developed has normally two segments and the spinning field is located at the tip of the terminal segment.

The orb weaver spider, *Neoscona* has well developed three pairs of short and stout spinnerets, the spinning field are provided with large number of spinning tubes. In contrast, *Plexippus*, a non orb weaving spider, mainly dependent on its sight and speed of the limbs, has also three pairs but the spinning field is poorly developed. The members of Lycosidae *Lycosa* and *Hippasa* have three pairs of spinnerets, but in these the posterior pair is the largest and has more hairs and bristles on the tip of the spinnerets than the spinning tubes. This is because of the reason, these spiders are mainly ground dwellers with elaborately arranged sensory system, in addition to the spinning tubes. In *Stegodyphus*, of the three pairs, the median is the smallest and the anterior and posterior pair are more or less of equal length and in addition has a flat spinning organ, cribellum.

The relative length of the spinneret are found important in the spinning activity. In all orb weavers, the spinnerets are short and are close to the mid ventral surface and all the spinnerets are involved in the orb web construction. In few spiders, the spinnerets are not much utilised in the spinning activity and hence the relative length has increased, these mainly act as tactile organ. This is noticed in *Herselia*, where spinnerets are extremely long and act as tactile organ. In this species the last segment of the posterior spinneret are as long as abdomen and the spinning field is poorly developed. Bristowe (1930) considers this specialisation for catching prey by running round it with extreme rapidity and emitting sheets of fine silk from the long spinnerets. In *Cryptothelae*, the spinnerets are hidden in mammillary hollow, from which it can be extruded or withdrawn.

The terminal segment of all spinnerets are characterised by the presence of spinning field containing spigots and spinning tubes. The spigots discharge silk from the ducts of ampullate glands and aggregate glands and the spinning tubes discharge silk from the ducts of aciniform, pyriform and cylindrical glands. The largest spigot is conical in shape and more constant in number and position. The spinning tubes which are more in number are scattered all over the spinning field, are classified into several types based on the nature of the duct and its base. The first type, type-I, has a cylindrical base and a long narrow pointed cylindrical tube. The apical part is longer than the basal part. The type-II has a short and a rectangular base, smaller than the filamentous type with an apical tube which is not pointed. The type-III, has a long tapering basal part whose tip of the apical part is not pointed.

The arrangement of spigot and the spinning tube vary in different species. In *Lycosidae*, the type-I tubes predominates and are located at the margin of the spinning field. The type-I in *Hippasa* and *Lycosa* corresponds to the ducts of the aciniform glands. The type-II are associated with pyriform glands. It is not certain, whether the cylindrical glands utilise different type of spinning tubes during cocoon formation or not, as it is difficult to recognise a third type on the spinning field. In *Stegodyphus sarasinorum*, the type-I is present on the anterior spinneret, the type-II are distributed on the anterior, median and posterior spinnerets and type-III are present on the median and posterior spinnerets. In contrast to the *Lycosids*, the type-III are associated with aciniform glands, the type-II are associated with pyriform glands and type-I are associated with cylindrical glands. In *Neoscona*, the anterior spinnerets are having spinning tubes of type-II and III. This appears to be same in median and posterior spinnerets also. In *Plexippus*, they have only few spinning tubes of type-II and III in the anterior, a median and posterior spinnerets. In *Neoscona*, the type-II are associated with pyriform glands and type-III are associated with aciniform glands but in *Plexippus* the type-II are associated with aciniform glands and type-III are associated with pyriform glands.

In *Lycosidae*, three spigots have been identified, two on the anterior spinnerets and one on the median spinneret, thus they correspond to the three pairs of ampullate gland. Though in adult, only two pairs of ampullate glands are identified and the third one which develops and later regresses is still represented by a spigot on the anterior spinneret and may be vestigial in adult animals.

In *Stegodyphus*, the anterior spinnerets has two spigots of type-I and type-II leading from the ducts of large red and median red ampullate gland and four pairs of type-III from the small red ampullate glands. The median spinneret has a pair of type-I leading from large yellow ampullate glands, a pair of type-II from median yellow ampullate glands and two pairs each of type-III leading from small red and small yellow ampullate glands respectively. The posterior spinnerets has four pairs of type-III, two leading from small red ampullate glands and the other two pairs from small yellow ampullate glands. In *Neoscona*, the anterior spinneret is characterised by the presence of large spigot of type-I carrying the ducts of anterior ampullate glands, the median spinneret is having three spigots, two of type-I and one of type-III, the former representing the duct of median and posterior ampullate glands and the latter representing the ducts of cylindrical glands, in female and the type-III are absent in adult male. The posterior spinnerets have five spigots-three of type-II carrying the ducts of aggregate glands and two of type-III connecting the ducts of cylindrical glands in female. It is only in this spider that a clear spigot of smaller nature has been identified for discharging the secretion of the cylindrical glands.

In *Plexippus*, two spigots of type-I are found in the anterior spinnerets and one in the posterior spinnerets, representing the three pairs of ampullate glands. This spider differs from others in lacking the spigot on the median spinneret and its presence on the posterior spinnerets.

The number and arrangement of spigots on the spinnerets of various spiders under investigation are found to be same in different sexes except for the male *Stegodyphus* species, which have four spigots of type-III less than that of the number found in female. This is mainly due to the presence of only four pairs of small red and four pairs of small yellow ampullate glands, whereas in female an additional four pairs of red ampullate glands are present. However, the number of spinning tubes are found to vary in different sexes. This difference in the number of spinning tube is mainly due to the less number of spinning glands in male than that of female and this may be associated with the under utilisation of silk in male spiders.

Investigation on various spider revealed that the number of spigots remains same in different sexes but the number of spinning tubes vary. Further, the number of spigots corresponds to the number of ampullate glands of the spider. But in *Neoscona*, additional spigots which are found is due to the presence of cylindrical and aggregate glands. The situation

appears to be similar in spinning tubes also, but investigation reveals slight variation in the number of spinning tubes and this is mainly due to the number of spinning glands varying at different developmental stages. However, it more or less confirms the findings of Peters (1955), Mikulska (1966) and Mukerji (1972) who also observed that the number of spigots and spinning tubes corresponds to the internal spinning organ and each spigot being the opening duct of one gland.

Histological description of the spinnerets in various spiders show more or less same structure except for the thickness of the cuticle and the difference in the number and arrangement of spigots and spinning tubes. The anterior and posterior pair of spinnerets are innervated by the division of the ventral longitudinal muscle band which elevates and depresses or assist in the rotary movement of the terminal segment assisting in the spinning activity. In addition it may also aid in discharging the secretion of the spinning glands as the glands are not invested by any musculature. The musculature in the median spinneret is poorly developed, which clearly shows that these are less employed in the spinning activity.

The presence of large number of hairs and bristles in the members of Lycosidae and cribellate spiders indicate that these structures are tactile and chaemosensitive, similar to the tarsal claws and the distribution of this may be associated with the ground dwelling and hunting activity.

LEGS AND TARSAL CLAWS

The evolution of spiders is mainly attributed to the variety and expertness of their use of silk. The silk produced by the silk glands is expelled through the tiny ducts of the spigots and spinning tubes present on the spinning field of the spinnerets. The effective utilisation of the silk by the spiders mainly depend upon the employment of the tarsus of the leg in the manipulation of the silk, during the construction of the orb web or hunting and wrapping the body of the victim with silk. Since, the legs and tarsal claws are associated with the various manipulation of the silk of spiders, the present investigation on this structure was found inevitable to be included as the accessory spinning apparatus of the spiders.

On the lateral side of the cephalothorasic region, four pairs of legs are present forming four pairs of appendages, which are normally designated as I, II, III and IV from the front. The legs of spiders are always eight in

number and consists of following segments viz. coxa, trochanter, femur, patella, tibia, metatarsus and tarsus. The segments are interconnected by transparent intersegmental membrane, which helps in the relative mobility of the segments. The coxa is firmly fixed to the sternum of the body. According to Manton (1973), this may perhaps be, to increase the leg length and need for stability. And also, alone in the animal kingdom, arachnid stepping does not involve a promotor-remotor swing of the leg base on the body. Of all segments, the tarsus is the only segment which moves freely. This generalised description is found in all species of spiders.

It is customary of all arachnologist to recognise the relative length of the legs and to express them in the form of a leg formula. In *Stegodyphus sarasinorum*, the leg formula is 1 4 2 3. Here the first pair of legs are the longest and third pair is the shortest. Similarly in *Neoscona*, the third pair assumes an unusually shortest length and this may be related to the function in handling the silk. Hence the leg formula in *Neoscona* is 4 1 2 3. In contrast *Lycosa* has the leg formula of 4 1 3 2 while *Hippasa* has 4 2 3 1. In *Plexippus*, the leg formula is 1 2 4 3.

Normally in *Neoscona*, the fourth leg is utilised in the manipulation of the silk strand from the spinnerets during the orb web construction, the leg III is utilised in winding up of the unwanted silk into a convenient ball and assisting in spacing of the radial and spiral threads, while the leg-I and II are primarily used for climbing and holding of the threads of the web. In case of jumping spider, *Plexippus* the legs are of moderate length, the first pair is unusually longer and thicker and assists in running and leaping. The long legs of *Lycosa* and *Hippasa* normally help in hunting as well as the construction of the funnel web in the latter species. In orb weavers and in the present investigation, in *Neoscona*, the length and web size follows a parallel course and it appears that the length of the leg somehow determine the extent of space to be occupied by the web.

According to Witt and Reed (1965), the accurate movement of the legs not only help in locomotion and catching the prey but is also essential in testing the distances. The spacing of the radial and spiral threads appear to require certain manoeuvres. Deprived of one leg or two ipsilateral legs have grossly irregular angles during the web building. This may also be true in *Neoscona*, as the construction of the orb web is more or less similar to that of *Araneus*.

The legs of spiders help in locomotion as well as in guidance during the placement of spiral threads in orb weavers and especially leg-I is utilised in probing. In *Neoscona* a typical orb weaver, the leg-IV pulls the thread from spinnerets as the body of the spider passes from one attachment to the other point on the radius. During this, the inner legs stretch the thread close to the attachment point. Witt (1963), Witt, Reed and Peakall (1968) while working on the web building behaviour of *Araneus diadematus* and *Araneus sericatus* have shown the importance of the legs during the web building. According to them, the first leg has measuring as well as locomotory function while the second leg can partly substitute for the measuring function. According to Marples (1967) and Eberhard (1977) orb weavers in general ingest the loose silk which has resulted from thread breaking activity, during this the leg-II and III help to pack the cut end of the loose silk and wrap it into a bundle of silk in the shortest possible time for ingesting into the mouth.

In orb weavers, when the prey falls into the web, it produces a vibration in the web, either due to the struggling of the prey or due to its impact and these vibrations are carried through the threads into the spiders body sitting in the hub. The location of the prey in the web often involves the pulling of the thread with the help of leg-I. The spider reaches the spot at the shortest possible time and touches with the leg-I or with the palps before attacking. Chaemoreceptors and tactile receptors abound on the tarsi and palps of the spider legs, help in probing the prey. Foelix (1970) suggests that the discrimination of the prey type may occur at this stage. Robinson (1969) obtained evidence for the tactile discrimination at this stage by showing that both *Araneus diadematus* and *Argiope argentata* could distinguish between lepidopteran and other insects after touching them with the legs and palps.

Plucking and jerking of the radial threads has been observed with the help of leg-I and occasionally leg-I and II are involved, during which the radial threads are pulled. This is followed by shaking of the web which normally involves leg-I and II in the downward direction. However, immobilisation of the prey occurs by biting during which the prey is grasped with leg-I, II and III and spiders appear to bite the nearest or most readily accessible part of the insect body. During this act, the prey is held in II or II and III legs. After immobilisation, the spider wraps the body of the victim with the help of silk and these are assisted by leg-IV.

During the wrapping of the prey, the spider retains its hold with the web by leg-I. The prey is either moved or held in its position by the leg-II and leg III and finally the leg IV assists in wrapping the prey. Mostly the prey is carried to the hub with the assistance of the thread from the spinnerets held by one or both the leg-IV. Holding with the leg-IV may prevent the insect from swinging side to side and becoming entangled in the radial threads. During feeding the leg-III will hold the prey while leg-I and II are assisting the spider in balancing on the web.

In *Stegodyphus sarasinorum*, the IV pair of legs have towards their innerside, a row of thin spines directed towards the outer side of the leg at an inclined angle to the leg surface. This row of dark coloured stiff hairs form the 'calamistrum'. The leg-IV having the calamistrum moves over the spinnerets and cribellum, the silk from the cribellum is ejected at this stage. This combing motion results in the production of a coiled mass of threads and thus a hackled band of silk is formed.

The terminal part of the tarsus of the leg has a slightly elevated hump on which two tarsal claws are present, which are variously modified at their ventral margin. These are the paired claws. In few cases, an additional median claw is present. The presence or absence of median unpaired claw forms the part of taxonomic importance, as the spiders are classified into two clawed and three clawed hunters. The importance of the tarsal claw can be well understood, as the spider always grips the web lines with the help of tarsal claws and normally with the exception of the calamistrum and spinnerets, the spider never touches the web with any part of the body other than the tarsi and tarsal claws and hence, the 'grip' in spiders refers to the contact with the tarsi only.

The paired claws are very hard and sharply pointed, generally curved and provided with a row of teeth on the inner surface of the claw. These paired claws are attached to the end by means of a thin cuticle and show considerable movement. The median claw is rigid and is the extension of the sclerotised terminal plate. According to Parry and Brown (1959), the extreme dorsal and ventral points of the terminal plate are attached by long median tendons of the median muscle which elevates the claw and the paired muscles depresses them.

Investigation reveals, *Lycosa*, *Hippasa*, *Stegodyphus* and *Neoscona* are classified under three clawed hunters and *Plexippus* under two clawed hunters.

The paired claws are the largest and carries on their ventral side a row of teeth, the height of which varies considerably at the basal and terminal part. The tooth at the proximal end are the largest while the tooth at the distal end are the smallest and the gradation in the height of the teeth occurs in paired claws. In addition, the number of teeth varies at different developmental stages. According to Savory (1928) sex seems to influence, the number of teeth increasing in the male spiders and decrease in females. The paired claws of *Stegodyphus* have 15 teeth on each and the first tooth is thicker and largest. Similarly the median third claw bears four teeth, the first being thicker and largest. In *Neoscona* the number of teeth in the paired claws are twelve of which the first is the largest and pointed, the rest of the teeth are thin and spine like. The median claw is curved in the form of a hook and bears two small teeth. The whole set of median claw is pivoted and move backwards and forwards on the terminal sclerite. Normally the median claw is associated with the manipulation of the thread in *Neoscona*. *Plexippus* possesses the paired claw, the claw has seven teeth of which the first one is the largest. In *Hippasa* the number of teeth on the paired claws are twelve and the median claw has one small tooth, in both the cases the first one is the largest. It can be summarised that normally orb weavers have fewer number of teeth in the tarsal claw whereas the non orb weavers have increased their number. In this respect an exception can be met in *Plexippus*, where the reduction in the number of teeth in the paired claws and the absence of the median claw can be considered as secondary since these spiders donot utilise the silk for spinning and the jumping mode of life is ably assisted by the presence of adhessive claw tufts at the base of the tarsal claw.

Hairs are distributed all over the legs in spiders on the inner and outer sides and the concentration of these are more on tibia, metatarsus and tarsus. These hairs are believed to be tactile and chaemosensitive (Comstock 1940 ; Foelix 1970). The distribution of the hair at the tip of the legs is mainly attributed to the sensory mechanism as this part makes the first contact with the environment. Three types of hairs have been recognised on the tarsus of the spiders viz.

- i. Straight, sharp pointed hairs which are more numerous and common.
- ii. Curved and serrated bristles which normally assist in the spinning activity of the orb weavers.

- iii. Slightly curved blunt tipped hair arranged in several rows between the straight hairs and which normally exhibit characters of a chaemosensitive hairs of insecta.

The slightly curved, blunt tipped hairs are more chaemosensitive and are situated on the tibia, metatarsus and tarsus. The chaemosensitive hairs are in the form of setae, the tip of the hair appears optically transparent, having an opening, through which the fluid emanates, when the legs are normally squeezed. Further, they appear to have spiral band around the shaft of the hair (fig. 57).

The straight and pointed hairs are believed to be tactile in function and are present in numbers numerous arranged irregularly. These spines are directed at an angle of 30-50° having a lumen but the tip of the spine is closed (fig. 58). According to Reichter (1970), these are similar to mechanoreceptors of honey bee and blow fly but in spiders they are used only for tactile fuction.

In the spider species investigated, numerous slightly curved blunt hairs and sharp pointed hairs are commonly present, however, the number of such hairs are innumerable in *Lycosa* and *Hippasa* and this may be due to their ground dwelling and hunting habit. In *Plexippus*, in addition to the tactile and chaemosensitive hair, a tuft of glandular hairs are present below the paired claw. These are often known as scopulae or tenet hairs. The adhessive tips of these hair enable the spider to adhere to the horizontal and vertical surfaces. The scopulae appear as brushes and their tips have well developed adhessive claw tufts.

In case of orb weaver spider, *Neoscona*, additional accessory claws are present at the tip of the tarsus opposing the paired and unpaired claw. These are distally curved and possesses small teeth on their ventral surface. The size of such claw often varies, some are large and some are small (fig. 59). Foelix (1970) prefers to use the term 'serrated bristles' instead of accessory claws. The distribution of serrated bristles follows a definite pattern in the legs. In *Araneus diadematus*, the leg-II to IV has bristles. The bristles of leg-III have 'V' shaped arrangement and the bristles of the leg-IV has six arranged in semicircular fashion. But in *Neoscona*, has six bristles on each leg but the bristles on leg-IV are the largest and the teeth on them are more prominent.

It is believed that these serrated bristles or accessory claws are tactile in function, but in addition to this, these bristles are found in assisting the threads in grasping during the web building, as they are found mainly opposed to the median claw. According to Nielson (1932), the little notches of the serrated bristles or accessory claws could serve as an excellent device for the thread to be pushed against the median claw, thus providing a firm grip. The distortion of web building by the removal of these bristles clearly indicates that there is grasping of the thread between median claw and serrated bristles. The work of Wilson (1962) confirms the gripping mechanism. Since, *Neoscona* belongs to the same family of orb weavers having more or less same mode of web building like that of *Araneus diadematus*, may have the same function, since, the structure of the accessory claws appear to be same.

Thus the legs of spiders are tactile and chaemosensitive in function and in addition, help in the web building mechanism and manipulation of threads during the orb web construction. The regulation of thread spacing movement in the orb web construction, though determined in the central nervous system, this pattern is relayed to the sensory and motor apparatus of the legs. In addition, the tarsal claws are of little help in the classification, at least at a larger scale into three and two clawed hunters. Among Indian forms twelve families exhibit two claws and seven families are under three clawed hunters.

The loss of median claw in certain families viz. Salticidae, is compensated by the presence of adhesive claw tufts or adhesive pads, which help in clinging the surface. According to Savory (1928), during the development of the two clawed spiders, the presence of the median claw has been noticed which substantiates that the primitive hunters are three clawed but the reduction of the median unpaired claw is secondary.

EVOLUTIONARY SIGNIFICANCE OF THE SPINNING APPARATUS

The adaptability in the environment and their reliance on the utilisation of silk in spiders is well known. The classification of spiders in an evolutionary sequence, though attempted by several workers viz. Pocock (1900), Savory (1928), Comstock (1940), Gertsch (1949), Kaston (1964), Levi (1971 and 1973), Patel (1975), Raven (1980) and Tikader (1980 and 1982), is often felt incomplete due to the absence of missing links in the fossil records and also because of inadequate studies on the development of various spiders. The present investigation attempts to find the inter relationship among

structure and function of the spinning apparatus in various groups of spiders with a view to find, if these structure has any bearing in the classification of spiders.

Origin of spiders is still a debatable question and according to Gertsch (1949) two lines of thought has been envisaged. The classical theory believes that the arachnids originated from the trilobite ancestors while few other workers are of the opinion that arachnids are derived from some land creatures perhaps, similar to that of slug like *Peripatus*. Having evolved on land, distribution and diversification took place at a later stage from the primitive group of spiders which we now recognise as "Archearaneid" and this has a closer resemblance with the members of fossil forms. These spiders had relatively long cephalothorax, front row of eight eyes, legs of moderate length, tarsus with paired and unpaired claws and usually with eight spinnerets on the abdomen. These spiders were mainly hunters, protecting the developing eggs with mud on the earth's surface.

From this typical archearaneid type, three lines of evolution took place leading to the modern day spiders. The first line comprises members of the orthognatha (atypical and typical tarantulas) and especially *Liphistius*, a member of Liphistidae, considered to have retained many characteristics of the archearaneid. Among Indian forms, the family Atypidae represents the atypical tarantulas and the families Theraphosidae, Barychelidae, Dipluridae, Ctenizidae, and Actinopodidae represents the typical tarantulas. The members of the family Liphistidae posses eight spinnerets on the mid ventral line of the abdomen whereas in Atypidae, two of the eight spinnerets are reduced. These are usually burrowers having paired and unpaired claw tufts and eggs are deposited in the soil by mud and sticky substance.

Slight modification have been noticed in typical tarantulas. The members of Theraphosidae and Barychelidae show slight variation in the apical segment of the posterior spinnerets but the members of Ctenizidae show smaller posterior spinnerets and moderately long anterior spinnerets. Members of Dipluridae have attempted to utilise the spinning appartus to a greater extent by constructing a sheet web to capture the prey. These spiders have developed good eye sight, tarsi of the legs are provided with median and paired claws, spinnerets are elongated and the terminal segments of long lateral spinnerets are provided with small spools, from which a sheet web is spun by their lateral movements.

From this three clawed, ground dwelling hunting spiders with eight spinnerets, diversification took place quite early from this main line leading to the present day cribellates. Among Indian families viz. Filistatidae, Oecobidae, Eresidae, Dinopidae, Uloboridae, Dictyniidae, Amaurobidae and Psecheridae have been included in this group. Under present investigation *Stegodyphus sarasinorum* (Eresidae) represents the group, Cribellatae. The members of the cribellatae have retained a flat spinning organ namely cribellum in front of the anterior spinnerets having large number of opening for the cribellum glands. Cribellum represents the anterior and median spinneret of the original Liphistomorphae and here the two spinnerets have fused and this fusion is represented by the division of the cribellum by a median furrow. In rest of the ecribellates cribellum is either absent or represented by the vestige of colulus or few hairs in this area.

Associated with the cribellum, cribellates are unique in having a row of bristles on the metatarsus of the IV leg, assisting in the production of a sticky hackled band of silk. This row of bristles on the metatarsus is said to be calamistrum. According to Gertsch (1949) the metatarsal comb-calamistrum, used to brush across the spinning field, was in all likelihood an early invention. In addition, many members of the cribellatae exhibit true social life, living in retreats of nest. This act of socaility may represent the primitive character of the group.

The members of Amaurobidae spin large web during night and dry frame work of the snare is commonly put down in a series of line from the central retreat, on which the cribellate silk is loosely spun thus making a thick mat of silk. The cribellate silk formation is ably assisted by the long calamistrum which they possess.

Among cribellatae, Uloboridae occupy a unique place as they spin an aerial orb web similar to that of members of Araneidae. The construction of webs similar to that of Araneidae in the members of Uloboridae is according to Kaston (1964), is believed to be a case of convergence or pallelism which just occurs with respect of morphology of the cribellate and ecribellate group. Another member which constructs a unique web is *Hyptiotis*, also belonging to cribellatae. Here the spider produces a triangular web consists of four rays of non viscid silk placed in vertical plane and the sticky thread of the cribellar silk is attached to the radii for a short distance. These spider assumes a position on the twig with her

spinnerets attached to the short line and the front legs holding the draw thread or the trap line.

Associated with the cribellum and calamistrum are the cribellar glands situated in the posterior region of the opisthosoma behind the plate as a whitish mass with very small ducts opening directly on the cribellum. In addition, the number of ampullate glands are found to be more than others, in the investigation. The presence of large number of large, median and small red and yellow ampullate glands in *Stegodyphus* possibly suggests that the earliest spiders possessed large number of glands, but later, during the course of evolution the number of such glands are reduced in the cribellate group. This may be because of the reason that the ampullate glands has developed to produce a particular type of silk in the web building activity.

To summarise, members of the cribellate group exhibit true social life, retained flat spinning organ namely cribellum, has large number of silk glands and the formation of sticky hackled band is ably assisted by the bristles-calamistrum on the metatarsus of the IV leg. All these are believed to substantiate, that this group has deviated quite early from the main stock of spiders evolution and retained many of the primitive characters.

Of the remaining group of spiders, which lack a definite cribellum, might have followed two distinct lines, one which developed many accomplishing hunting types and the other culminated in the aerial sedentary spiders that rely on silken webs as snares to capture the prey. Thus spiders show an adaptive radiation from the general ground dwelling arachneid into hunting and vagrant type on one line and the aerial spinners on the other, while the typical cribellates represents several morphological features of the ancestral condition.

The evolution of spiders in hunting as well as aerial type is mainly due to the nature of utilisation of silk with greater efficiency. The earliest spiders were wanderers and the eggs are protected by the sticky secretion along the mud. In course of time, the dependency of spider on the silk has increased, for nurturing young ones by producing egg cocoons made up of silk. The habit of formation of silk for the protection has led to yet another type namely, the drag line formation of the modern day spiders. The drag line is assisted by the secretion of the ampullate gland. The drag line of the

primitive spiders probably led to the construction of snares of various shapes and sizes, relatively at a later stage.

Pocock (1900), Comstock (1940) and Bristowe (1932) believed that the silk was first used for covering the eggs. It is supposed that the web itself evolved from a mass of threads distributed around the egg sac or from a tube constructed as a retreat in which the spider hides its eggs. This supposition is based on the assumption that the simple tube constituted the primitive form of nest. As these spiders are mainly having hunting habit, locomotory organs are well developed with long legs accomplished with powerful muscles and coxa firmly fixed to the body and with large number of tactile and chaemosensitive hairs on the tarsi of legs. In addition, the tarsus has paired and unpaired claws and the spinnerets are long with few spinning tubes and spigots. These are mainly associated with ground dwelling and hunting activity.

The hunting spiders have developed the eye sight to a greater extent, associated with it are the development of a sensory system at the tip of the tarsus and the spinnerets. These spiders rely on the utilisation of silk to a lesser extent, as they rarely construct any aerial web to capture the prey. Exception to this can be seen in the members of Lycosidae *Viz. Hippasa* which constructs a tubular funnel web. Gertsch (1949) believed that two distinct lines were followed by hunting spiders, one culminating in the wolf and lynx spiders and the other in the jumping spiders.

The members of the wolf spiders (Family : Lycosidae) are usually found on grass or rocky surface with the colour of the body matching with the surroundings. These spiders occupy a variety of terrestrial habitats, the habitat selection depends on the availability of the food. temperature, humidity etc. The members of Lycosidae, rarely utilise silk, to capture the prey by constructing the snare. An exception to this is found in two genera namely *Sossipus*, which depends on the silk as it spins a sheet web similar to that of grass spider. Yet another genus *Hippasa*, constructs a funnel like web. The webs are constructed in open spaces, which offer protection to these spiders as well as minimise the water loss from the body. These spiders hide in their retreat for the prey to fall on its web as victim. The members of *Lycosa* live on the ground, under stones or in the crevices waiting for the

prey. Since, it does not spin web, it mainly depends upon the eye sight and swiftness of the limb.

Yet another character found in the members of Lycosidae, is the intial protection offered to the developing young ones. The female spiders, after laying the eggs, secrete silk to cover these eggs and thus forms an egg cocoon and carry it on its under surface till the spiderlings are ready to hatch. At this stage, the mother rips open the seam of the cocoon and liberates the spiderlings. In addition, they offer protection till the youngones are ready to move, by taking them on its back. Hence, according to Gertsch (1949), the success of the wolf spiders is unquestionably due to the intial protection given to the eggs and young ones by the mother.

The members of the lynx spiders (Family : Oxyopidae), are good hunters and are specialised to live on plants. These spiders are small with long abdomen and legs with prominent spines. Similar to the members of Lycosidae, they offer intial protection to the young ones, forming egg sacs which are supported by large number of silk threads, to the branches or leaves investing the whole branch in a silken web, where young ones can remain till they are ready to lead their lives independently.

Jumping spiders (Family ; Salticidae) are mainly ground dwellers and have modified many of their structures to cope with their habits. The legs are short and stout with two tarsal claws, the median claw being absent. But these spiders have developed a tuft of hair at the base of tarsal claw (tenet hair or scopulae) provided with adhessive pads. Compared with well developed legs and eye sight, spinning apparatus of these are poorly developed, as they rarely depend on the silk for capturing the prey. The main function of the spinning glands is the production of silk, used only as a life line or drag line. Hence, the modification in the spinning apparatus in Salticidae is retrogressive but with progressive development of the visual and muscular system equipping the spider with hunting mode of life.

The members of higher orb weavers exhibit highest degree of modification and represent a divergent line in the evolutionary history. According to Gertsch op. cit. the evolution of orb web progressed hand in hand with changes in the silk and in the spider. The silk glands became voluminous gradually in the abdomen and were able to produce silk of different proper-

ties. The external spinning apparatus of these orb weavers have undergone modification and show a variety of structural adaptations. These aerial spiders have modified the unpaired claw on their tarsi into hooks that allow them to climb on their threads from which they hang back downwards. The spinnerets are short, conical and are located on the centre of the ventral surface close to the book lungs for the effective drawing of silk by the tarsal claws. The height of the spinnerets has also decreased for a greater mobility and the spinning field are well developed. The number of spinning tubes has enormously increased probably for the growing demand of silk during the orb web construction. Along with this, the median spinnerets and the spinning field on it are also well developed. The aggregate and cylindrical glands also open on the surface of the spinnerets by means of spigots for greater efficiency.

Of the 14 families of higher orb weavers listed (Tikader 1982) seven are represented in India and are well studied systematically, viz. Pholcidae, Theridiidae, Linyphiidae, Araneidae (Argiopidae), Tetragnathidae, Agelinidae and Habniidae. Among various families of orb weavers, the comb footed spiders (Theridiidae) have curved setae on the hind tarsi which are used to comb out the swathing film of silk to envelope the prey. Their webs are irregular tangles of silk and the spiders are small and plump. The aerial sheet weavers (Linyphiidae) spin conspicuous space webs consisting of tangle mass of lines and horizontal sheet. These weavers run over the bottom of the sheet, hanging back downwards and cut through it to capture the insects that fall on its upper surface. The members of Pholcidae spin loose irregular webs with a closely woven sheet. These long legged spiders shake the web violently to hasten through entanglement and capture the prey. The members of Agelinidae constructs a sheet web, composed entirely of dry silk. During web building, the spiders lay a frame work of long drag lines, coming from the anterior spinnerets, later put down many threads drawn from hind spinnerets, which move from side to side like brushes and lay multiple filaments. The members of Araneidae or Argiopidae spin familiar orb webs consisting of a frame to which the spiral and radial threads are fastened and represents highest degree of orb web evolution. It therefore, appears that various families of orb weavers have evolved independently and represents various lines that are detached from the main stream and forming isolated groups, which are imperfectly bridged by the intermediate forms.

Interrelationship among structure and function of the spinning apparatus in various groups of spiders reveals that from three clawed, ground dwelling hunting type, diversification took place quite early from the main line leading to the present day cribellates. Of the remaining groups of spiders, which lack a definite cribellum, might have followed two distinct lines, one which developed many accomplishing hunting type and the other culminated in the aerial sedentary spiders that rely on the orb webs as snares to capture their prey. Thus spiders show an adaptive radiation from the ground dwelling archearaneid into hunting type on one line and the aerial spinners on the other while the typical cribellates represent several morphological features of the ancestral condition.

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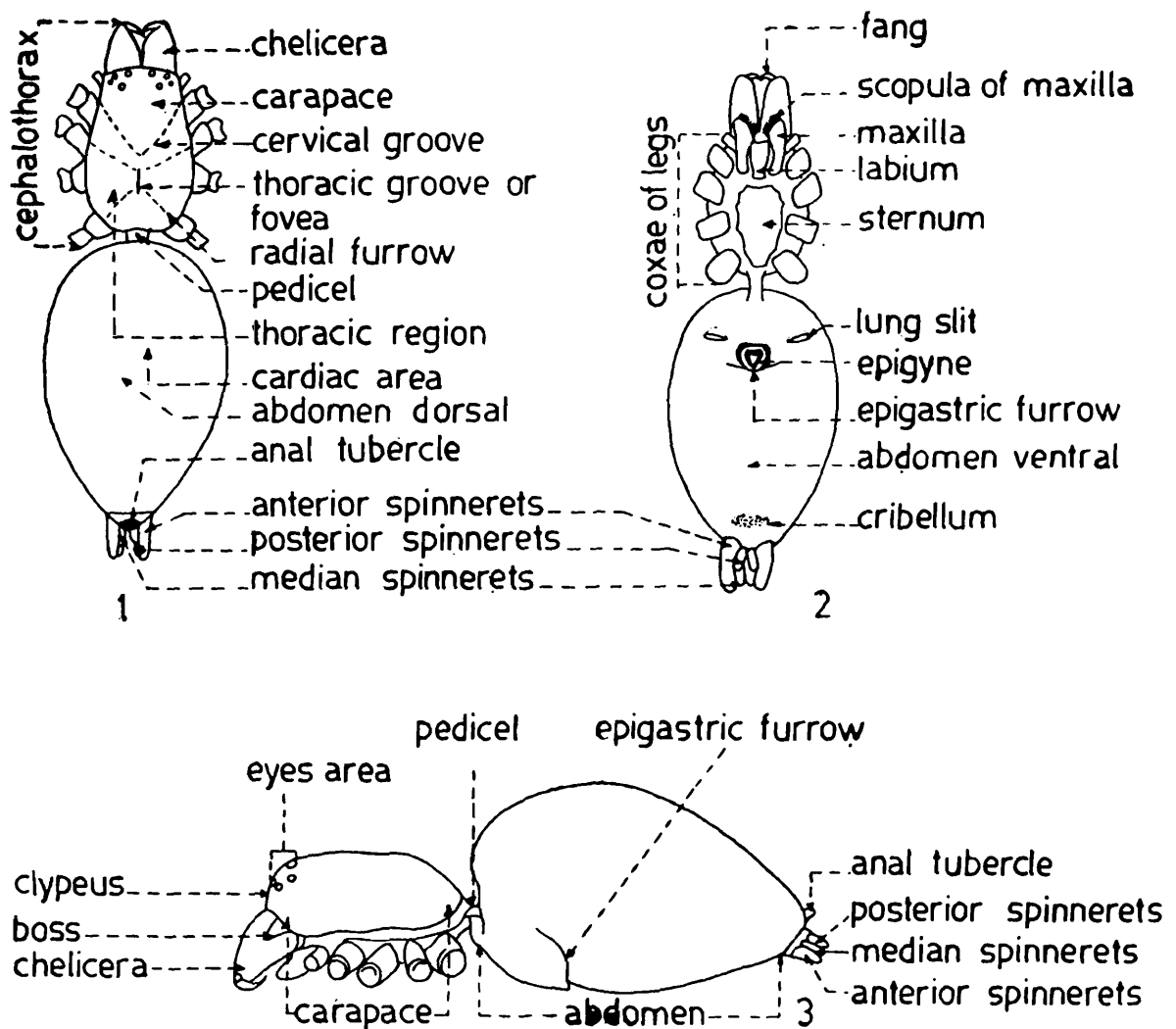
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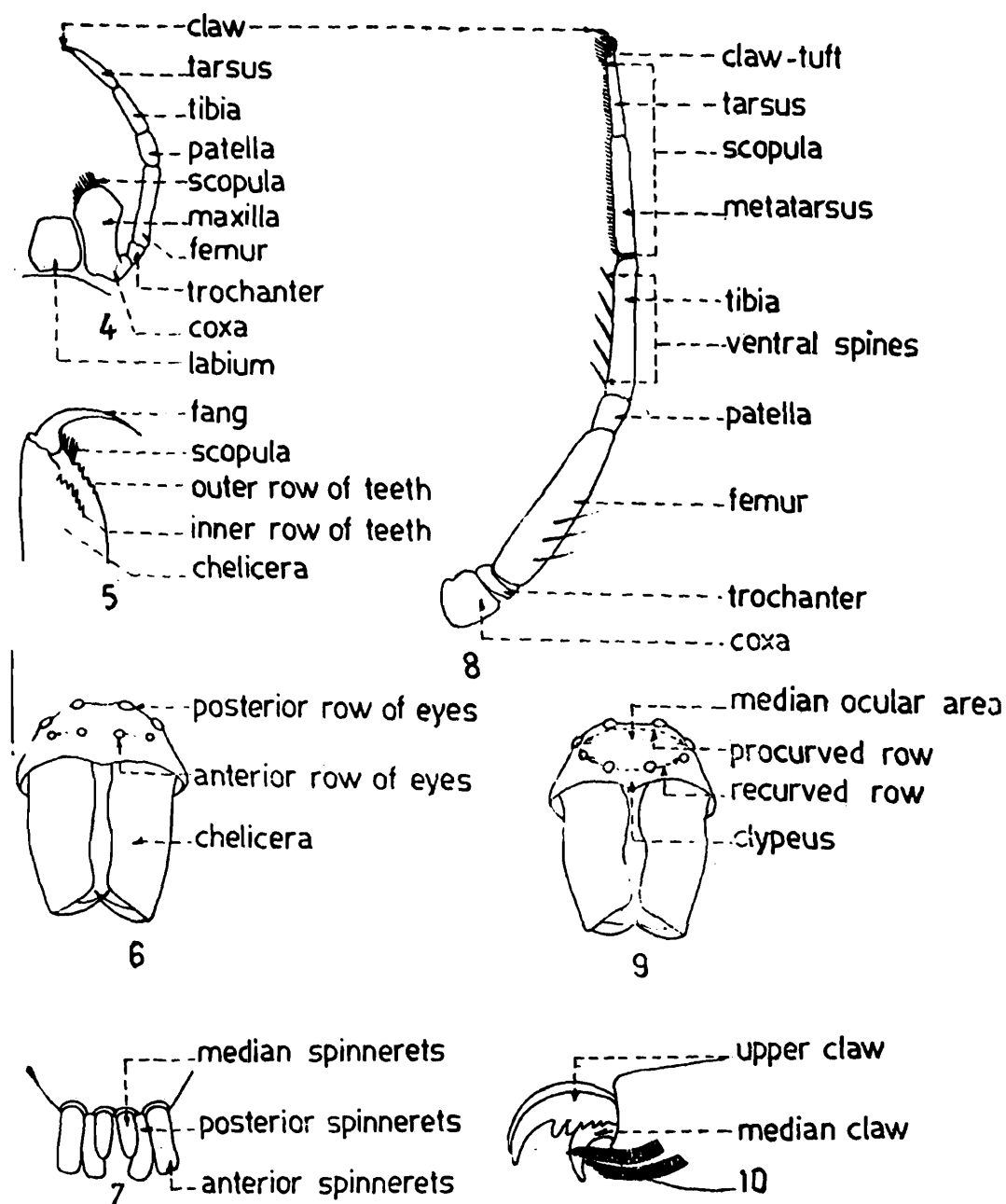
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Figures



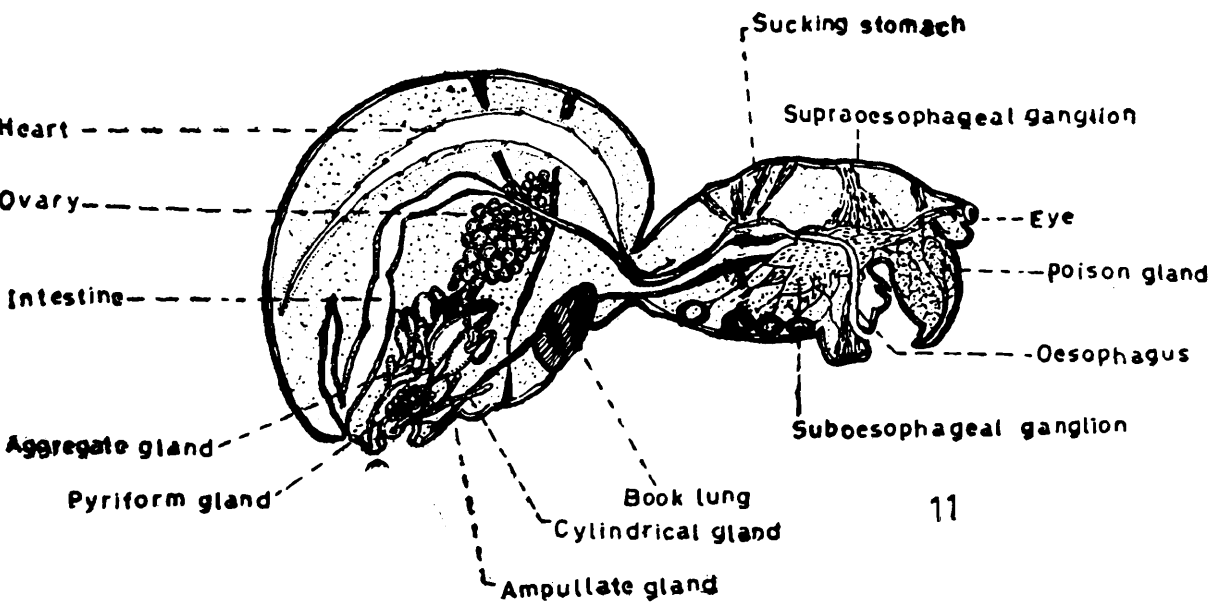
Schematic General Morphology of spider (Figures I—3)

1. Dorsal view of a typical spider
2. Ventral view of a typical spider
3. Lateral view of a typical spider

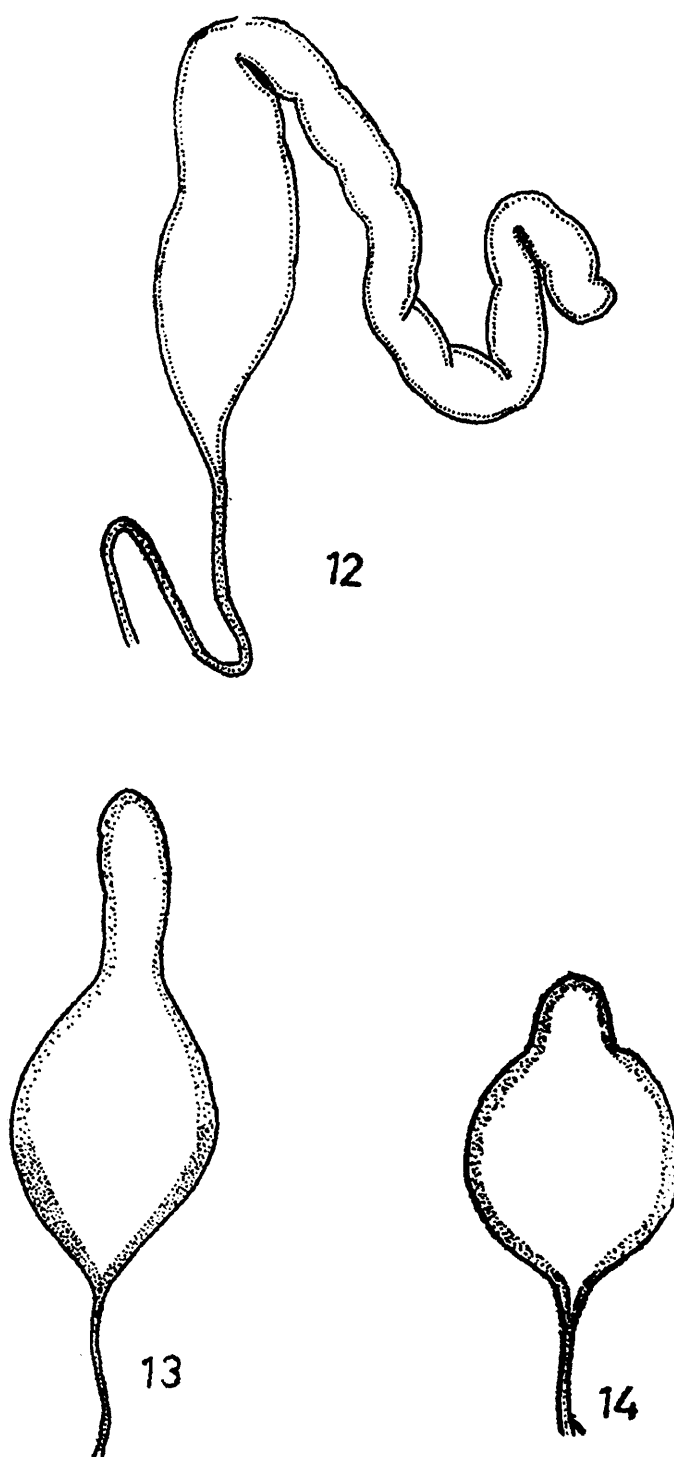


Appendages of the Cephalothorax (Figures 4—10)

4. Labium, Maxilla and Pedipalp of a female spider
5. Inner view of the chelicerae
6. Cephalic region showing the arrangement of eyes
7. Ventral view of the spinnerets
8. Lateral view of the leg
9. Cephalic region showing arrangement of eyes
10. Tarsus with tarsal claws

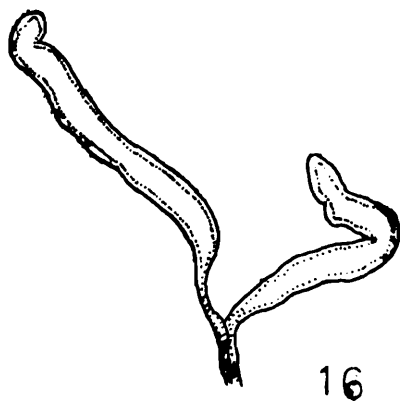


11. Schematic representation of the internal anatomy of the spider



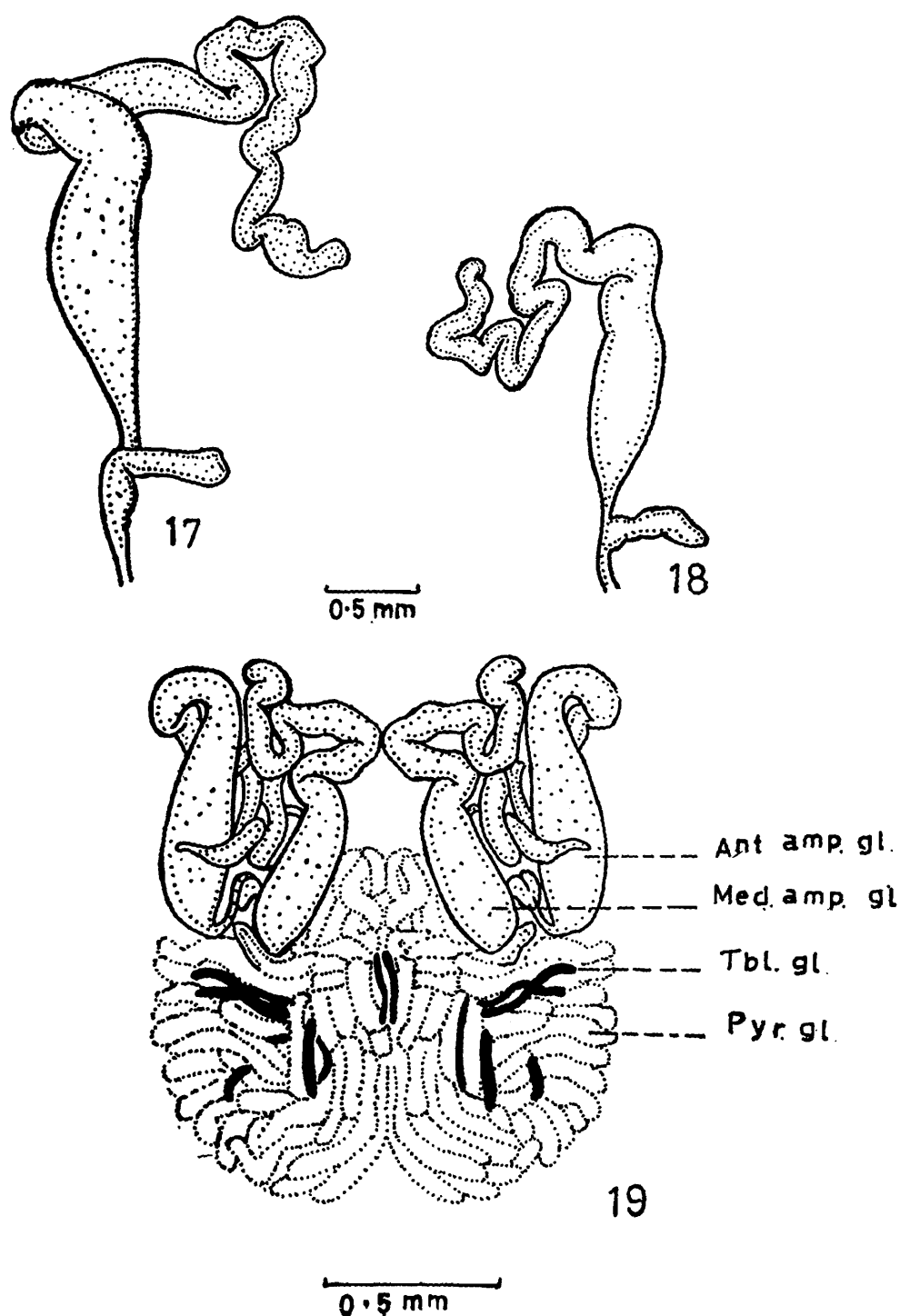
Morphology of the spinning glands in spiders (Figures 12—14)

- 12. Ampullate gland
- 13. Pyriform gland
- 14. Aciniform gland



(Figures 15—16)

- 15. Aggregate gland
- 16. Cylindrical glands

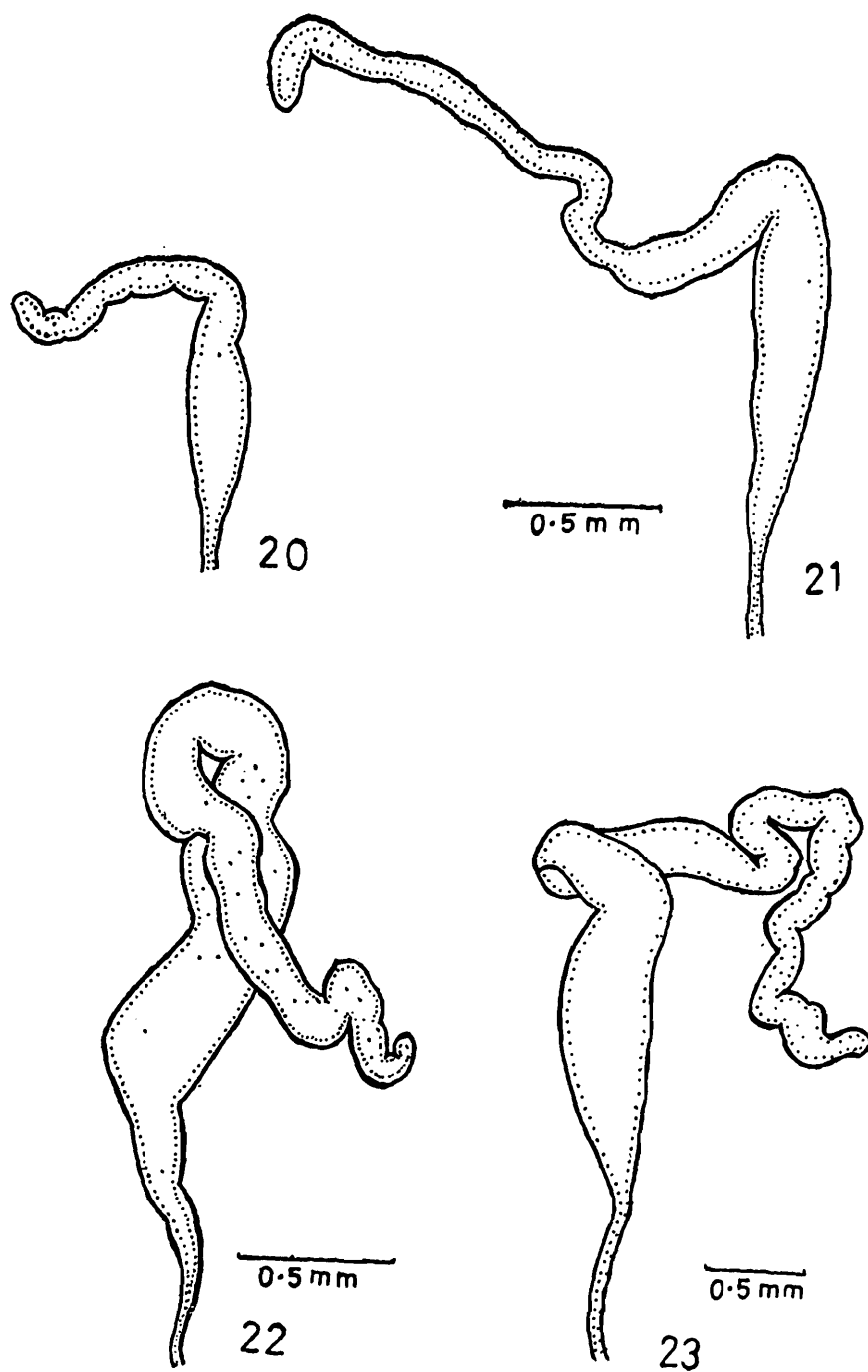


Spinning glands in female *Lycosa nigrotibialis* Simon (Figures 17—19)

17. Anterior ampullate gland in *L. nigrotibialis*

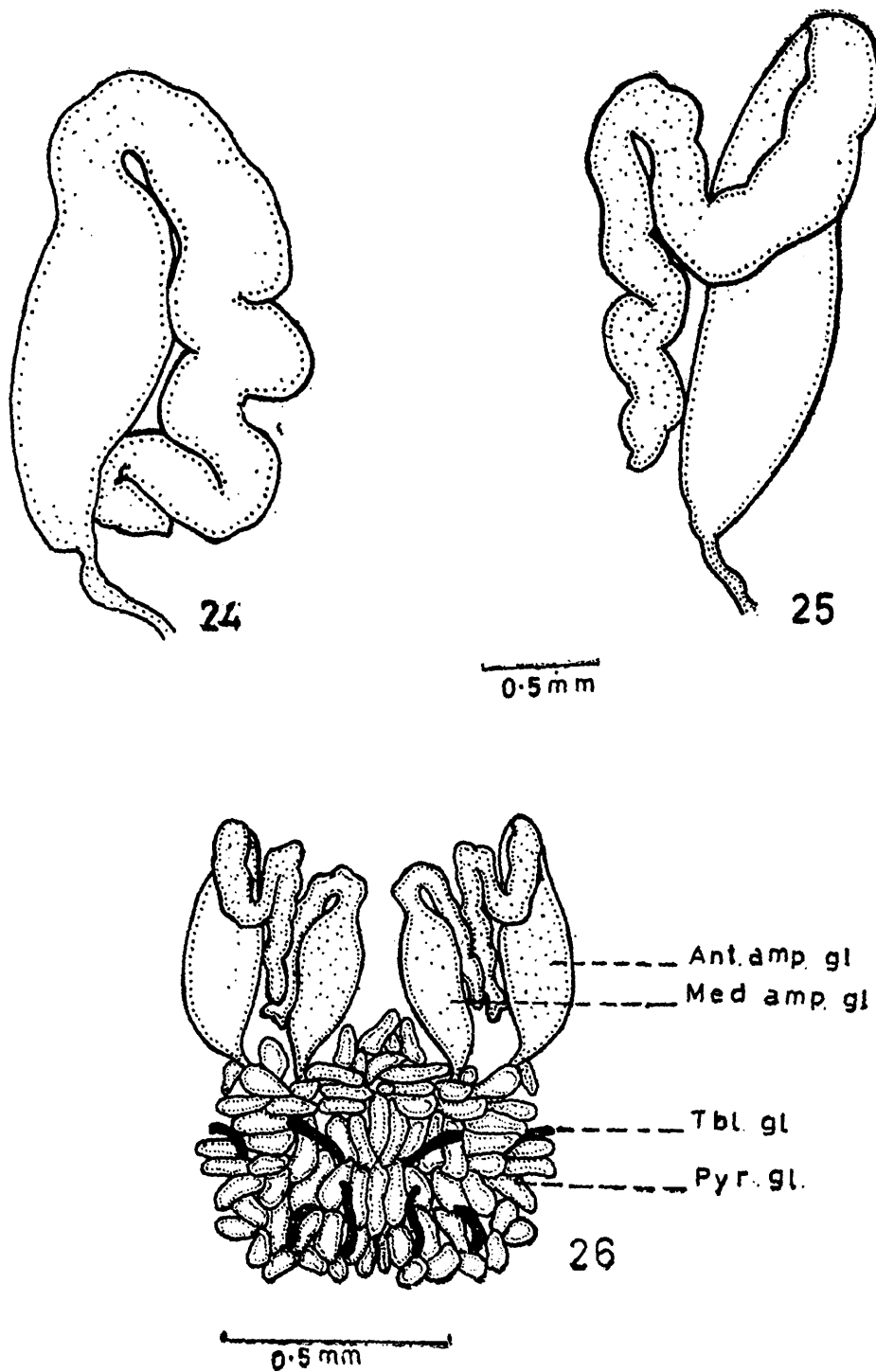
18. Median ampullate gland

19. Disposition of various spinning glands in *L. nigrotibialis*



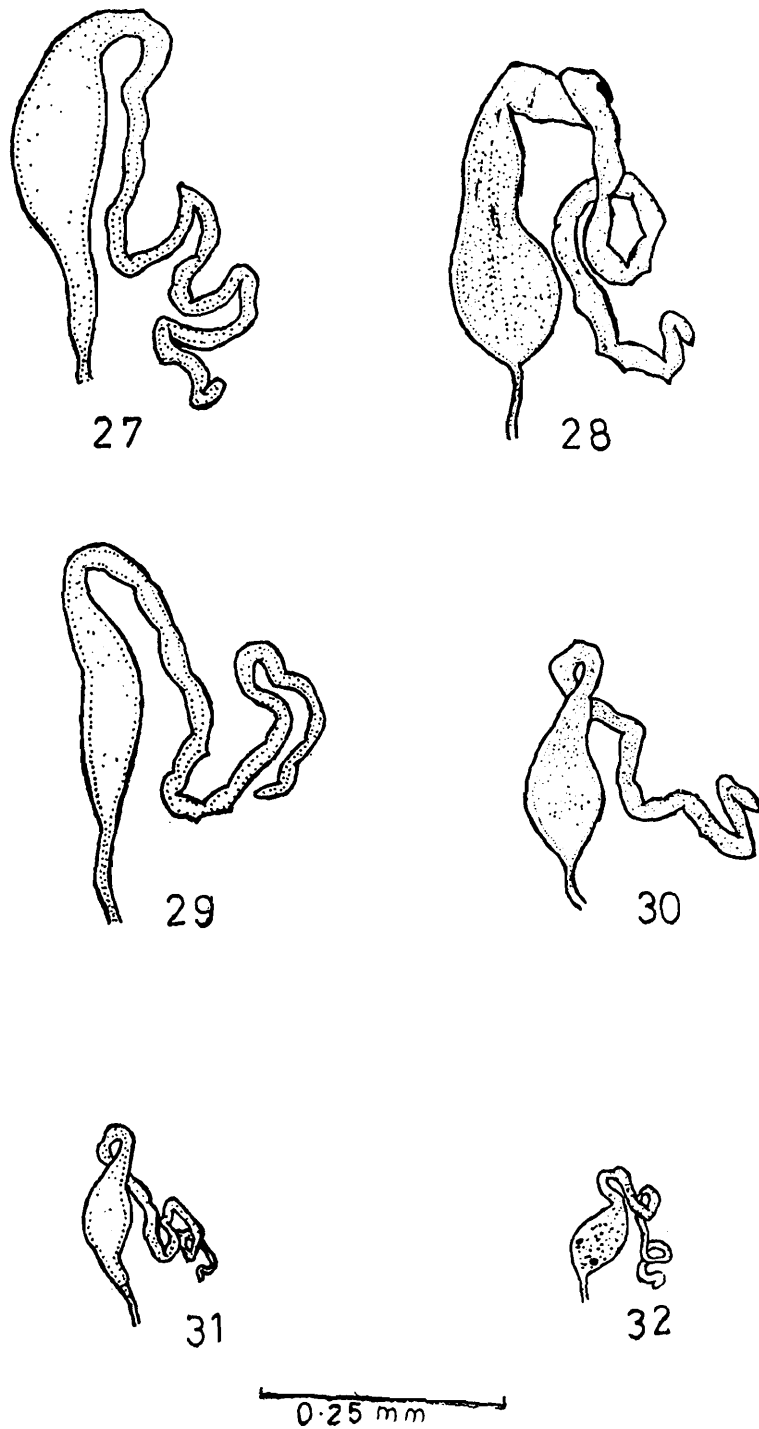
Development of anterior ampullate gland in female *L. nigrotibialis*—Simon.
(Figures 20–23)

- 20. Anterior ampullate gland in third instar
- 21. Anterior ampullate gland in fourth instar
- 22. Anterior ampullate gland in fifth instar
- 23. Anterior ampullate gland in eighth instar



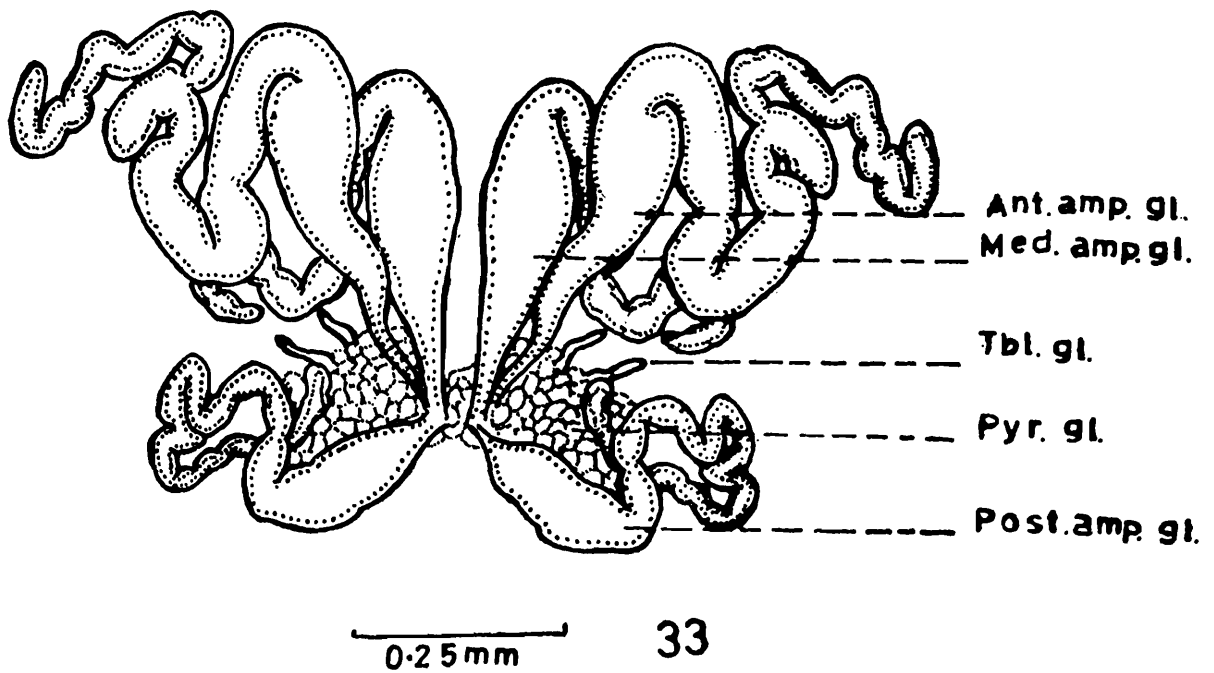
Spinning glands in *Hippasa pisaurina* Pocock (Figures 24—26)

- 24. Median ampullate gland in *H. pisaurina*
- 25. Anterior ampullate gland in *H. pisaurina*
- 26. Disposition of various spinning glands in *H. pisaurina*



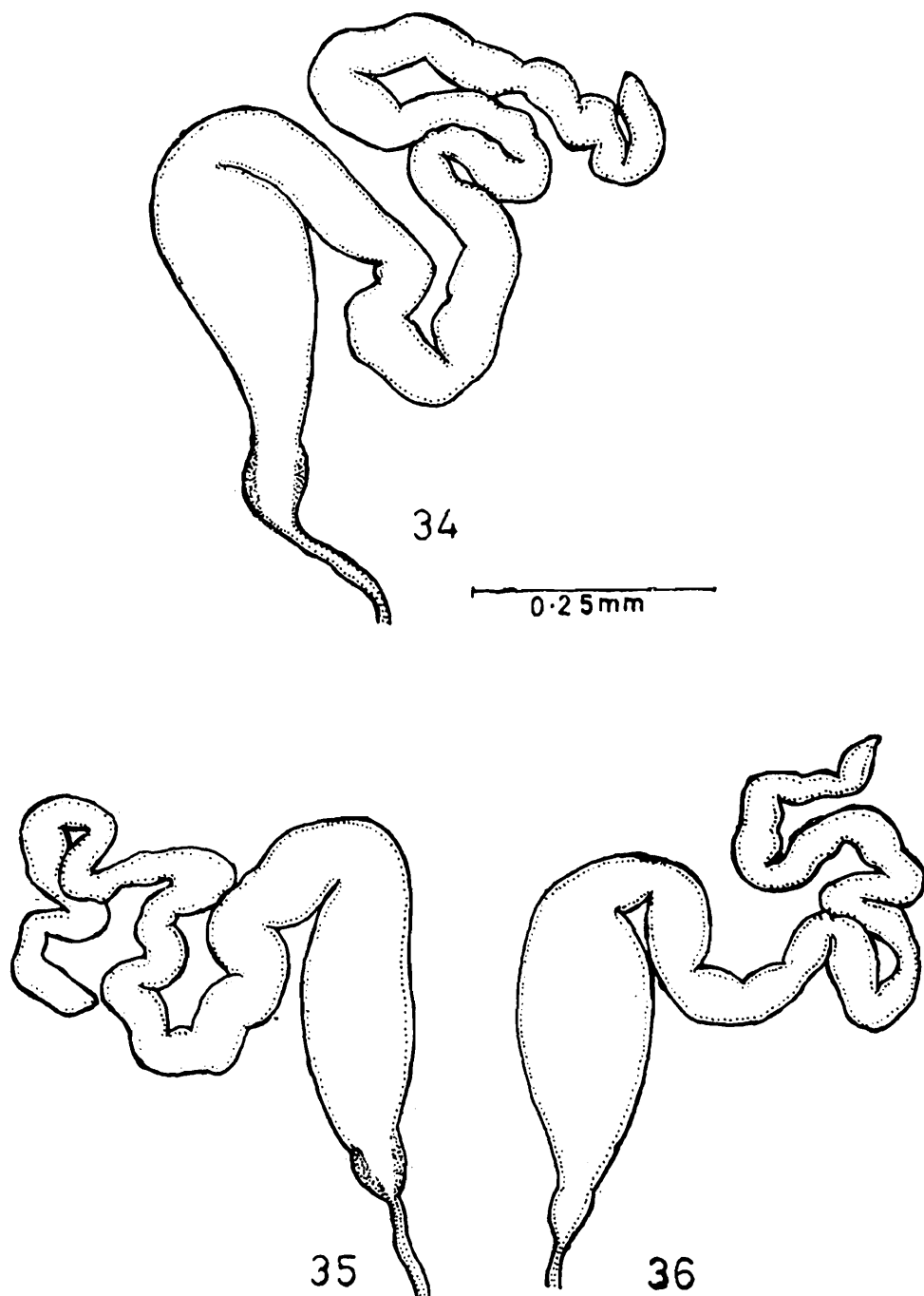
Spinning glands in *Stegodyphus sarasinorum* Karsch (Figures 27—32)

- 27. Large yellow ampullate gland
- 28. Large red ampullate gland
- 29. Median yellow ampullate gland
- 30. Median yellow ampullate gland
- 31. Small yellow ampullate gland
- 32. Small red ampullate gland



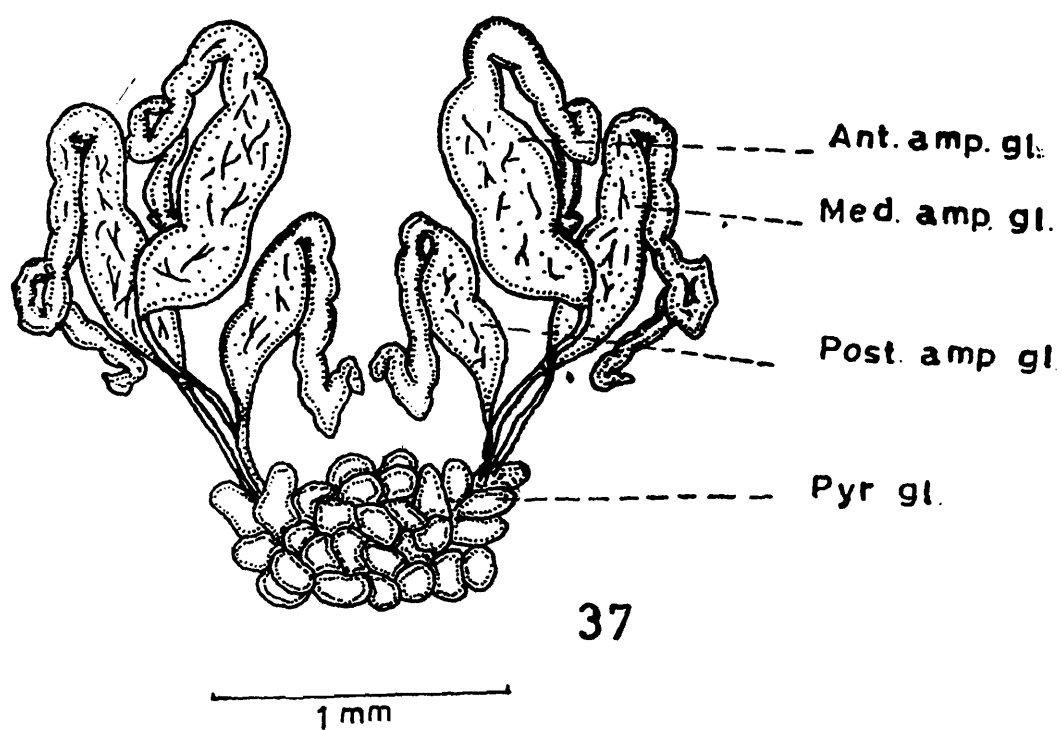
Spinning glands in *Neoscona mukulji* Tikader (Figure 33)

33. Disposition of spinning glands in female *Neoscona*



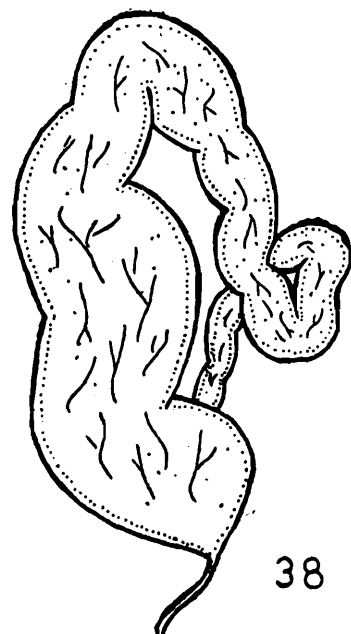
(Figures 34—36)

- 34. Anterior ampullate gland
- 35. Median ampullate gland
- 36. Posterior ampullate gland

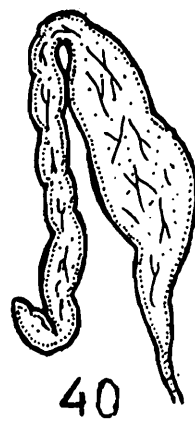
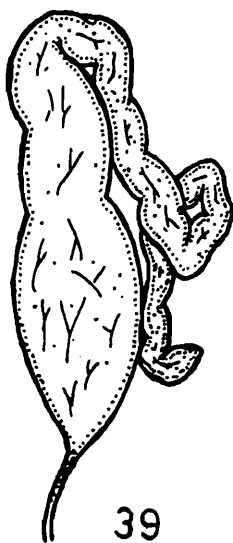


Spinning glands in female *Plexippus paykullii* (Aud.) (Figure 37)

37. Disposition of the spinning glands in female

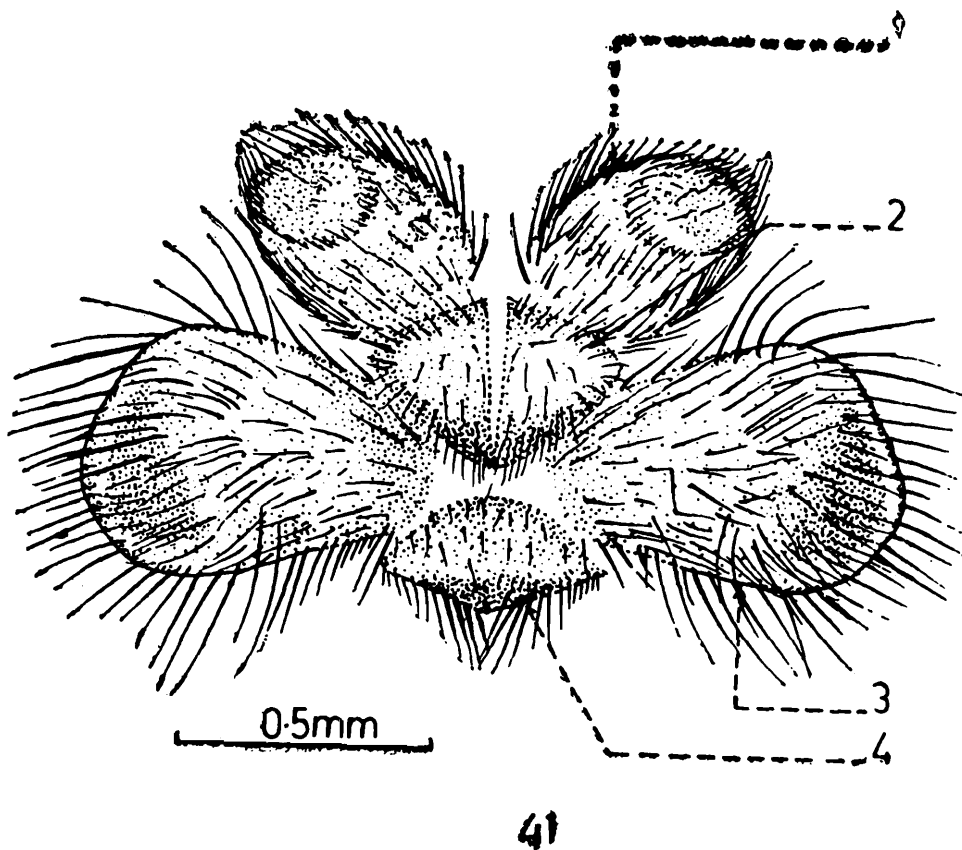


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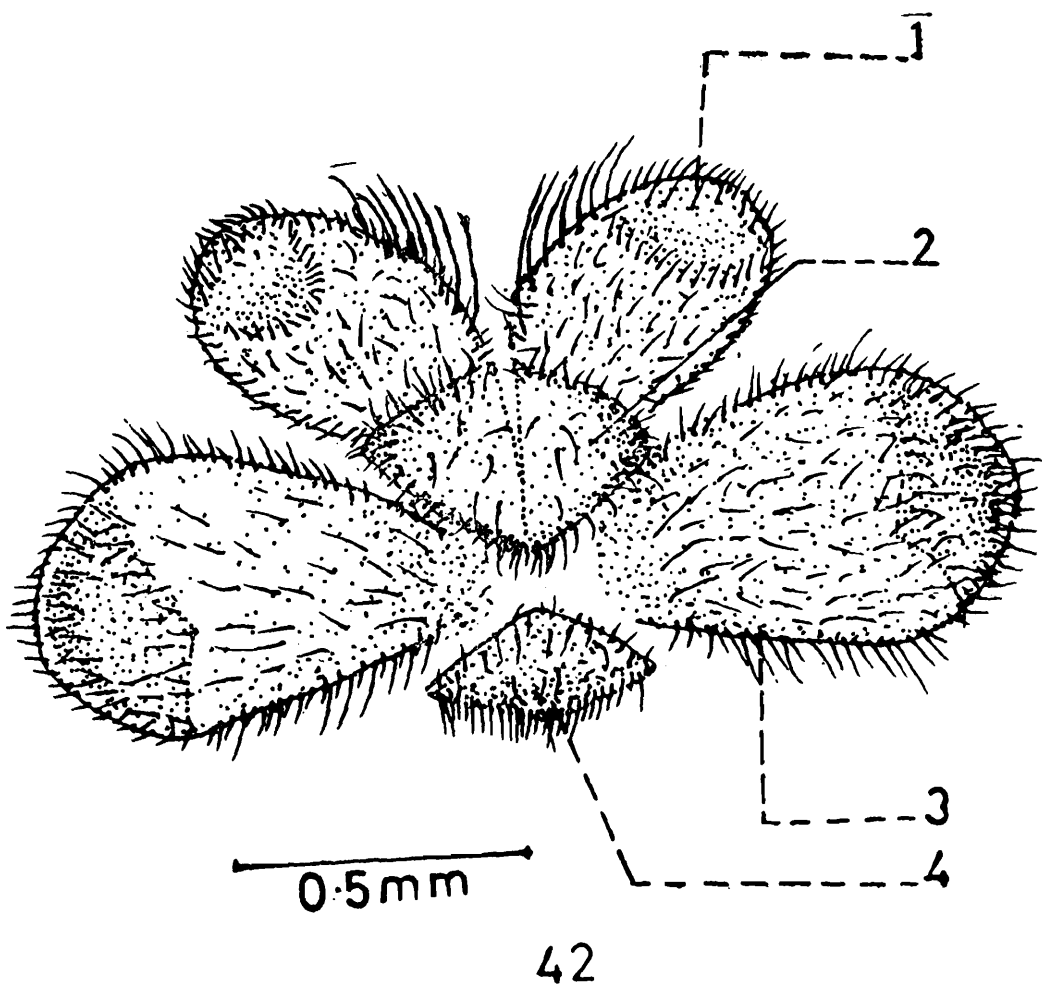
(Figures 38—40)

- 38. Anterior ampullate gland
- 39. Median ampullate gland
- 40. Posterior ampullate gland

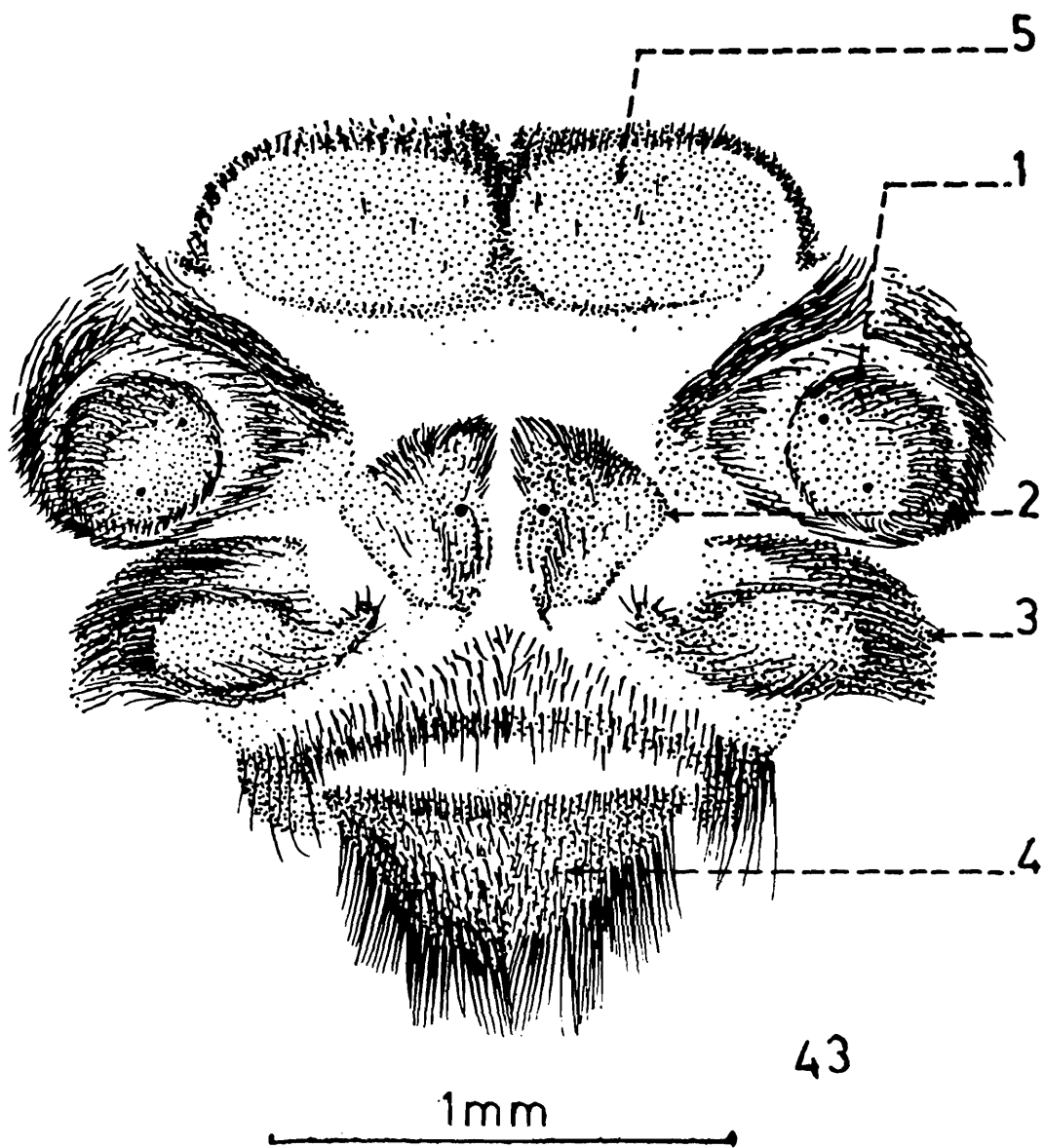


Morpaology of the external spinning apparatus ; Spinnerets, Spigots and spinning tubes in spiders (Figure 41)

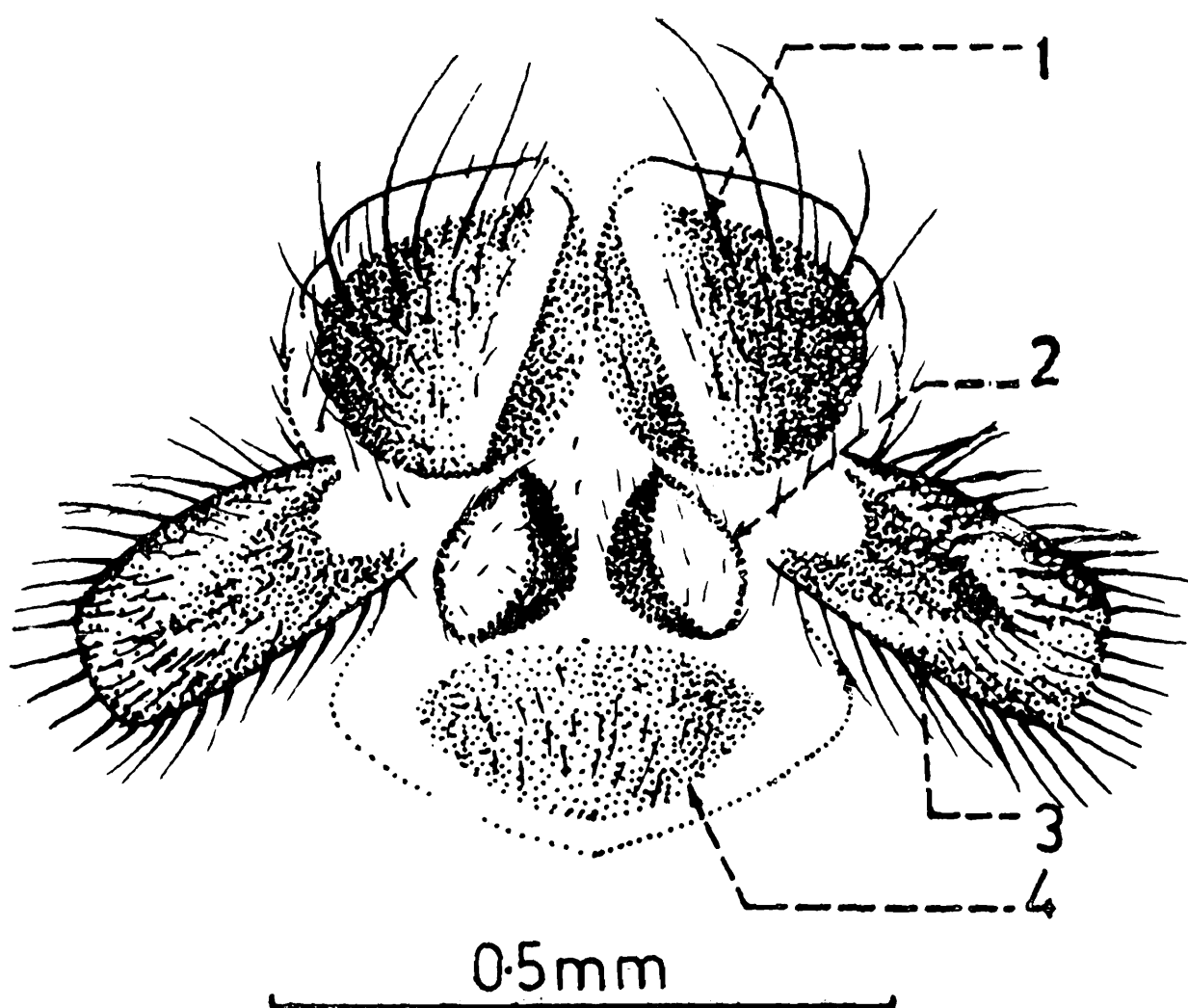
41. Disposition of spinnerets in *L. nigrotibialis*



42. Disposition of spinnerets in *H. pisaurina*



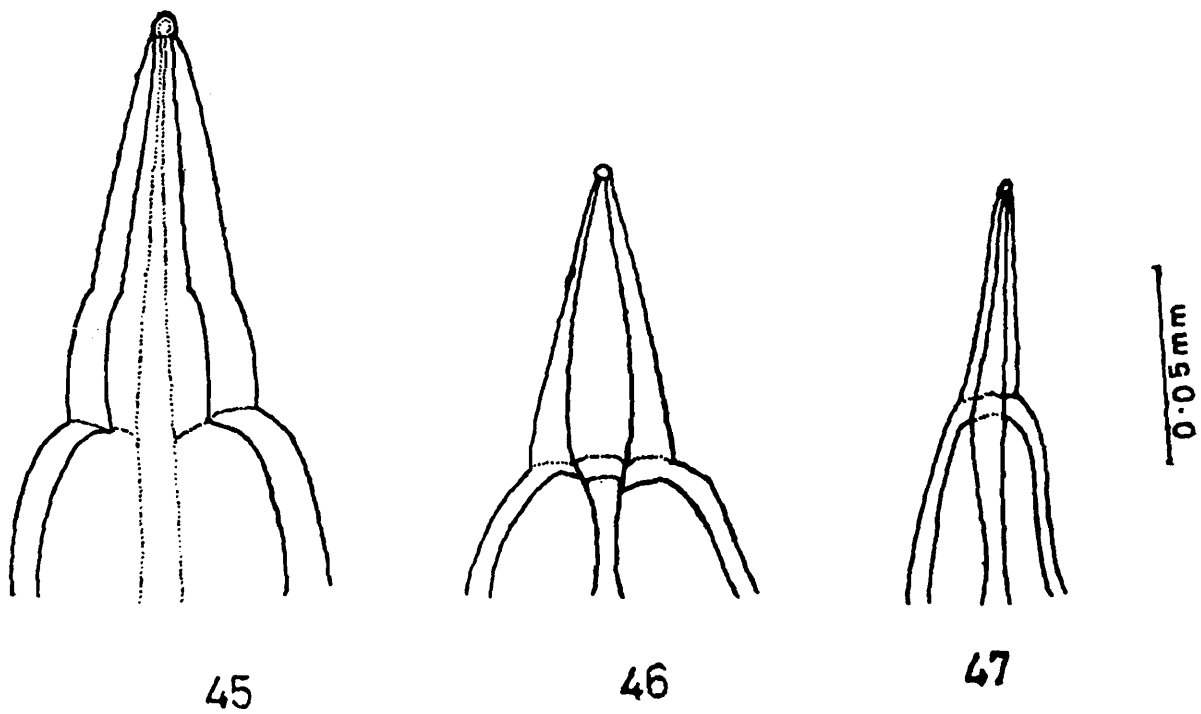
43. Disposition of spinnerets and cribellum in *Stegodyphus sarasinorum*



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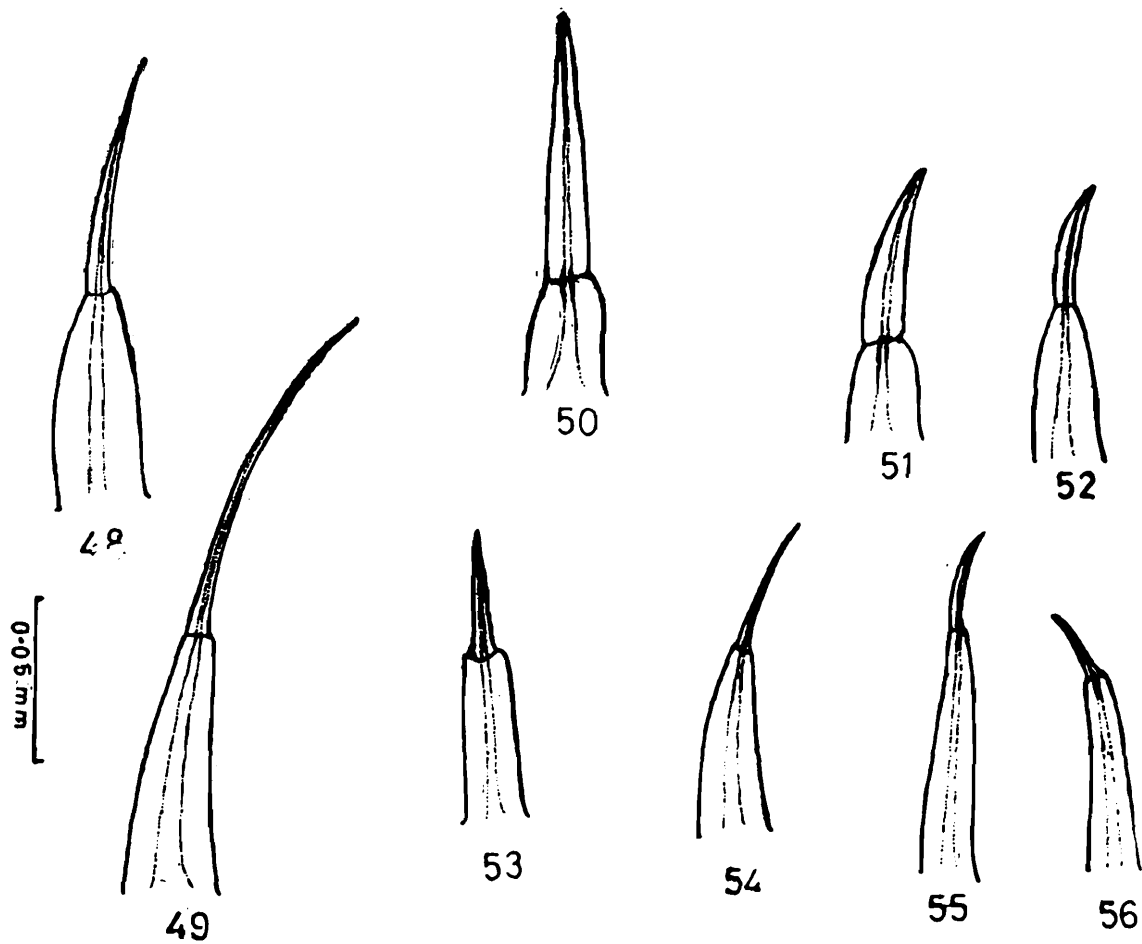
44. Disposition of spinnerets in *P. paykullii*

1. Anterior spinnerets
2. Median spinnerets
3. Posterior spinnerets
4. Anal tubercle
5. Cribellum)



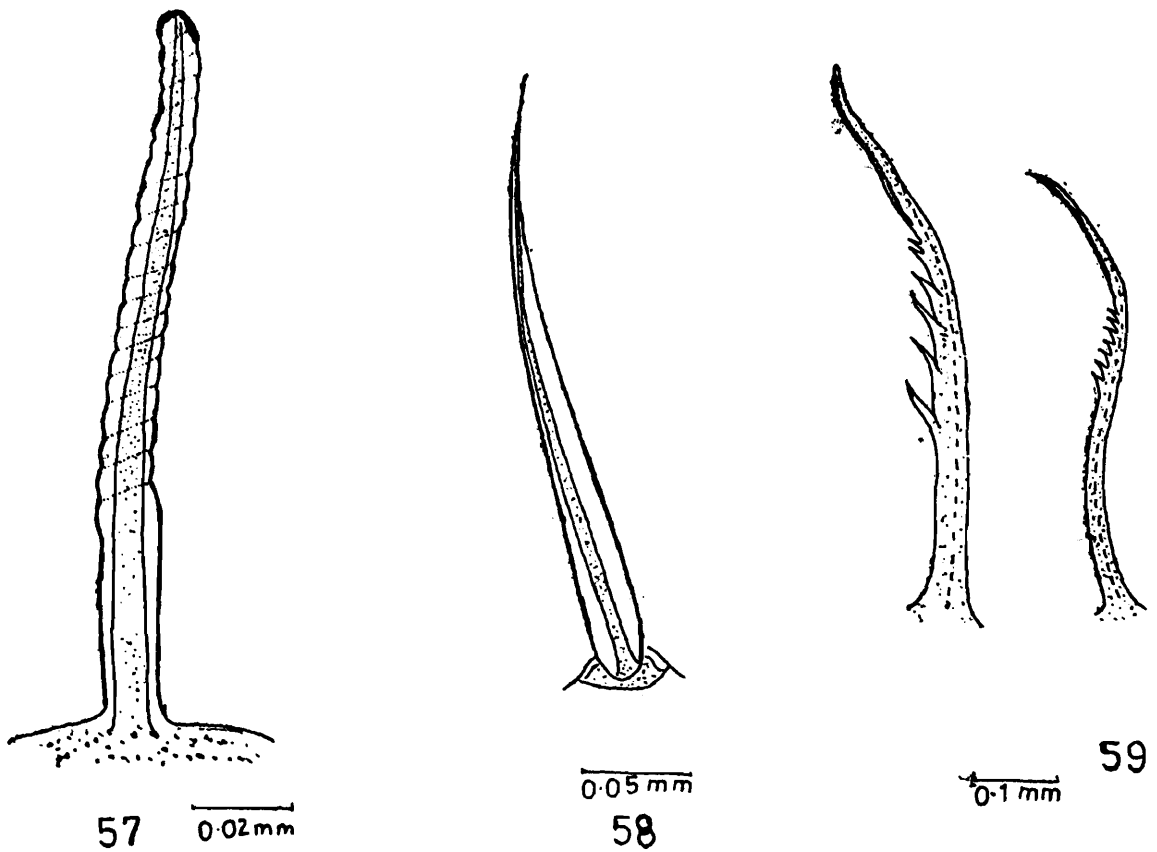
Morphology of the spigots on the spinnerets of spiders (Figures 45—47)

- 45. Spigot Type-I
- 46. Spigot Type-II
- 47. Spigot Type-III



Morphology of the spinning tubes in spiders (Figures 48—56)

48. Spinning tube in *L. nigrotibialis* and *H. pisaurina*, Type-I
49. Spinning tube of *L. nigrotibialis* and *H. pisaurina*, Type-II
50. Spinning tube of Type I in *S. sarasinorum*
51. Spinning tube of Type II in *S. sarasinorum*
52. Spinning tube of Type III in *S. sarasinorum*
53. Spinning tube of Type II in *N. mukerjei*
54. Spinning tube of Type III in *N. mukerjei*
55. Spinning tube of Type II in *P. paykullii*
56. Spinning tube of Type III in *P. paykullii*



Morphology of Hairs and Bristles in Spiders (Figures 57—59)

- 57. Chaemosensitive hairs
- 58. Straight and pointed hairs
- 59. Serrated bristles or accessory hairs of orb weavers