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SOME OBSERVATIONS ON ORB-WEAVING MECHANISM OF INDIAN ARANEID SPIDERS

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ABSTRACT

Orb-weaving mechanism of Indian Araneid spiders are given with full illustrations and their two types of primary web-building operations and pattern of orb-weaving of some genera of the family Araneidae (=Argiopidae) have been discussed.

Introduction

The first thing which strikes our mind by the name of spider, is its spinning habit. Among spiders araneids are unique because of their peculiar habit to construct the orb-webs having geometrical precision. Their finished product of web is a masterpiece of their craftmanship. The webs mainly serve as trapping nets to capture their prey, often camouflage the spiders from their prey and predators. The threads of webs are nothing but the secretion of silk glands, present inside the abdomen. The silk secretion which is a kind of protein, solidifies as soon as it comes in contact with the air. The secretion of silk gland comes out from the minute microscopic spigots present on the mound of spinnerets. There are very little work on this subject in our country. Only Dugdale (1969) and Tikader (1961, 1966 and 1978) have published some observations of spiders and their biology and protective device of orb-weaving spiders from India. Levi (1978) and Kullmann (1975) have also published some observations of orb-weaving spiders from America and West Germany respectively. In this paper we have given our observations of orb-weaving technique of araneid spiders with illustrations, and also discussed the pattern of orb-weaving of different genera of spiders of the family Araneidae (=Argiopidae).

Orb-Weaving Mechanism

Orb-weaving spiders are of various kinds, so their modes of web-building also different to some extent. Primarily two types of operations are seen. One, the bridge line alongwith the outer frameworks are constructed first. By this way the orb-webs are either vertical or horizontal in position with the adjacent supporting objects. The other type, where after formation of bridge line a V-shaped two radii are formed from a second thread just below the upper bridge line, and the other radii alongwith outer frames are constructed. But in both the types the operations are a little bit variable according to the availability of adjacent supporting objects. After formation of all radii, the spider construct the non-viscid spiral thread from centre to periphery which later replaced by viscid spiral thread from periphery to centre.

Here the two types of web-building operations have been discussed :

In the first instance the spider *Gasteracantha mammosa* C. L. Koch (=*G. brevispina*) pays out silk from its spinnerets to the wind from at a point A until the free end of the thread gets entangled to an end B on the shrub (Fig. 1). From A the spider goes over to the point B and sticking the end firmly there. The spider then walks back and forth along the line to strengthen it by laying more silk on it. Thus the bridge line A-B is established (Fig. 2). From A the spider proceeds upto the middle of the bridge line, *i.e.*, C, from where it drops down a thread over a weed below and fixes the thread at D on the weed (Fig. 3). From this point the spider continues the thread and carrying it loose by one of its hind legs not to be entangled on the supporting weeds on which it walks, and goes over the weeds upto a stump E of the shrub where it entangles the line. Now, it climbs up along the branch from E by trailing the thread and attaches it to the point A (Figs. 4, 5). Thus D-E and E-A outer frameworks have been formed.

Then the spider crosses the bridge without any trailing thread upto B and from there it drops down on the weed below by a dragline thread and fixes it at the point F on the weed, thus B-F is formed (Fig. 6). From the point F the spider crawls down along the weed with a thread to form F-D (Fig. 7). In this way a pentagonal framework is built with the bridge line A-B and outer four boundary lines B-F, F-D, D-E, E-A, the line C-D, which passes from the middle of the bridge line C as a diameter through the centre of the entire space upto the middle of the opposite boundaries of the future web.

After this, the spider starts to construct the radial threads through a point on the already formed diameter C-D, which will be the centre or hub at the future web. In anticipation to this operation, it crawls upto a point G on D-C. At G the spider attaches a thread and trailing it loose behind proceeds upto C and from there it goes a little distance towards B and at point H entangles the line tight and makes the radius GH (Fig. 8). From H point the spider moves a few centimetres further towards B and at the point I fixes a fresh thread and trailing it loose comes back to G alongwith the radius HG and by pulling tight the thread at G the spider makes IG radius (Fig. 9).

Next, the spider spins a new thread from G and trailing the line loose descends down to D and turns towards E, at J it fixes the thread tight and thus the radial thread GJ is formed (Fig. 10). From J, the spider moves a little away towards E upto the point K, where it fixes a new thread and carrying the thread upto G via JG and attaches it to G. In this way another radial thread KG is formed.

The spider repeats the operation to construct the radial threads in pair, are laid alternately on the right and left until the required radii are formed which are sufficient to hold the future web (Fig. 11).

After completion of all radii, the spider moves to the centre of the web and gives attention to some extent to give sufficient support to the radial threads, so it spins a few turn of spiral thread immediately outside the hub. This small spiral around the hub is called attachment zone (Fig. 12), and it is, ofcourse, before the spider starts a temporary non-viscid spiral. Because of this attachment zone, the radial threads are getting the uniform tension.

Once the hub and the attachment zone are completed, the spider starts to weave a spiral from the end of the attachment zone and continuing to the periphery in an anti-clockwise direction (Fig. 13), with turns as far as the spider can stretch. The thread of this temporary spiral is coarse and non-viscid and its function is to hold the radial threads for subsequent operations.

When the temporary spiral is completed, the spider reverses its direction, rolls up the old one and puts down the new, finer and more closely interspaced viscid silk which is elastic too (Fig. 14). This viscid spiral is weaving in a clockwise direction with measured action and uniform speed. In spinning the viscid thread the spider fastens it to a radius and then moves on pulling out the thread from the spinnerets, but before the thread is fastened to another radius the spider takes hold of it with the claws of one hind leg, and straightening this leg pulls out from the spinnerets ; the spinnerets are then applied to the next radius and the thread fastened in place. After this the spider takes away its hind leg and the thread contracts to the length of the space between the two subsequent radii.

The viscid spiral does not cover entirely upto the hub but leave a space between the viscid spiral and the attachment zone called free zone (Fig. 15). By following the above mentioned modes of operation to construct the web, the final product gets a "geometrical precision" which reveals the highest achievement of the craftmanship of orb-weaving spiders (Fig. 15).

In the second instance the young *Araneus* spider starts to weave its web at the beginning of dark in the evening. At point A on a tree branch it fixes a thread and then crawls along the branch in an inverted position by trailing behind the thread carefully and attaches at the points X, Y, Z and finally at B (Fig. 16). From B the spider returns to A carrying behind a loose thread which it fixes to A. Thus an upper bridge line A-B is established (Fig.17).

Soon after this the spider drops down by a thread upto a level of a small plant below (Fig. 18) to reach to the plant the spider dangles to and fro, and as soon as it gets the plant, fixes the thread on any of the branches firmly. Through this oscillation and also with the help of wind it reaches to the plant (Fig. 19). Thus A-C is formed, and along this A-C the spider climbs back to A and then towards B upto D, the mid-point of A-B. At the point D the spider cuts the thread and attaches the spinnerets to the cut end, and makes the thread A-B longer by rotating itself. Thus a V-shaped structure of thread is formed (Fig. 20). From the bent point of V the spider drops down by a thread forming a Y and attaches the end of the thread at C (Fig. 21).

The spider then fixes a thread at C and trailing it behind and climbs upto B following the way C-D-B. At B the thread is hauled tight and fixed (Fig. 22). Thus a boundary line of the framework at future orb-web C-B is formed. From B the spider moves down a little distance towards D and fixes a thread there at E. The spider then trailing loose a thread, goes upto F via D, a little below of A where the thread is pulled tight and fixed. Thus the upper boundary line E-F is formed after removing the original bridge line A-B (Fig. 23).

From F the spider moves a few distance towards E and at G fixes a thread, and by holding it carefully not to be entangled to any pre-existing thread the spider moves upto D via F. At D the thread fixes tight. Thus the radial thread GD is formed. Then from D the spider trailing a thread upto H via C, and the thread is pulled and fixed tightly at H. In this way another spoke DH is formed (Fig. 24). The spider then moves to the point J and attaches a thread there and return to D via H to fix a thread to form the spoke JD (Fig. 25). By following the same procedure all other spokes or radial threads at the future orb-web are formed, one or two to the right alternating with one or two to the left (Fig. 26).

Next to this, the spider starts the subsequent phases to complete the orb-web, so the attachment zone and non-viscid spirals are formed after leaving the free zone as stated in the first case (Fig. 27). Then the non-viscid spiral is removed by closer meshed viscid spiral, weaving clockwise from periphery to the centre (Fig. 28). In this way the orb-web in vertical plane is constructed by *Araneus* spiders.

Different Features of a Typical Orb-Web

The bridge line (A) as in the text-fig. 29 is a line which is spun by a spider between the two supporting objects. Foundation lines (B) are outer framework lines spun subsequently after establishment of bridge line, with different supporting objects. After construction of outer framework the spider spins the radial threads (C) in the open space of the framework, each intersecting the hub or the web-centre (D). Thus after formation of the hub the spider spins a few turn of spinal thread, just adjacent to the hub, which gives more strength to the radial threads, called the attachment zone (E). At the end the spider spins the viscid, elastic spiral thread (F) from periphery to the centre in a clockwise direction by leaving an area of less width called free zone (G). The viscid spiral thread removes the non-viscid spiral thread which is spun from the centre to the periphery in an anti-clockwise direction.

Net Element or Thread

Generally large orb-weavers produce thicker threads. Within one species of spider, the diameter of the thread also changes with age. The thread thickness of an adult large orb-weaver is 0.010 mm. to 0.012 mm. per individual thread. The thread produced by *Nephila* is the strongest among spider's thread. The strong webs of *Nephila*, matted and twisted, are used by South Sea Islanders for various kinds of bags and fish nets. (Kullmann, 1975).

As a spider walks around, it usually emits a double or even quadruple thread—this is called "dragline". This dragline serves as a safety line so that in the face of danger the spider can let itself fall without loosing contact to the last attachment disk to which it can return by climbing up the thread.

The Mesh of the Orb-Webs

The mesh is the geometrical elements of the web. It is formed by the joining together the threads and knots of the close lines.

Accordingly, they are only of four kinds found in orb-webs. The Trapezoid mesh (Fig. 30) as found in general orb-webs. The Square mesh (Fig. 31) which is constructed in the sheet of the orb-web made by *Cyrtophora*. The Rectangular mesh (Fig. 32) constructed by *Nephila*, and the rest one is Irregular mesh (Fig. 33) which is also found in the hub of the orb-web of some araneids.

Net-Support

Orb-webs are suspended by one or more pairs of threads or thread bundles from objects close to it, such as grass, leaves, branches, ropes, stones and spanned between them. On one side it consists of objects found ready to hand such as grass, leaves, branches, fence wire, stones, walls etc. and on the other hand, at adjusting elements such as foundation lines and anchoring threads (Figs. 34, 35). They transmit the forces to the net supports such as branches (Fig. 36). External net supports such as blades of grass (Fig. 37) or wall or building corners (Fig. 38) are known. However, internal net supports, particularly blades of grass, may also be observed (Fig. 39). If the net supports are very elastic, as in case of very long suspension threads or very flexible grass (Fig. 40), their elastic-constructive behaviour is an essential help for trapping the prey.

SPECIAL FEATURES IN ORB-WEBS OF ARANEID SPIDERS IN DIFFERENT GENERA

The spiders of *Gasteracantha* weave some small fussy silk balls along the viscid spiral, which are afterwards entangled with debris to form rounded mass of waste products of their body size. So it is very difficult to locate the spider in exact position in the web (Fig. 41). This is also a kind of protective device. The young *Gasteracantha* may make a stabilimentum where as adults do not (Levi, 1978).

In the genera *Argiope* and *Cyclosa*, the orb-webs are commonly provided with stabilimentum. It is a zigzag ribbon like structure across the hub. It consists of large number of minute threads resembling a swathing band and spun from the small spigots of the aciniform glands.

In the webs of *Argiope*, the stabilimentum is X-marked across the hub (Fig. 42). It is always more elaborate in young than in adults. Despite its names the ribbon like white bands do not function in support of the web, so it is seen the webs of largest females often lack of stabilimentum. The stabilimentum may obscure the out-line of the spider, which does not have a retreat but hangs in the centre of the web (Levi, 1968). It is not periodically replaced as the viscid silk. Since the decorative stabilimentum is found in diverse groups, sometimes only in the webs of immature, it may have different functions in different webs (Levi, 1978).

In the orb-webs of *Cyclosa*, the stabilimentum is generally a small one, placed just above and below the hub. *Cyclosa insulana* does not spin stabilimentum in the webs but the female spider fastens her egg-sacs in a series which extends across the web from the hub to the upper margin looks like a dead twigs or debris in a row in the web. The spider hangs in the web in a small gap at the centre between the upper half and the lower half of the structure (Fig. 43). This band of egg-sacs and the spider are of the same grey colour, so it is very difficult to find out the spider in the web, *C. mulmeinensis* constructs horizontal web without any stabilimentum. The spider waits in the hub for prey and the female fastens its egg-sacs in the webs at a side.

Some orb-weavers wait away from the web in a retreat which is directly connected with the hub by thread called trap-line. This retreat is made up of leaves fastened together with silk, a little away above or a side of the web (Fig. 44). When any insect gets trapped in the web, the disturbance caused on the web is communicated to the spider waiting in the retreat, and the spider rushes to get the prey. These retreats or nests are commonly found in the spiders—*Araneus mitifica*, *Neoscona* *rumpfi*, *N. mukerjei*, *Parawixia dehaanii*, *Zygeilla* sp. etc.

Zygeilla builds the orb-web, in which characteristically one sector remains free of viscid spiral threads (Fig. 45). There is one radius leading through this open sector to the retreat of the spider as a trap-line. Their webs are renewed almost everyday.

In case of *Gea*, the orb-web occationally has a sector missing from the lower half, compare with the web of *Zygeilla* where the sector is missing from the upper half. *Gea* constructs the web close to the ground in low vegetation and not having any stabilimentum.

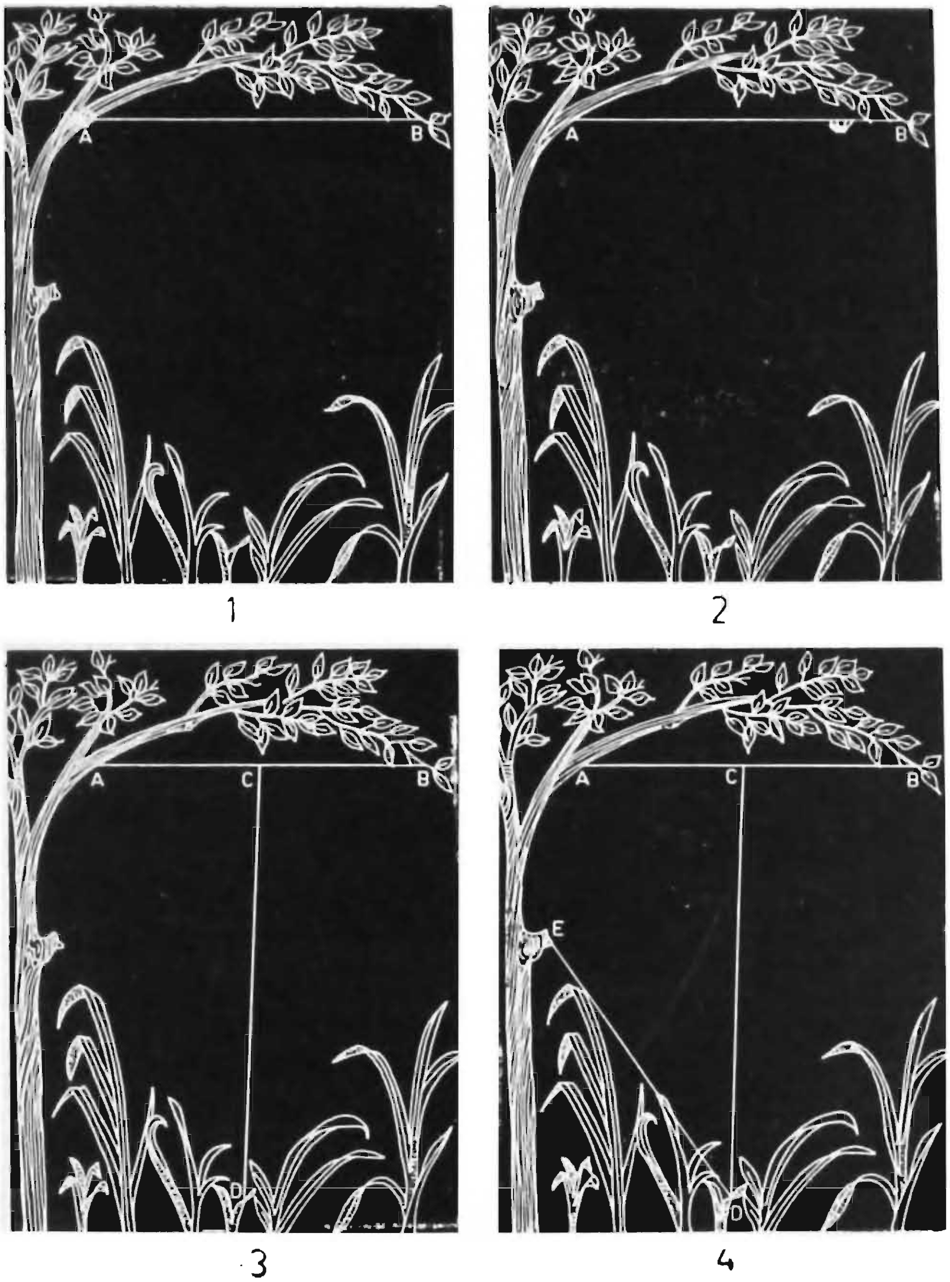
In some genera, as in *Meta*, *Leucauge*, *Gasteracantha*, the hub is open. This open hub fascilitates the spider to move from one face to the other. The hub of *Neoscona* is not fully open but crossed by only one or two threads (Fig. 46), unlike webs made by *Araneus* where the hub is meshed (Fig. 47). *Neoscona* sits in the hub with the tip of the abdomen pushed through the open space of the hub.

Leucauge builds the web in horizontal plane in low bushes during day time. Very quickly they construct their webs, which are devoid of retreats. The spider hangs at the centre upside down posture. Almost everyday they build their nets after removing the old one.

Nephila makes a huge web, nearly one metre or more in diameter, in shaded woods. The webs are different in number of respects from the others in the family. The radii are pulled out at their direct course to give a notched appearance (Fig. 48) and the viscid spiral is of yellowish in colour rather than white. The silk of *Nephila* is the strongest natural fibre known (Levi, 1968). The strong webs of *Nephila*, matted and twisted, are used by South Sea Islanders for various kinds of bags and fish nets. Unlike other orb-weavers, the *Nephila* makes use of the same web for a long period replacing only the viscid lines. The webs of young *Nephila* are complete orbs but the adults construct incomplete webs in the upper side. *N. maculata* is having an orb-web with a barrier web in the lower side.

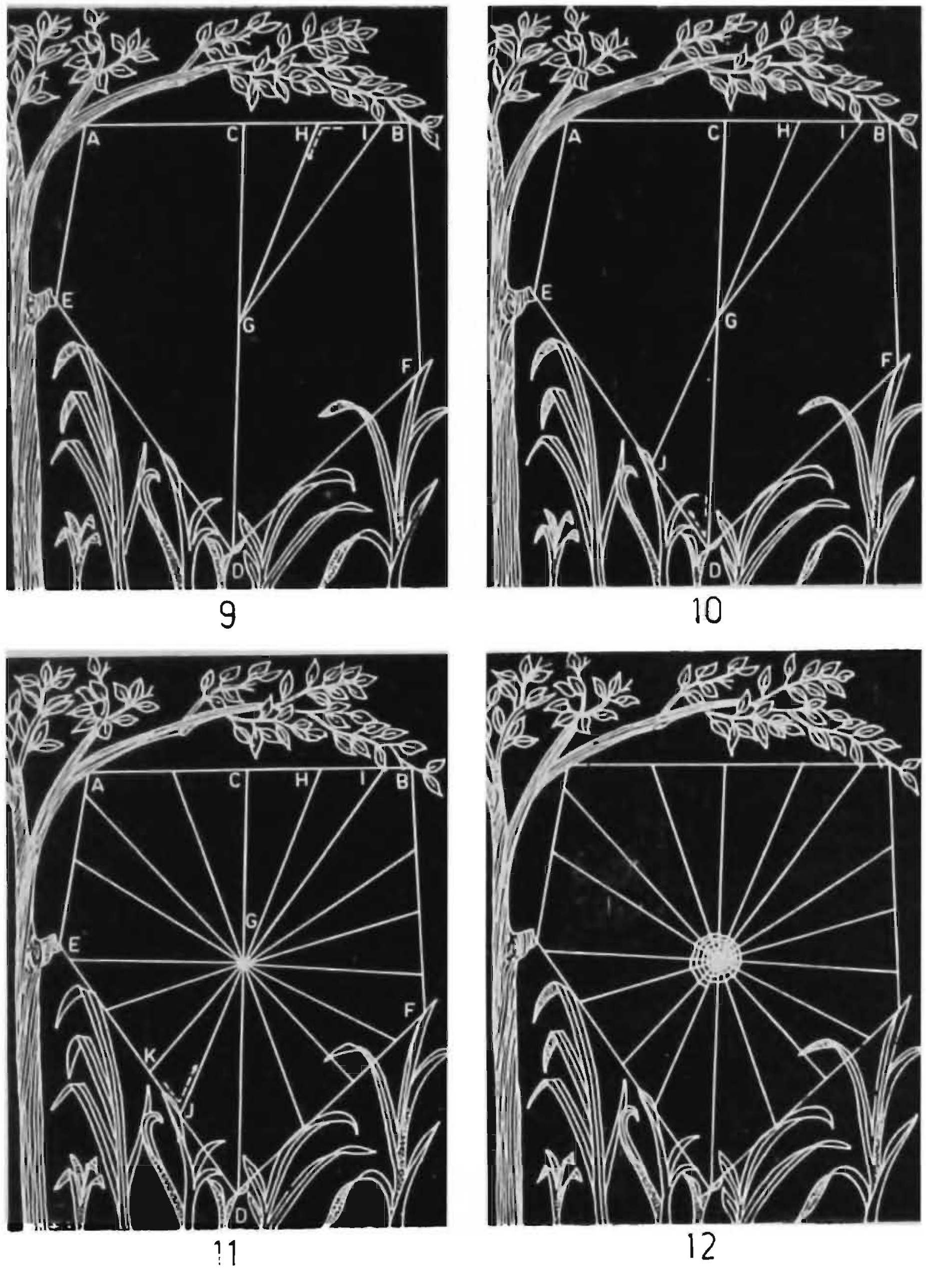
Larinia makes the orb-web in the low bushes without any retreat. It does not rest in the centre of the web but on the vegetation to the side in day time. At night it sits in the hub only.

Members of the genus *Cyrtophora* produce the most unusual webs, thus perhaps the most specialised one. They make horizontal dome shaped webs with a barrier-web above and below (Fig. 49). The webs are devoid of viscid silk which is a specialised character since sticky threads are found in almost all araneids. The mesh of the web, which takes several nights to build, is so extraordinarily small that it can be said that it is a derived character. The webs of *Cyrtophora* are the best example of highest achievement of technical masterpiece among the spiders. *C. cicatrosa*, *C. citricola*, live in large colonies that span huge areas with contiguous barrier webs. These spiders make very few catches but since new webs are not constructed frequently, little energy is spent. The moths or other insects fly against the barrier web, tumble down to the domed horizontal orb-web, and are pulled through by the spider from below the web. The threads of the orb are not viscid and thus the rain water does not affect them, so no need to replace them frequently. It is observed that *Cyrtophora* takes 4-5 nights to complete its web (Kullmann, 1975).

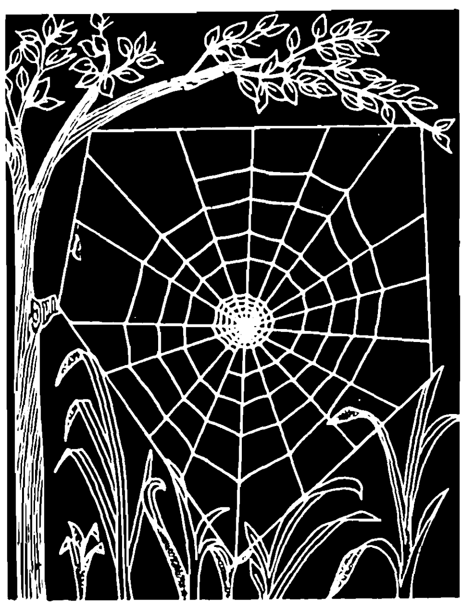


Figs. 1-4. Orb-weaving mechanism of *Gasteracantha mammosa* C. L. Koch.

Figs. 5-8. Orb-weaving mechanism of *Gasteracantha mammosa* C. L. Koch.



Figs. 9-12. Orb-weaving mechanism of *Gasteracantha mammosa* C. L. Koch.



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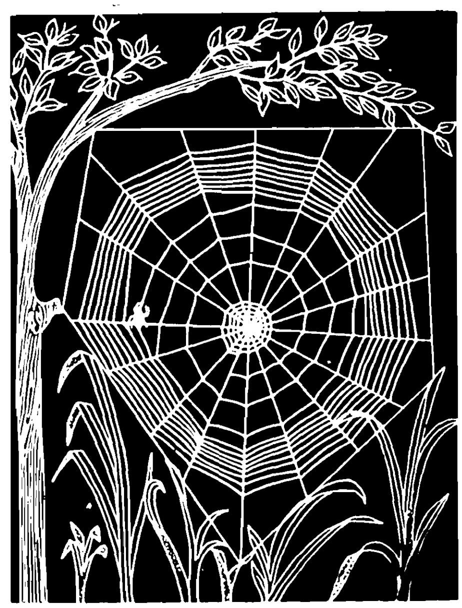

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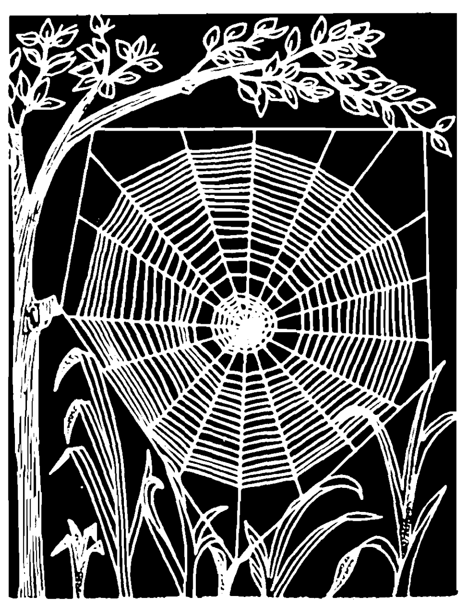

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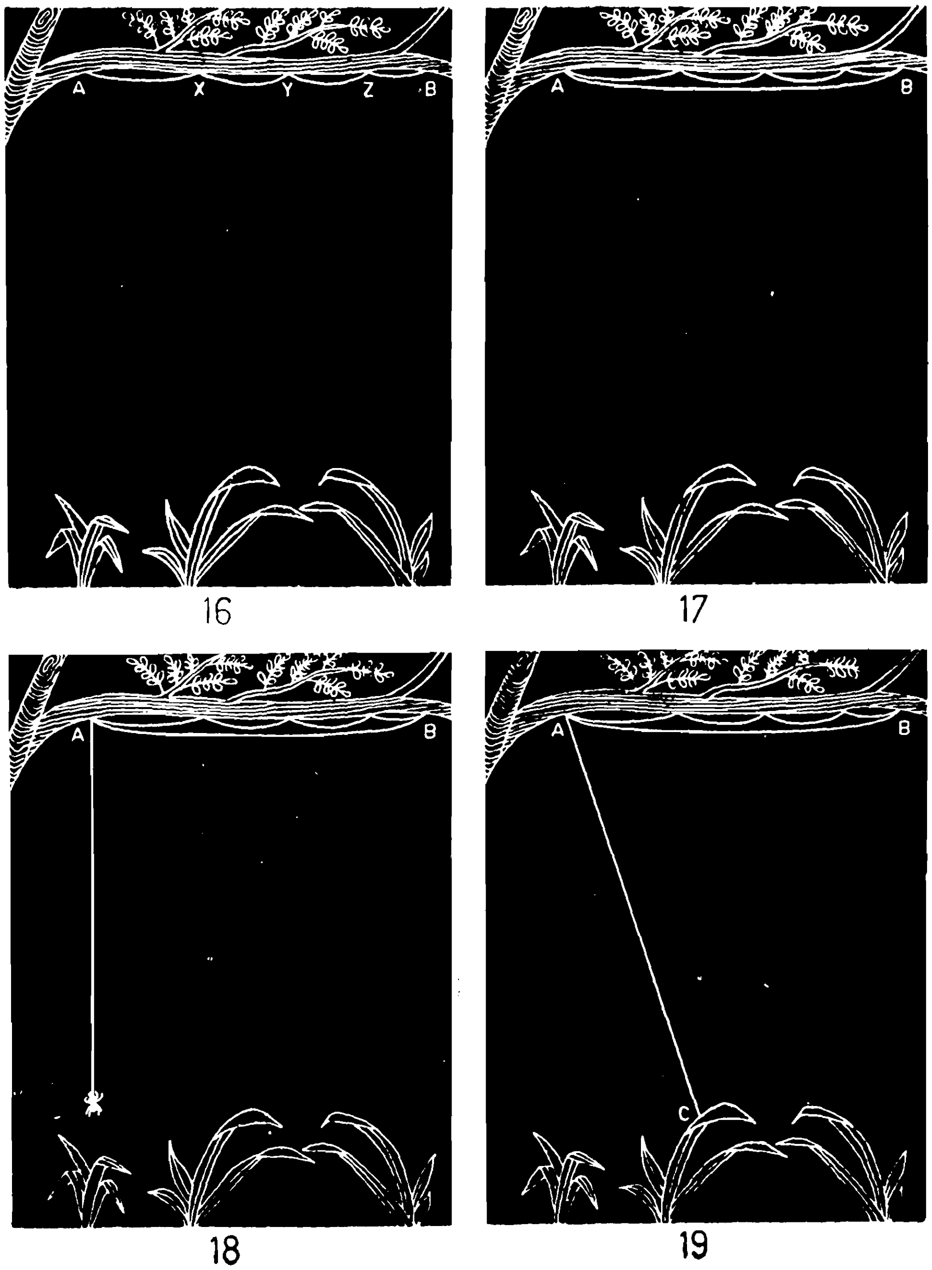
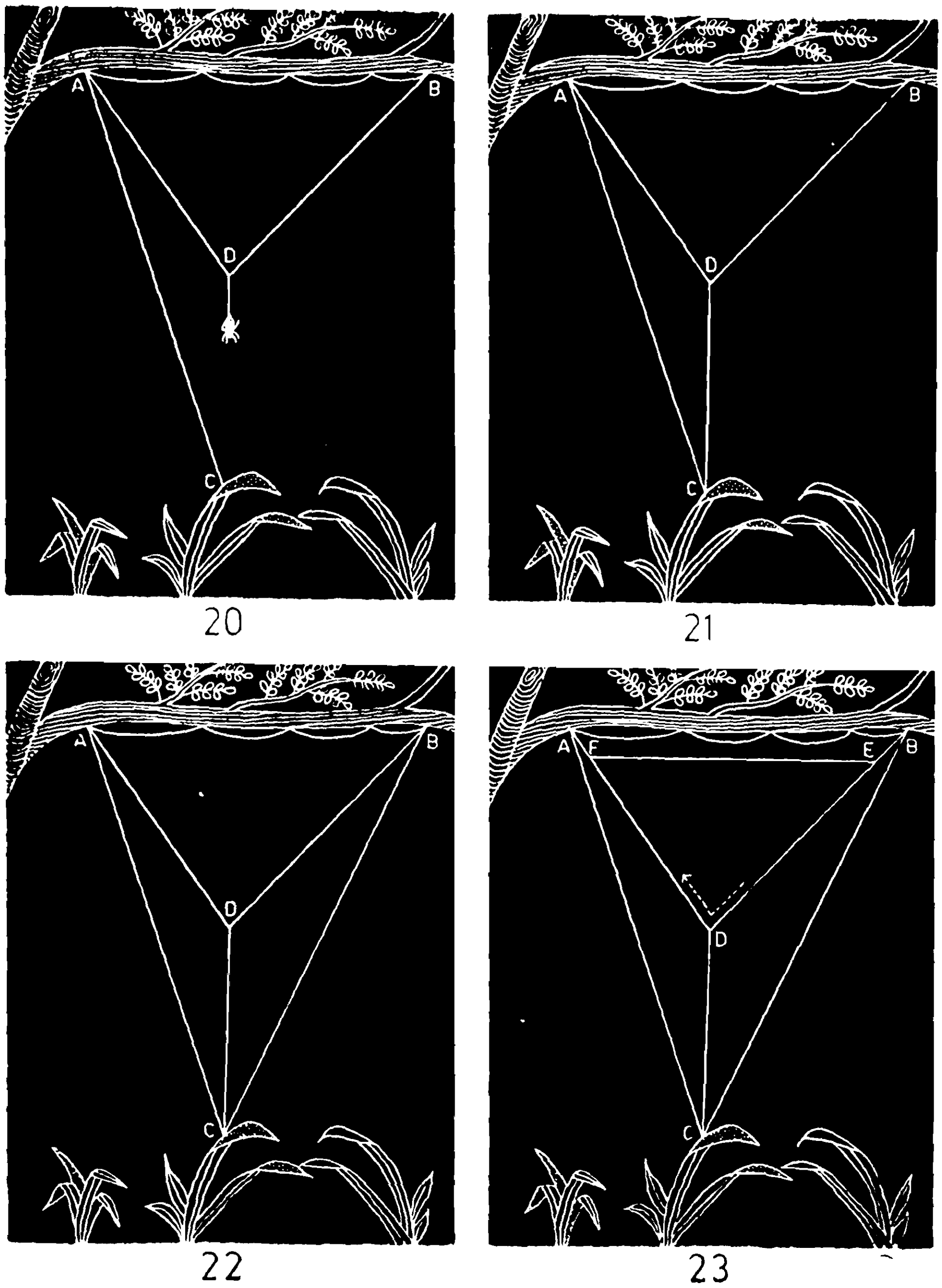
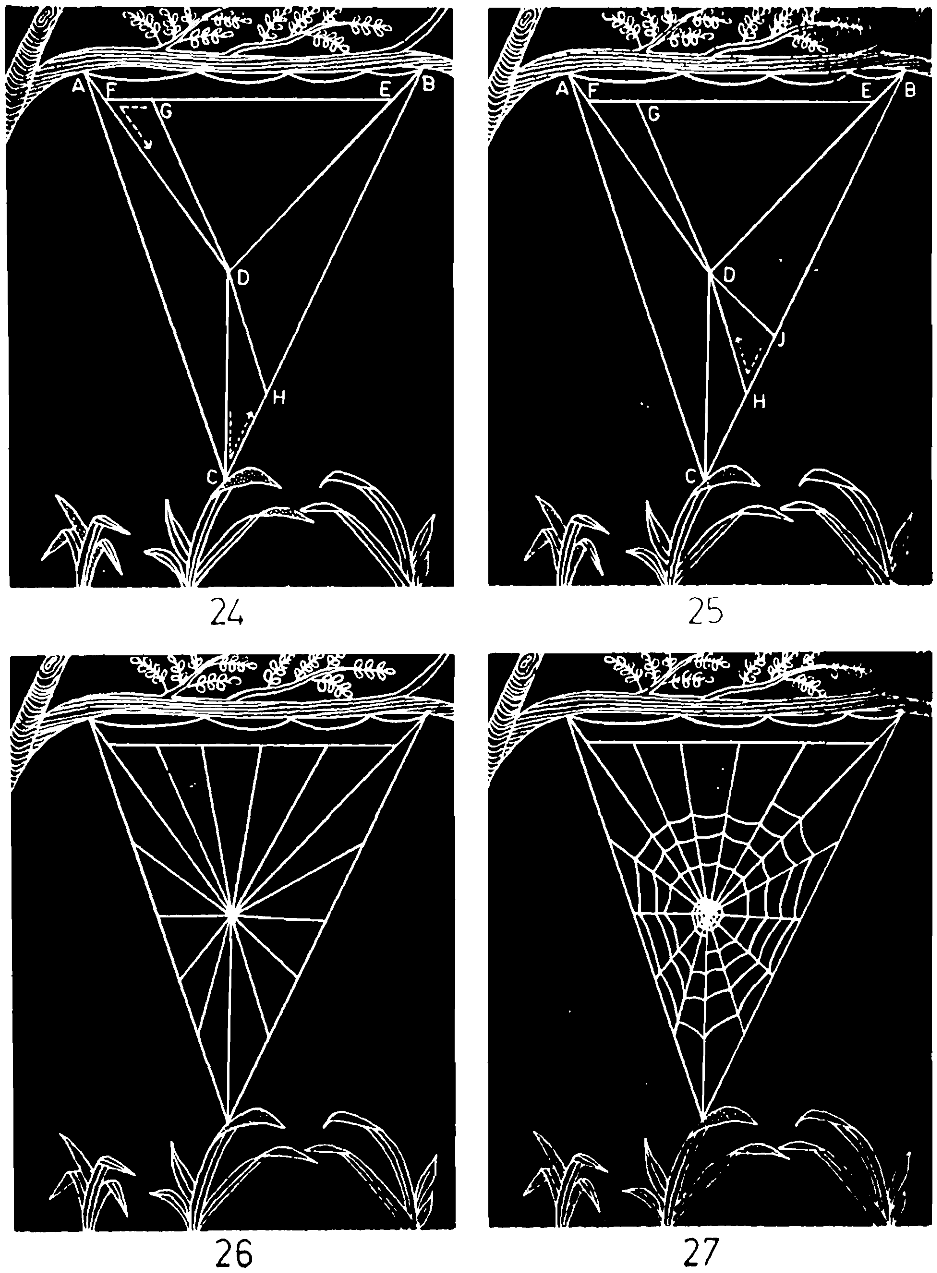
Figs. 13-15. Orb-weaving mechanism of *Gasteracantha mammosa* C. L. Koch.



Figs. 16-19. Orb-weaving mechanism of young *Araneus* spider.



Figs. 20-23. Orb-weaving mechanism of young *Araneus* spider.



Figs. 24-27. Orb-weaving mechanism of young *Araneus* spider.

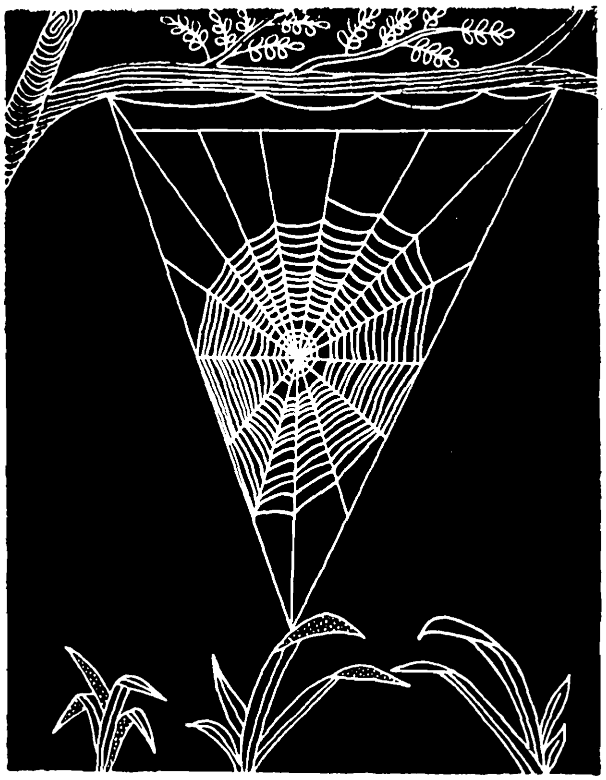


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Fig. 28. Orb-weaving mechanism of young *Araneus* spider.

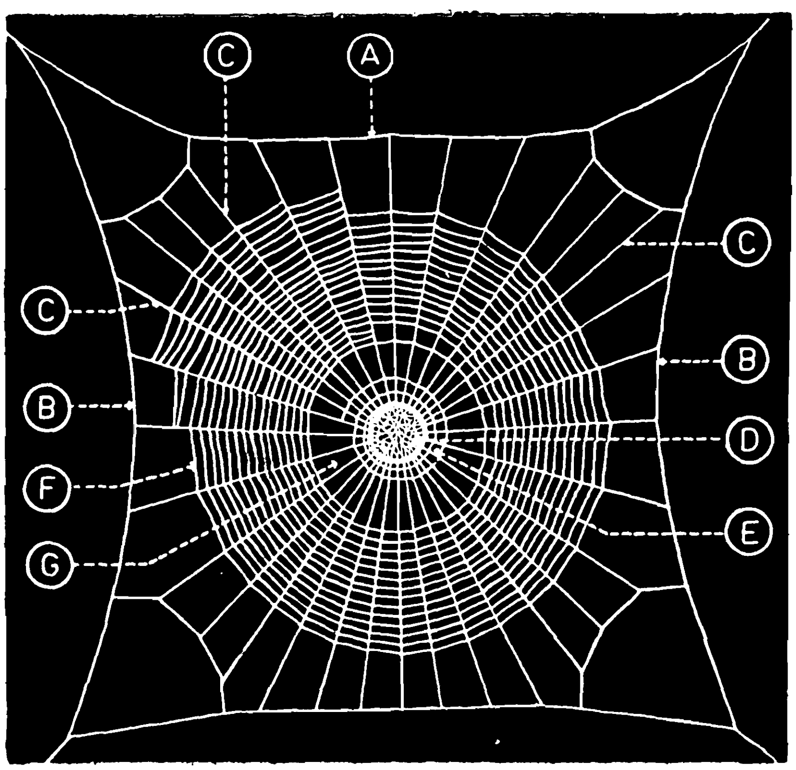

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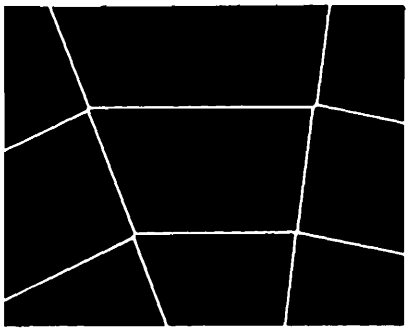
Fig. 29. Different parts of a typical orb-web.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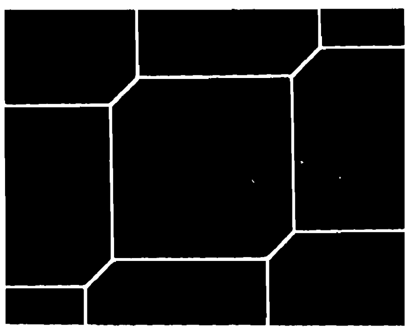
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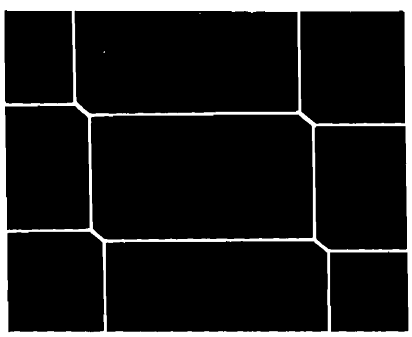
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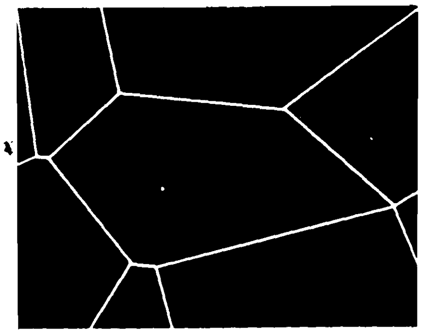
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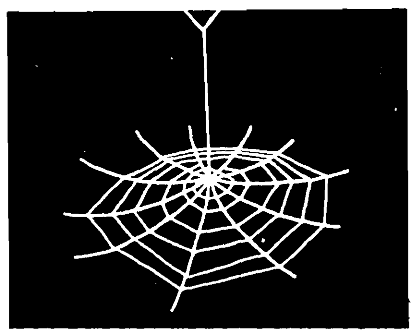
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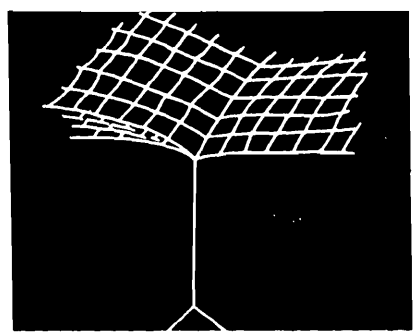
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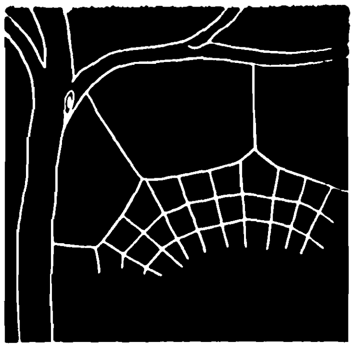
Fig. 30. Trapezoid mesh.
Fig. 31. Square mesh.
Fig. 32. Rectangular mesh.

Fig. 33. Irregular mesh.
Fig. 34. Anchoring threads.
Fig. 35. Anchoring threads.



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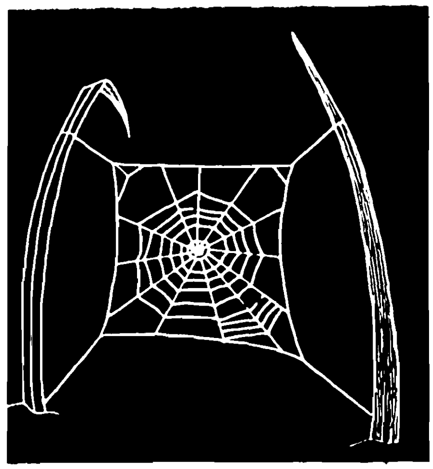

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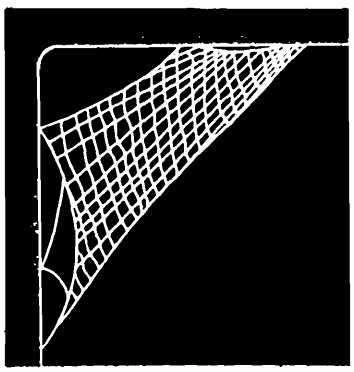

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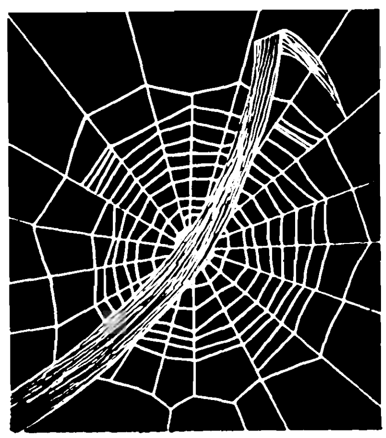

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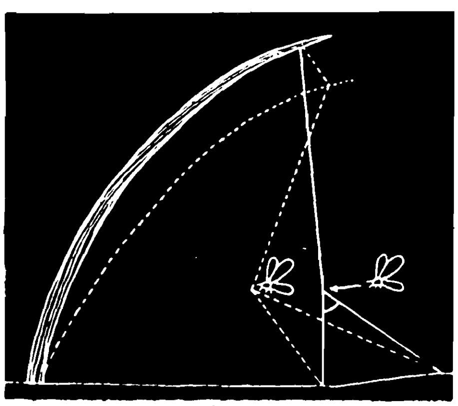

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Fig. 36. Tree branches.

Fig. 37. Blades of grass.

Fig. 38. Building corners.

Fig. 39. Blade of grass as internal net-support.

Fig. 40. Very flexible grass.

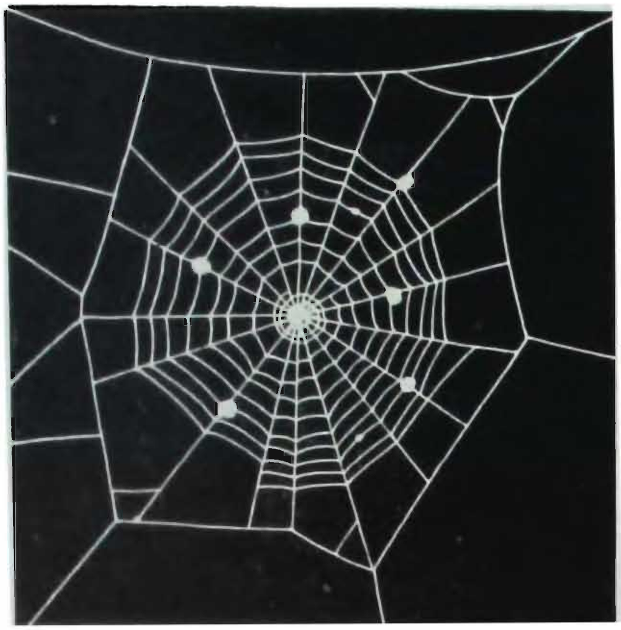

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Fig. 41. Orb-web of *Gasteracantha* with fussy silk balls.

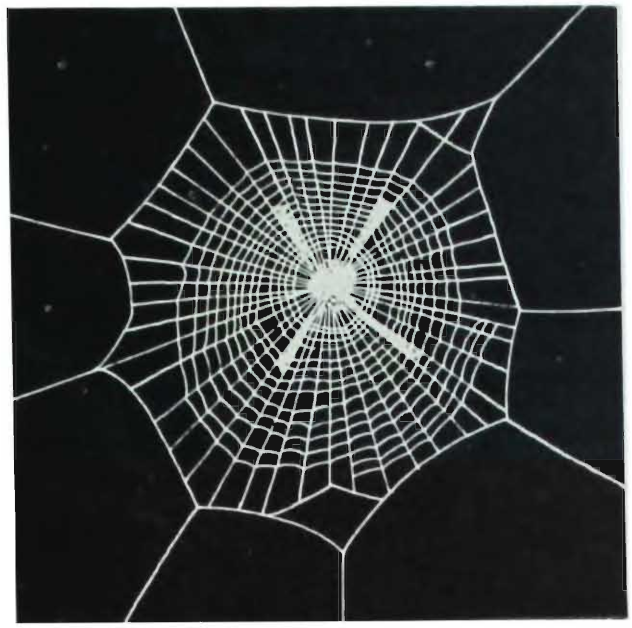

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Fig. 42. Orb-web of *Argiope*, provided with X-shaped stabilimentum.

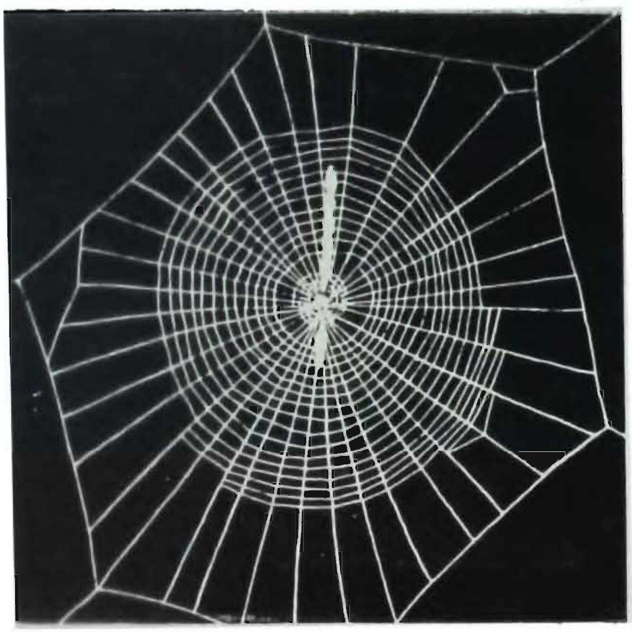

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Fig. 43. Orb-web of *Cyclosa insulana* (Costa).

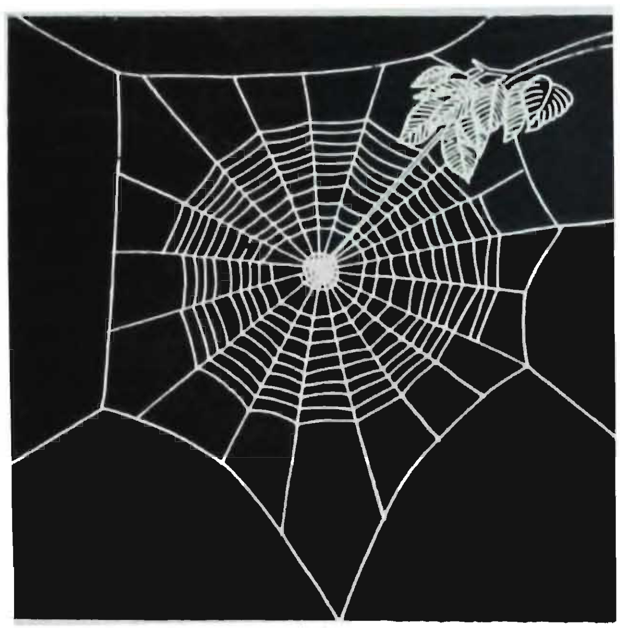

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Fig. 44. Orb-web of an araneid spider with retreat.

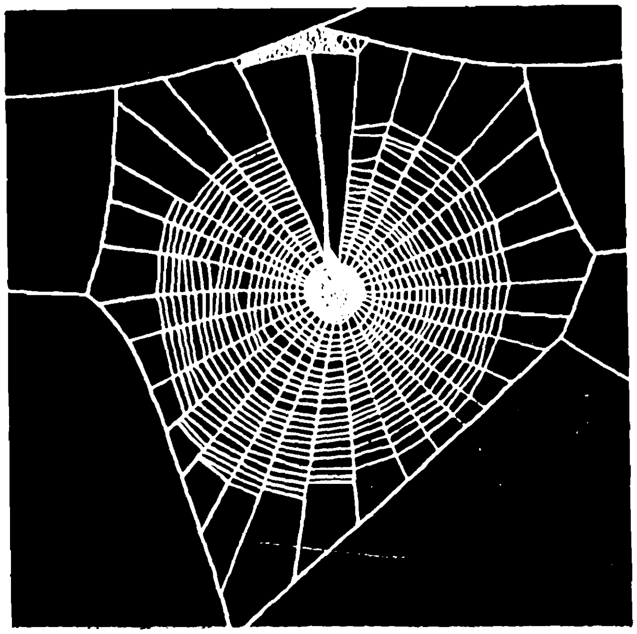

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Fig. 45. Orb-web of *Zygeilla*.

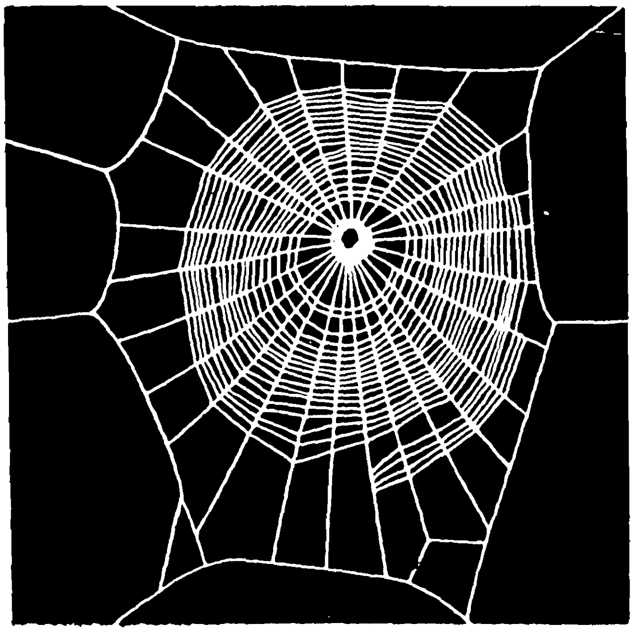

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Fig. 46. Orb-web of *Neoscona*.

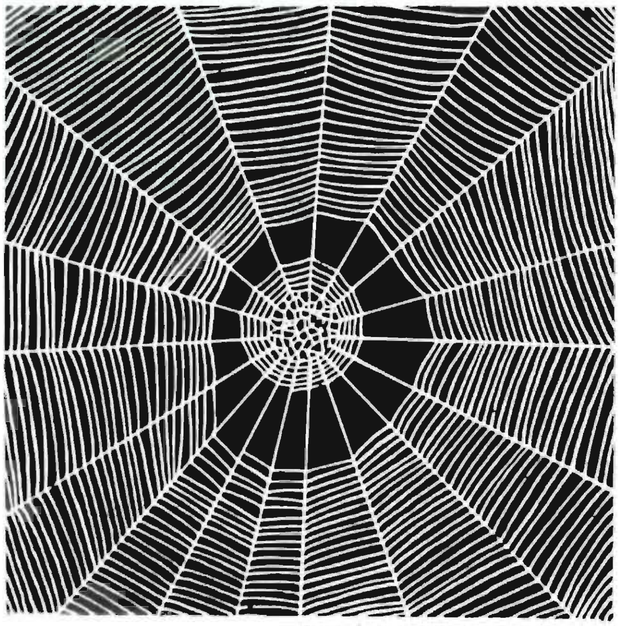

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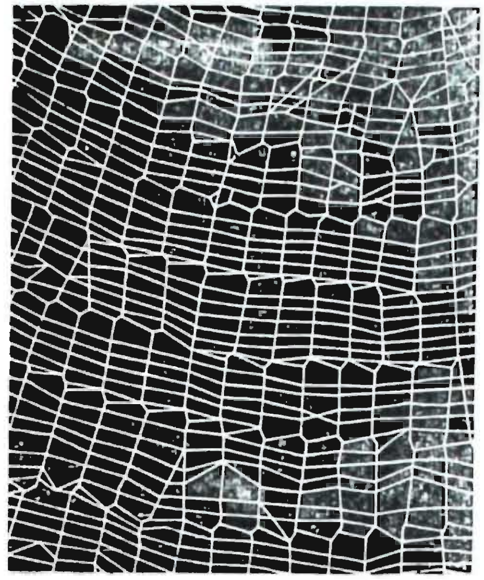
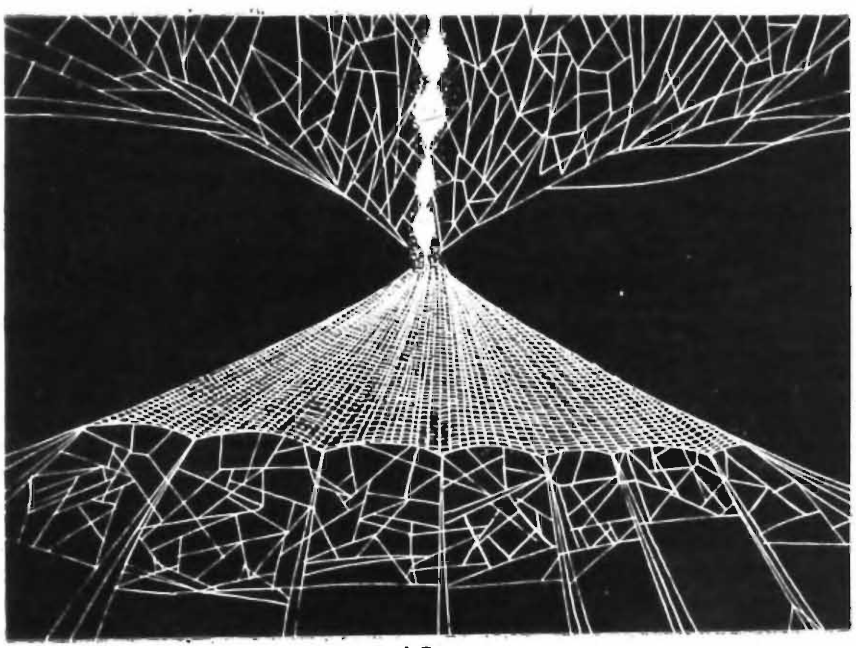
Fig. 47. Orb-web of *Araneus.*



48

Fig. 48. Part of the orb-web of *Nephila.*



49

Fig. 49. Horizontal dome shaped web of *Cyrtophora citricola* (Forskal) with a barrier web above and below.

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