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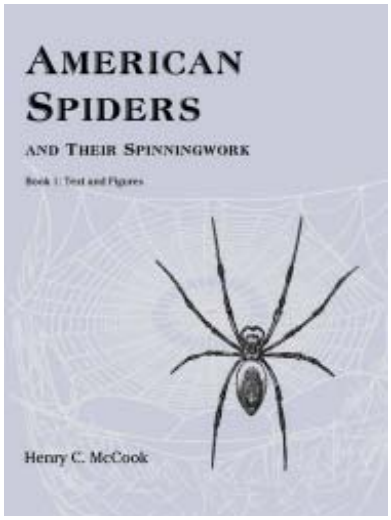

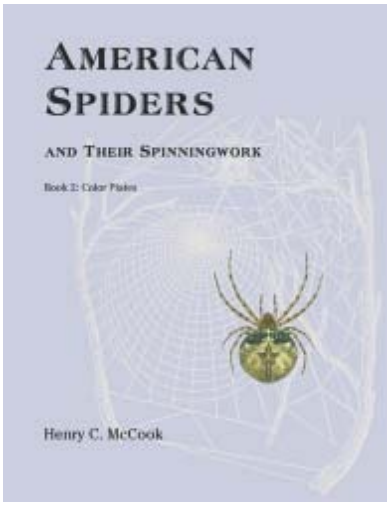

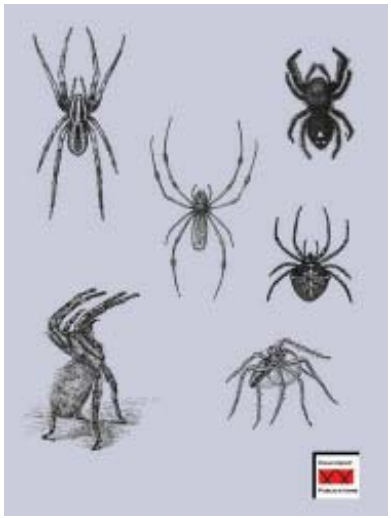

Chapter IX.

The Aeronautic or Ballooning Habit.

Many accounts have been published, more or less valuable, of what are popularly known as "flying spiders." As the natural habits of familiar animals have come to be better understood, this popular phrase has yielded to the more accurate one, "ballooning spiders." However called, the habit referred to has been and remains interesting and attractive to the ordinary scientific observer. The fact that an animal which has none of the natural provisions for progress through the air granted to winged creatures, should, nevertheless, be able to overcome gravity, mount into the atmosphere, and accomplish aerial journeys, sometimes of immense distances, is certainly well suited to captivate the imagination, awaken curiosity, and stimulate research. This interest is quickened by the fact that the mode by which the spider aeronaut reaches these results bears a marked likeness to the artificial means by which man has himself solved the problem of aerial navigation. The thought that the invention of Mongolfier's mind possesses this striking analogue in the natural history of an inferior creature, strikes into a profounder depth than curious wonderment, and touches the problem of a Supreme Mind over Nature.

I.

I have studied the aeronautic habit of spiders from representatives of the Orbweavers, Tubeweavers, Citigrades, Laterigrades, and Saltigrades, and have not been able to note any difference in the mode of flight as practiced by all. It is probable that the young of most spiders, and many of the small species of all the great groups, are more or less addicted to such mode of motion. Certainly the habit is very strongly fixed in Orbweavers. Epeiroid spiderlings just out of the cocoon lift themselves into the air and sail away, precisely in the manner hereafter described. Indeed, the infant aranead, when separated from its fellows and exposed to a strong puff of air, seems instinctively to throw out its spinnerets and send forth jets of silken filament, just as a human baby sets in motion its feet and hands.

As the jets almost instantly acquire sufficient buoyancy to counterbalance the spider's weight, the creature becomes an aeronaut, nolens volens, and one can see how readily the deliberate habit of ballooning could have been formed and fixed by heredity. The largest Orbweaver that I ever saw taking flight was a partly grown Domicile spider about the size of a marrowfat pea, say one-fourth inch long. After having floated over a field and above a hedge row, it crossed a road and anchored upon the top of a young tree. It never attained a height of over twenty feet, but moved quite as fast as I could run.

Young and small spiders fly rapidly, their motion depending, of course, upon the state of the breeze, although they do not appear to undertake their aerial voyage when the wind is strong.

However, even when the air seems quite still to the observer, the little aeronauts find a sufficient current in the height to which they immediately ascend to bear them along with a good degree of speed. Indeed, I have been surprised at the velocity of their progress in the midst of what might be called a dead calm.

Spider ballooning is not limited to a special period of the year, but may be practiced at any time. In point of fact, however, the seasons when it most prevails are the spring or early summer, and the autumn after the young have been hatched. The fall of the year is more especially the season for "flying spiders," and October the month most favored. But in early November also the balloonists are abroad, particularly during the Indian summer, or when a series of cool days is succeeded by a warm day.

II.

The following studies[1] were made during October, in fields adjacent to Philadelphia and in the adjoining Delaware County. The days were warm and bright, with a soft wind from the west, or a gentle breeze blowing, but not steadily from any quarter. Stooping low and glancing along the meadow, the eye caught the sheen of myriads of fine silken filaments glistening in the sunlight. The tops of grass spires and the bushy heads of tall weeds were netted together by innumerable threads, and from many points of the same filaments were streaming out at various lengths into the air. Numerous small spiders, chiefly Orbweavers, especially the young of Tetragnatha extensa, were rising from these plants and sailing over the field.

The finest exhibition of the aeronautic flight was seen along a post and rail fence which divided the meadow, and the description of this may be considered as covering the like behavior among all balloonists scattered over the fields. The tops of the fence posts were the favorite ascension points, and upon these clusters of young Lycosids were gathered, sometimes eight or ten in a group. The purpose in choosing these elevated spots is quite apparent, the currents of air being stronger there than close to the surface of the earth, and consequently affording much better facility for flight. The presence of a deliberate and wise volition seems evident from the fact that the Lycosids are ground spiders, and not found habitually in such positions as the above. They had certainly mounted to the top of the fence with the settled purpose of taking advantage of the stronger breeze and better "send off" which the superior height afforded.

Fig. 270. Attitude of aeronautic spider just before taking flight.

At least, it was easily determined that such an advantage did ensue from elevation. I selected some of the lower stalks of grass from which silken streamers were fluttering quite lazily. Close up to the stalk or blade I saw the spider placed back downward clasping the thread with its claws. Sometimes a thickened conical or flattened piece of silk marked this end of the line. When these grass stalks were broken off and lifted into the air the streamers fluttered out briskly and were soon snapped off, carrying the

young araneads away with them. These experiments showed that the act of ascension is aided by elevation, both in these cases and in those where the spider mounts directly from the perch.

The young Lycosids had generally chosen the very tops of fence posts as points of ascent, and fortunately this site suited the observer's convenience as much as the spider's, and I could therefore notice with comparative ease the methods of the miniature balloonists.

The spider's first action was to turn its face in the direction from which the wind was blowing. Then the abdomen was elevated to an angle of about forty-five degrees, and at the same time the eight legs were stiffened, thus pushing the body upward. In order to permit this movement the claws were brought in somewhat, but not beneath the body, so that when the legs were stiffened the body stood high above the surface. From the spinnerets at the apex of the abdomen a single thread or ray of threads was exuded, and rapidly drawn out by the breeze until, by reason of its delicacy, it was lost to sight. Four, five, even six or more feet of the lines would at times be in view. Gradually the legs were inclined in the direction of the breeze, and the joints straightened out. The foremost pair of legs sank almost to the level of the post; and these especially, but indeed all the legs and the entire attitude of the creature, presented the appearance of an animal resisting with utmost force and tension of muscles the effort of some superior power to snatch it away.

Suddenly and simultaneously the eight claws were unloosened, and the spider mounted with a sharp bound into the air, and went careering away across the meadow, at a rate more or less rapid according to the velocity of the wind. The utmost care was used to determine whether in this upward bound the volition of the spider had any further agency than the simple unclasping of the feet from the post. Owing to the extreme difficulty of such an observation, I cannot speak with absolute confidence, but was able to satisfy my own mind that the aeronauts always vaulted upward and clear of the post at the moment of releasing their hold. I can hardly be mistaken in the belief that this was so in many cases, at least.

A similar action was frequently observed during the preliminary and tentative movements in which the spiderlings indulged prior to the final flight. Something was noticed among them not unlike the frolicsome pranks of kittens or lambs. One would rush up to another, who thereupon would immediately change position, either by running or quickly vaulting to another part of the post. At times a leap would be made quite away from the post, but the buoyancy of the thread which had been exuded being insufficient to overcome the weight of the animal, instead of rising into the air, the creature returned to the post or struck upon the adjoining rail. In these and similar movements I was able to detect distinctly the vaulting action of the spider, and the eye, being thus familiarized with the movement, was less liable to be deceived in the more difficult observation of the quick spring at the time of the aerial flight.

The posts and parts of railings adjoining were covered with threads adhering to the wood and streaming out into the air. These were the result in part of the feints at flight just referred to, but were partly owing to another cause. The spiders, previous to flight or vaulting, attached themselves to the post in the manner common to most of their order. The apex of the abdomen was thrust down upon the surface, and the liquid silk at the same time exuded from the spinnerets was thus caused to adhere thereto. As the creature moved away the thread was run out into line, and gave the spider a firm attachment. It is a question whether this anchorage is always made previous to flight, and whether the thread is cut immediately before the ascent. The observations made all pointed to an affirmative answer, but the matter was not positively settled.

The attempt was made to follow some of the aeronauts beyond the point of ascent. The difficulty in getting the minute objects in position relative to the sun favorable for such observation, the motion of the air which carried them upward, as well as the rapidity of flight, frustrated many attempts. A position was finally taken beside one of the side posts of the sliding "bars," which being opened gave a point of observation with the back to the sun, the eye upon the object, and a fair opportunity to follow it without the delay of leaping over a high fence, which before had been between the observer and the course of the aeronaut sailing before the wind.

Fig. 271. Attitude of ballooning spider just after taking flight.
Fig. 272. Attitude when floating before the breeze.

Fig. 273. Floating with head depressed, holding to a foot basket.
Fig. 274. Ballooning spider gathering in its threads for descent.

Fortune favored patience, and at last a spider took flight in a line which was a little higher than the face.

Following the aranead at a moderate run, with the eye held closely upon it, I observed that the position of the body was soon reversed; that is, the head was turned in the direction toward which the wind was blowing, instead of the point from which it blew, as before the ascent. Thus the long thread which streamed out above the aeronaut inclined forward, and at the top was in advance of its head. I also observed that the legs were spread out, and that they had been united at the feet by delicate filaments of silk. The action by which the spinningwork was accomplished was not noticed, owing to the smallness of the creature, the rapidity of its movements, and the difficulty of such an exceptional mode of observation. But the fact was noted. The reason naturally suggested for it is the increased buoyancy resulting from the increased surface thus offered to the resistance of the air, provided, of course, any reason be required beyond the animal's need of some sort of foothold, while afloat. Mr. Emerton,[2] in the course of some accurate observations of ballooning spiders, says that the most of them while afloat hung by their spinnerets only, and drew their legs close against their bodies, a posture which I have also sometimes observed.

The spider whose behavior I am now describing was followed for a distance of eighty feet, when it gradually settled downward upon the meadow. Before, or rather during, this ascent a small, white, flossy ball of silk was seen accumulating at the mouth, which, with the peculiar motion of the fore feet, palps, and mandibles, at once suggested the drawing in of a thread. This behavior is not infrequent with spiders under other circumstances; indeed, it may nearly always be observed when webs are being cleared away, and during ascent upon a dropped dragline after a spider has thrown herself from her snare. But it became especially interesting at that moment, for at once it suggested an act of volition on the part of the Lycosid, by which, in a measure at least, it might control its descent. Evidently the shortening of the overhanging thread operated like the furling of sails upon a vessel, and decreasing the motion of the spider increased the influence of gravity upon the body, which thus sank toward the ground. At the same time, the diminution of the surface of the thread above, and the increase of bulk at the mouth (trifling as it might be), tended to increase the buoyancy of the whole, and allowed the creature to fall. The same effect was thus produced by the spider aeronaut, and by a strikingly analogous mode, as that which the human aeronaut accomplishes when he contracts the surface of his balloon by causing the inflating gas to escape.

The manner in which the lines of spiders are carried out from the spinnerets by a current of air appears to be thus: As a preparatory measure, the spinnerets are brought into close contact, and the liquid silk is emitted from the spinning tubes; the spinnerets are then separated by a lateral motion, which breaks up the silk into fine filaments; on these filaments the air current impinges, drawing them out to a length which is regulated by the will of the animal; and, on the spinnerets being again brought together, the filaments coalesce and form a compound line.[3] According to Mr. Emerton,[4] the line seems to come from the middle pair of spinnerets only, but the posterior pair were in constant motion, folding together over the middle ones and then spreading apart as if to help throw out the threads.

III.

It will here be in place, and will add to the understanding of the reader, to insert a few field notes giving in detail the above and some further facts as to the posture and action of spiders before and during flight.

There is no difference between the aeronautic habit of these araneads and that of spiders in other parts of the United States. Moreover, observations of naturalists on ballooning spiders in various quarters of the globe show that the same methods everywhere prevail. It will be further observed that the notes relate chiefly to Lycosids, which appear to be universally addicted to the ballooning habit. This is probably true of all Citigrades. It is worthy of special notice that these ground spiders, when seeking aeronautic flight, take pains to seek some elevated spot as a point of departure. This is not limited to the Lycosids, for Mr. Enock speaks of young Atypinæ in England securing an easy and unobstructed flight in the same way. The instinctive impulse which urges spiderlings to leave their resorts on the ground and seek spots essential for favorable ascent, certainly has the appearance of reasoning intelligence. At all events, the younglings, by whatever process they reach the conclusion, do the best thing possible to aid their ballooning enterprise.

Fig. 275. Ballooning Lycosids ascending from a fence post, and floating before the wind.

Example No. 1. A young Lycosid, apparently *Lycosa scutulata* Hentz, was posed on the side of a fence post opposite the wind, face downwards, abdomen elevated, the body raised by the legs. I followed it after flight for two hundred feet; it rose as high as thirty feet before it was lost to sight. Its flight was across a wide meadow, and promised to be a long one. Several threads were streaming out and up behind and before the spider.

No. 2. A Saltigrade, probably the young of *Astia vittata*, was posed on the side of a fence board opposite the wind. Its legs were elevated, thus raising up the body; the abdomen was turned well nigh straight upward; a long thread floated out and up from the spinnerets. The spider walked several inches upward along the rail, keeping its body in the same stilted position, the thread meanwhile flying. Then it was off, rather slowly, and about on a line with my face. It showed, in motion, one small thread in front and one (or more) behind. It moved straight forward for about fifty feet, and then rose suddenly upward, as though it had passed into an ascending current of air.

No. 3. *Lycosa*; observed at 2 P.M. Pose and actions as No. 1. After flight I distinctly saw one thread before and (apparently) two behind; the head was toward the wind. After sailing fifteen feet it rose up and out of sight, a long stretch of meadow before it. Once, before it mounted, it lifted up one hind foot, as though laying hold upon the stay thread.

No. 4. *Lycosa*; this example was followed for a distance of forty or fifty feet; in front of it there appeared to be but one thread, a ray of several fine diverging threads floated behind from the spinnerets. Its back was toward the ground. Its abdomen seemed, but could not be certainly determined, to be riding in front, i. e., toward the direction of the wind. The body of the spider was thus at the apex of the angle formed by the fore and hind filaments, the free points of which were quite far apart. The balloon struck a tree, and part of it went on, the spider apparently staying on the tree.

No. 5. *Lycosa*; this specimen floated with the abdomen toward the point of departure. Several threads ascended from it, one thread in front; the feet were gathered together; but, apparently, the back was upward. It crossed the highway, and a carriage just then passing interfered with the observation.

No. 6. The head rode in front, the back was certainly toward the ground. A fourfold streamer of threads was thrown out, before mounting. At first the spider moved off slowly, but soon climbed up the fore thread, the "bow," so to speak; further on it climbed up the rays of threads a distance of several inches. The balloon, when lost sight of, had at least three separate filaments. It was followed one hundred feet before it rose out of sight.

No. 7. *Lycosa*; riding back downward; it sailed sidewise part of the time; afterward the head seemed to be directed toward the course of the wind.

Before vaulting into the air many of the spiderlings turned their elevated abdomens first to one point then to another; repeating the action many times, as though testing the direction of the wind. The whole process of aeronautic flight, as it has been described, may be briefly given as follows: First, the spider seeks a high position, such as the top of a bush, grass stalk, or fence post, as the point of ascent. Second, the abdomen is elevated to as nearly a right angle with the cephalothorax as may be. Third, a ray of threads is issued from the spinnerets, the face being meanwhile turned to various points; the legs are stretched upward, thus raising the body; fourth, they gradually incline in the direction of the breeze, the joints straighten out, the legs sink forward and down until the first pair are almost on a level with the surface, the whole attitude of the animal being that of one resisting some force exerted from above. Fifth, suddenly and simultaneously the eight claws are unloosed, and the spider mounts with a sharp bound, apparently, and (sixth) floats off with the back downward, usually, but sometimes with this position reversed. Seventh, at first the abdomen seems to be in advance, but generally the body is turned so that the head rides, in front. Eighth, the ray of threads is apparently grasped with the feet and floats out in front, upon which (ninth) sometimes the spider will climb upward, as though to adjust the centre of gravity. Meanwhile (tenth) a thread or cluster of threads issue from the spinnerets

and float out behind, leaving the spider to ride in the angle of the two diverging rays, or, as it sometimes happens, of three, which are widely separated at the upper free ends. Eleventh, the feet seem to be united by delicate filaments, which would serve to increase the buoyancy of the balloon. Twelfth, the spider is now carried forward by the wind, riding for long distances in an open space, and often borne high upward upon ascending currents. Thirteenth, the anchorage of this miniature balloon appears at times to be within the spider's own volition, by the fact that it can draw in with its claws the forward ray and gather it in a white roll within the mandibles. But most frequently the balloonist is stopped by striking against some elevated object, or by the subsidence of the breeze. A bright warm day in October is commonly chosen for the ascent, and judging from the presence of a number of dry moults, apparently of the same species of spider observed in flight, the animals had recently cast their skins.

IV.

The greatest height to which I have seen spiders ascend is about one hundred and fifty feet; but, undoubtedly, they often rise much higher. Dr. Lincecum observed the gossamer balloons of certain Texas species floating at an altitude of one to two thousand feet.[5] Blackwall found ascending currents of air acting with such force upon the gossamer streamers as to raise them in the atmosphere to a perpendicular height of at least several hundred feet.[6] Dr. Martin Lister, the earliest observer of the habit (A. D. 1670), says: "As to the height they are able to mount, it is much beyond that of trees or even the highest steeples in England. This last October the sky here upon a day was very calm and serene, and I took notice that the air was very full of webs. I forthwith mounted to the top of the highest steeple[7] in the Minster [York], and could thence discern them yet exceeding high above me; some that fell and were entangled upon pinnacles, I took and found them to be lupi [Lycosids], which seldom or never enter houses, and cannot be supposed to have taken their flight from the steeples."[8] I once found a number of half grown Epeiras upon their round webs on the topmost railing of the dome of St. Peter's at Rome (Italy), whither they or their maternal ancestor had doubtless been carried by the wind from the surface of the earth.

October 25th, 1883, was a bright day following a series of cold, wet days caused by a severe northeast storm: At noon, while crossing the Chestnut Street Bridge, Philadelphia, I saw a great number of aeronautic threads floating in the air, streaming from the tips of the bridge balustrade and lodged upon the piers. One of the threads, a long filament, was sailing slowly toward the river as a Pennsylvania Railroad train dashed along the river track beneath the bridge. It was low enough to strike the cars as they rolled by, and so was carried on southward with its tiny voyager—another illustration of how artificial habits of man tend to the geographical distribution of life. The filaments were long, pure white, curled or wrinkled, about one millimetre wide or less, occasionally expanded into thicker wads, and frequently carried attached to them minute insects which had doubtless entangled in the fibres as the threads floated in the air. (Fig. 280.) On one thread I found three, on another two small flies. The young balloonist is thus provided with food upon his landing, if he choose to avail himself of these chance supplies. The insects are simply entangled, as the fibre is without viscidity.

Fig. 276. Young spider sending out aeronautic threads while hanging upon a web.

The field observations recorded above have been confirmed by numerous studies made with spiderlings reared in the house, especially the young of *Epeira sclopetaria*, *Epeira domiciliorum*, *Epeira insularis*, and *Agalena nævia*. As the results obtained were not different from those already

Fig. 277. Aeronautic Orbweavers preparing to ascend from floating threads.

given, they require but brief mention. When let loose into the air from the finger tip, the spiderlings floated out by a single thread, which was always and instantly first attached to the finger. At first the head was outward, the abdomen being turned toward the hand, from the apex of which the long superior spinnerets of the tubeweavers diverged. Presently the little creature turned and cast out a thread behind, when, if permitted, it would usually clamber up the original thread to the finger. When this was broken off, the spider, seated midway of the two filaments, floated off and outward, and was lost to sight. Again, by an eddy of the air, the thread would be thrown backward and upward and catch against the wall, upon which the little voyager would anchor.

At other times, much to my surprise, after the thread had been quite lost to view, the spider was supposed to be far away upon its flight, it would descend as from the clouds, and send out its silken grapnels against the cheek or nose. The will of the little spider seemed to have no control over these movements, which apparently were always wholly at the mercy of the wind. However, the manner of accomplishing aerial flight by means of the buoyancy of a single thread, or rather of two threads united at or near the middle, was quite in accord with the methods above described.

V.

While the young balloonists were adventuring their flight in the fields in the manner heretofore described, several species of small Orbweavers were making or waiting for their ascension in a manner so different that it requires especial notice. These were stationed upon the small grasses and weeds, from which innumerable cords of spider silk were streaming, and upon which similar threads were twisted and meshed by the eddies of the wind and the passing of the spiderlings from point to point. The attitude of most of these was one of expectation. Only two were observed in actual flight, and one of these I assisted. The nearness to the ground and the shelter of surrounding herbage doubtless retarded the process. However, this greater deliberateness is quite in harmony with the more phlegmatic Orbweavers, just as the energy of the Lycosids in mounting the fence and their haste to be off are characteristic of that group. The little Orbweavers were hanging upon the lower part of the floating strings near the point of

attachment to the grass. Their backs were downward and their heads outward, or toward the free end of the thread. (Fig. 276.) The first, second, and fourth pairs of legs were stretched along the thread, and the third and shortest pair were held off, curved, the feet apparently united to the main thread by taut filaments. This position, as far as could be determined, was maintained after flight. In some cases a series of two or three puffs or pellets of floss were gathered around the thread between its free end and the spiderling. They were generally cone shaped, the apex being turned toward the animal. In form they were not unlike the pellets which one used to see gathering upon the roll of wool as it passed from the fingers of our maternal ancestors into the whirling "flyers" of an old fashioned spinning wheel. (Fig. 277.) Perhaps they may have been wrought by a similar process, the twisting of the loose threads through the action of the wind and the counteraction of the spider. The continuation of such twisting must presently break the thread, and thus set the occupant afloat. The greater force of the wind secured by gently breaking a stalk and lifting it into the air soon snapped off a thread, carrying the little aranead away with it.

I am inclined to think that this mode of ballooning prevails, particularly among Orbweavers; that is to say, the spider, having spun out a long thread, sometimes thickened at the attached end, lays hold upon it and waits for the wind to pull it loose, when it is borne away and aloft. It is even probable that the spider may cut the thread, and thus, procure her own release. This would place the moment of ascent within her own volition, and the fact (should it be established) would add greatly to the interest with which one must regard this variation in the aeronautic habit of these interesting araneads.

Dr. Gideon Lincecum has put upon record a case in point.[9] He describes the balloon of a Texas Orbweaver, which he calls the "Gossamer Spider," as follows: A lock of white gossamer five or six inches long and two inches wide in the middle, tapering toward the ends, is attached to a stalk, bush, or other elevated object by a thread two or three inches long. At the free end or "bow," two lines thirty or forty feet long are spun out, and one twenty or thirty feet long is spun from the attached end or stern of the aerial craft. All being ready for ascent, the voyager cuts the cable which holds the balloon, and floats briskly upward and forward on an inclined plane, or bounds aloft with a sharp spring that eludes one's efforts to stop it. Lincecum's description of the hammock shaped balloon and its float lines answers very well to the above described aeronautic spinningwork of Orbweavers (Fig. 277), and I am disposed to accept as quite trustworthy the statement that the attached end was actually severed by the spider, who thus controlled, in some measure, the period of her ascent.

Blackwall had already observed that occasionally spiders may be found on gossamer webs after an ascending current of rarefied air has separated them from the objects to which they were attached, and has raised them into the atmosphere. He, however, added the opinion that, "as they never make use of them intentionally in the performance of their aeronautic expeditions, it must always be regarded as a fortuitous circumstance."[10] This opinion, I think, must be abandoned, and the conclusion reached that there are two modes of ballooning practiced by spiders, viz.: First, ascent by means of the buoyancy of lines issuing directly from the spinnerets, the aranead vaulting upward from its perch; and, second, the ascent upon lines, sometimes thickened by flossy tufts or strands, which are first spun out and attached to fixed objects, and afterward released by the force of the wind or cut loose by the spider.

VI.

While arranging a collection of spiders in the Academy of Natural Sciences of Philadelphia, I discovered a number of specimens of a large Laterigrade, the Huntsman spider, *Heterapoda venatorius*, from various localities, as represented upon the accompanying tables and chart. (Fig. 278.) Starting with the specimens in my private collection, the line of distribution was traced from Santa Cruz, Virgin Isles, to Cuba, to Florida, across Central America, Yucatan, and

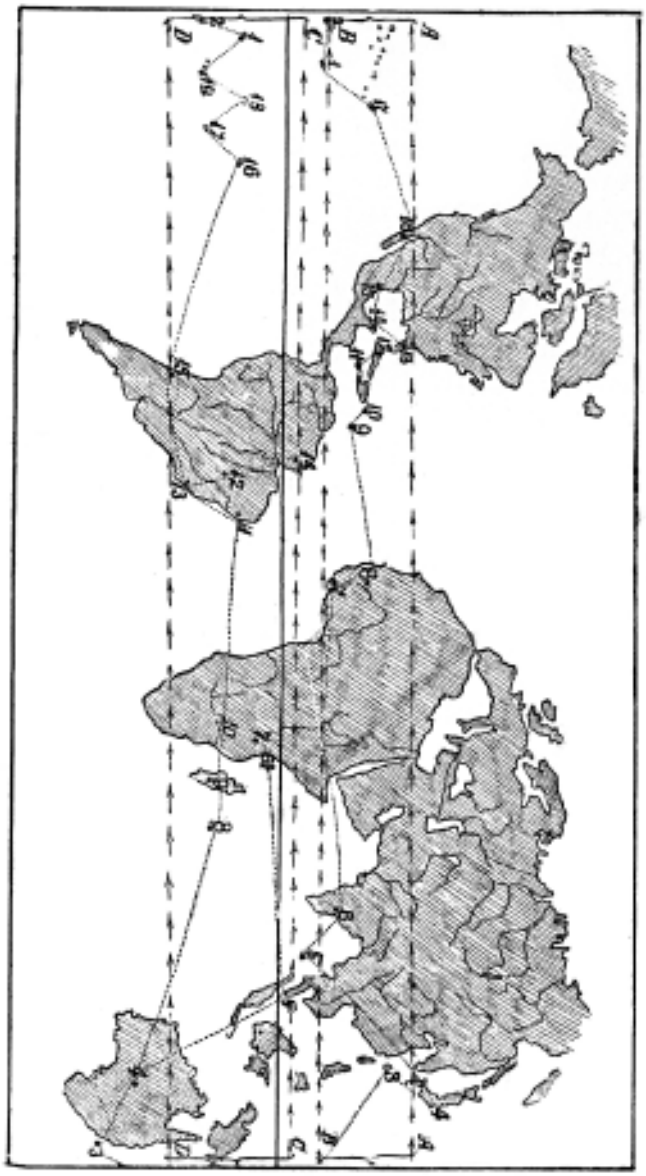

Fig. 278. Chart to show the circumnavigation of the globe by the Huntsman spider, in the course of the Trade Winds.

Mexico; across the Pacific Ocean by way of Sandwich Islands, Japan, and Loo-Choo Islands; and thence across the continents of Asia and Africa to Liberia. The line thus indicated extends from the extreme eastern limit of North America to the extreme western coast of Africa, thus girdling the globe, with the exception of 54° of longitude. This excepted area expresses substantially the width of the Atlantic Ocean.

It occurred to me, when this fact became apparent, that this line of distribution is within the belt of the North Trade Winds; and, further, that there might be some connection between the two facts and the fact that Laterigrade spiders, to which group this animal belongs, are among those which are most addicted, in the earlier stages of growth, to balloon migration. Thereupon I referred to the general course and limits of the North Trades, which are roughly indicated in the chart (Fig. 278) by the two upper lines of arrows, marked (at the ends) A A and B B. In the Atlantic Ocean the North Trade Winds prevail between latitude 9° N. and 30° N.; in the Pacific between 9° N. and 26° N. We now may turn to the chart, in which the following geographical points (shown by black spots and figures) are represented by our spider. The specimens which have been examined in the Academy, and my own collections, whose habitats are personally known, are marked by an asterisk (*).

TABLE OF DISTRIBUTION NORTH OF THE EQUATOR.

LOCALITY.	LATITUDE.	LONGITUDE (GR.).	AUTHORITY.
1. Palmyra Island	6° N.	163° W.	*
2. Pelew Islands	7°– 8° N.	134° E.	L. Koch.
3. Loo-Choo Islands	25°–29° N.	128° E.	*
4. Japan	30°–40° N.	130°–140° E.	*
5. Nicobar Islands	6°–10° N.	96°– 97° E.	Böck.
6. Tranquebar, India	12° N.	80° E.	Fabricius.
7. Liberia, Africa	5°– 9° N.	10° W.	*
8. Senegal, Africa	17° N.	16° W.	Walckenaer.
9. Martinique, North America	15° N.	61° W.	*
10. Santa Cruz	18° N.	65° W.	*
11. Jamaica	18° N.	77° W.	Walckenaer.
12. Cuba	20°–23° N.	74°–85° W.	*
13. Florida	30° N.	81° W.	*
14. Yucatan	20° N.	82°–91° W.	*
15. Mexico, Jalapa	20° N.	97° W.	*
16. California	?	109°–117° W.	L. Koch.
17. Oahu, Sandwich Islands	20° N.	155°–160° W.	*

The species is credited to the other localities named on the authorities given therewith.

A comparison of this table with the chart will at once show that the dotted lines in the latter, which indicate the geographical belt over which Venatoria is distributed correspond, with remarkable general exactitude, with the belt over which the North Trades blow. It is not, therefore, an improbable conjecture that this distribution has been accomplished by means of those winds and the spider's habit of aerial flight. It is, of course, supposable that commerce, following largely the same belt, may have originated or aided this distribution. But certain facts in the history of the spider seem to forbid this hypothesis.

Some of the facts are: First, the early discovery of the species as already widely distributed; second, its presence at so many different insular points nearly or altogether contemporaneously with first visits by commercial nations; third, the existence of the species or its close allies among the fauna of the tropical interiors of continents far distant from coast lines; fourth, the variations, chiefly in color, which have been observed, and which would seem to require for their development a longer period than that which has transpired since the commencement of commercial communication with the localities in which the variations have been wrought. While one may not conclude with absolute certainty from these facts, they warrant the theory that the Huntsman spider has become cosmopolitan by the action of Nature, independent of the aid of man.

I was so impressed by the above chain of facts, and so confident of the inference therefrom, that I ventured to predict that corresponding results would follow a comparison of specimens collected from all quarters; that is to say, they would be found to lie within the belt of the North or South Trade Winds. The only specimens at hand were those cited above, and from Zululand and Surinam. But I was able to pursue the matter by reference to locations given by a number of naturalists. I was aided in this by references kindly sent me by Mr. William Holden. Some of the localities thus obtained have been named above, and others were found to correspond with the points represented by the specimens examined. So far my conjecture was verified.

The two lower arrow lines in the chart, C C and D D, give a general view of the course and limits of the South Trades, which prevail in the Atlantic Ocean between latitude 4° N. and 22° S., and the Pacific between latitude 4° N. and 23 1/2° S.[11] It is, of course, understood that these limits are not stationary, but follow the sun, moving northward from January to June, and southward from July to December; an oscillation which is also indicated in the zone of distribution. They are, however, substantially as above given, and may be compared with the following table, which shows the southern geographical distribution of this species, according to the authorities cited therein:—

TABLE OF DISTRIBUTION SOUTH OF THE EQUATOR.

LOCALITY.	LATITUDE.	LONGITUDE (GR.).	AUTHORITY.
1. Viti Levu, Fejee Islands	16° S.	180° W.	L. Koch.
2. New Caledonia	20°–22° S.	163°–162 E.	"
3. Sidney, Australia	33° S.	150° E.	Böck.
4. Australia	11°–30° S.	105°–115 E.	L. Koch.
5. Singapore	2° N.	104° E.	Walck.
6. Zanzibar, Africa	6° S.	40° E.	Gerstaecker.[2]
7. Southeast Equatorial Africa	10°–20° S. (?)	30°–50° E.	Blackwall.
8. Mauritius	20° S.	56° E.	Walckenaer.
9. Madagascar	8°–26° S.	43°–50° E.	Vinson.
10. Zululand	20° S.	28° E.	*
11. Pernambuco	7° S.	37° W.	
12. Brazil		37°–70° W.	Simon, Walck.
13. Rio Janeiro	23° S.	50° W.	Walck.
14. Surinam	6° N.	55° W.	*
15. Valparaiso, Chili	33° S.	70° W.	L. Koch.
16. Tahiti, Huahcine, Society Islands	18° S.	150° W.	"
17. Rarotonga, Cook's Islands	22° S.	162° W.	"
18. Upolu, Navigator Island	13½°–14½° S.	168°–173° W.	"
19. Tongatabu, Friendly Islands	20° S.	172°–176° W.	"

This table shows a distribution corresponding with the limits of the South Trades, with, in three cases, viz., Sidney (3), Surinam (14), and Valparaiso (15), a slight oscillation in accord with a fact above stated. Thus was entirely fulfilled the expectation with which I entered upon the preparation of these comparative tables.[13]

It may not be without interest, and may, perhaps, have some bearing upon the above theory of distribution, to remark that the genus (or a closely allied genus) to which *Heterapoda venatoria* belongs, is probably one of the oldest known forms of the spider fauna. Thorell[14] places the now existing genus *Heterapoda* (*Ocypete*, Koch; *Oxypete*, Menge) among those, which are represented in the amber spiders. Amber probably belongs to the tertiary (oligocene) period, and in it numerous spiders are found, generally well preserved. How far any supposed contiguity or closer approach of continents now separated might have facilitated or occasioned the world round distribution of our Huntsman spider, is a point upon which geologists may more properly express an opinion.

The question, what variation of species, if any, occurs in the course of this distribution, is of great interest. The specimens examined by me show no variations which may not come within the range of those natural differences which obtain in many species. Most of the specimens had been so long in alcohol as to obliterate any differences in color and markings which might have

existed. The normal color is a uniform tawny yellow, varied upon the cephalothorax by a circular patch of blackish or blackish brown color covering nearly two-thirds of the space; and, further, by a white or whitish marginal band quite or nearly girdling the same. In some of the specimens this circular patch seems to have been more or less of a brownish color. Gerstaecker[15] speaks of this species as distributed over a large part of Africa, Asia, and South America. Specimens were examined by him from Dafeta, Mombas, and Zanzibar. In these there was some variation in the coloration of the maxillary palpi: on the one hand, from a light rust color to brownish red and pitch brown; on the other hand, to a more or less sharp division or limitation of the light yellow color of the anterior and posterior borders of the cephalothorax. There was also a browning of the region about the eyes. But the araneologist will not regard such differences as having any special value as specific characters.

VII.

There seems nothing improbable in the theory of aerial circumnavigation suggested to explain the series of facts above presented. There are not, indeed, many recorded observations of the distances to which spiders are carried out to sea in their aeronautic flights. But, before a strong steady wind, or in cases of storm, it is possible that the greatest distances which appear in the tables could be overcome. An observation of Mr. Darwin is the only recorded one to which I can refer.[16] At the distance of sixty miles from land, while the "Beagle" was sailing before a steady, light breeze, the rigging was covered with vast numbers of small spiders with their webs. The little spider, when first coming in contact with the rigging, was always seated upon a single thread. While watching some that were suspended by this filament, the slightest breath of air was found to bear them out of sight. I have observed similar single threaded "balloons" sailing at considerable height above the surface of the earth, and know no reason why, with a favorable breeze, they might not have been carried hundreds of miles. That they were carried at least sixty miles, as Mr. Darwin's testimony shows, and that before a light breeze, gives great probability to such a conjecture. It is to be noted, moreover, that the spiders arrested by the "Beagle's" rigging were evidently moving on when so stopped, and some of them, when arrested, soon resumed their flight across the main.

I am able to add a valuable observation in the same line as that of Dr. Darwin's. The late Capt. George H. Dodge, of the American Line steamer "Pennsylvania," informed me, during a

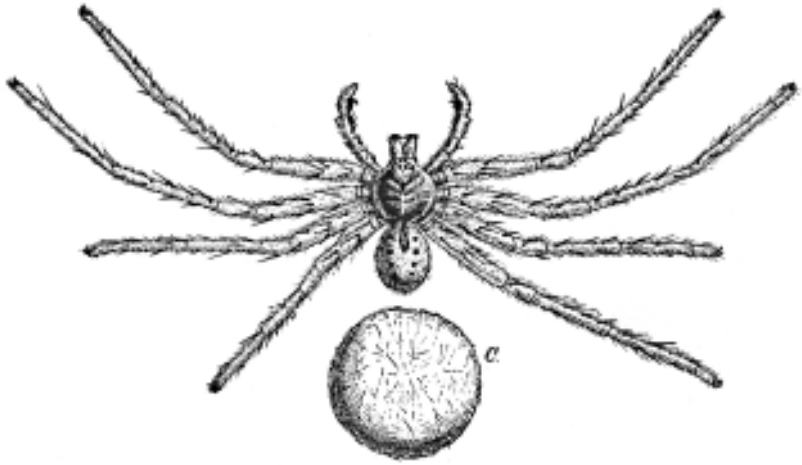

Fig. 279. The Huntsman spider; a male. C, the female's cocoon.

voyage across the Atlantic in the Winter of '81-2, that he had found the masts and rigging of his vessel covered in the same way with innumerable webs of spiders, while sailing during the month of March along the eastern coast of South America. His ship was more than two hundred miles from land and about four hundred miles south of the equator. The wind at the time, according to his recollection, was blowing from the westward; that is, from the continent. Captain Dodge, at my request, communicated the facts in writing, the incident having been impressed upon his memory by the strangeness of seeing such creatures so far out at sea. "The spiders seemed like little elongated balls, with a sort of umbrella canopy above them. They settled upon the sails and rigging, and, finally, disappeared as they came."[17]

The purpose of such a remarkable habit as these facts exhibit is, doubtless, to secure the distribution of species throughout wide regions. The buoyant filaments of spider gossamer serve the tiny arachnid the same good office that is rendered the dandelion and thistle seed by the starry rays of down surrounding them.

VIII.

The ballooning habit of spiders gives a complete explanation of a natural phenomenon which has attracted the attention of men from an early period, and which has been variously alluded to in prose and poetical writings, viz., Showers of Gossamer.

One who walks the open fields in the latter part of September or in the soft bright clays of October, which is the most delightful period of our American year, will notice great quantities of spider silk trailing and floating from the stalks of weeds and grasses, and indeed from all elevated objects. In the early morning, when the dew deposited upon these filaments betrays their presence, one will be surprised at the vast amount visible. Further on in the day he will observe quantities of this threaded spinningwork sailing through the air. (Fig. 280.) A great excess of these floating tufts and filaments constitutes what is commonly known as a gossamer shower. Doubtless Pliny alluded to such a phenomenon in the statement which he makes[18] that "in the year that L. Paulus and C. Marcellus were consuls it rained wool about the castle Carissa, near to which, a year after, T. Annius Milo was slain."

In later days, among our English ancestors, an explanation of this phenomenon even stranger than Pliny's prevailed and found expression through some of the English bards. For example, Spenser writes:

> "More subtle web Arachne cannot spin;
> Nor the fine nets, which oft we woven see,
> Of scorched dew, do not in th' ayre more lightly flee."[19]

Still later 'Thomson in his " Seasons " utters the same idea:—

> "How still the breeze! save what the filmy threads
> Of dew evaporate brushes from the plain."[20]

Fig. 280. A flocculent thread of gossamer, with small flies entangled.

We have, however, passed beyond the period when so simple a natural phenomenon could be accounted for on such an impossible theory as that of autumnal dews scorched by the sun.

I have never been so fortunate as to observe anything that could be called a "shower" of gossamer, although I have seen quantities of the material afloat in the air or fluttering from the foliage. I will therefore quote from others a description of the phenomenon. Mr. Kirby describes the gossamer observed by him early in the morning as spread over stubbles and fallows, sometimes so thickly as to make them appear as if covered with a gauzy carpet, or rather overflown by a sea of gauze, presenting, when studded with dewdrops, a most enchanting spectacle.[21]

Rev. Gilbert White, whose "Natural History of Selborne" has been so long and deservedly popular, describes such an incident as occurring in England on September 21st, 1741. At daybreak he found the stubble and clover grounds matted all over with a thick coat of cobwebs, in the meshes of which a heavy dew hung so plentifully that the whole face of the country seemed covered with two or three fishing set-nets drawn one over another. The dogs were so blinded by this deposit that they could not hunt, but lay down and scraped the encumbrances from their faces with their fore feet. "As the morning advanced," writes the author, "the sun became bright and warm, and the day turned out one of those most lovely ones which no season but autumn produces, cloudless, calm, serene, and worthy of the south of France itself. About nine, an appearance very unusual began to demand our attention—a shower of cobwebs falling from very elevated regions, and continuing without any interruption, till the close of the day. These webs were not single filmy threads, floating in the air in all directions, but perfect flakes or rags; some near an inch broad, and five or six long, which fell with a degree of velocity that showed they were considerably heavier than the atmosphere.

"On every side, as the observer turned his eyes, he might behold a continual succession of fresh flakes falling into his sight, and twinkling like stars, as they turned their sides towards the sun."

This shower extended over at least eight miles of territory, for Mr. White received an account from a trustworthy gentleman living that distance from his house, corroborating his own observation. This gentleman met the gossamer shower while he was riding abroad, and, concluding that he could escape it by mounting a hill above his fields, which was three hundred feet in height, rode to that point. But, to his astonishment, when reaching this lofty spot, he found webs apparently still stretched as far above him as before, still descending into sight in a constant succession and twinkling in the sun as they fell. Neither before nor after, says Mr. White, was any such a fall observed; but on this day the flakes hung in the trees and hedges so thick that a diligent person sent out might have gathered baskets full.[22]

Another account, quite as noteworthy as the above, was reported in the "London Times" on October 9th, 1826, which I quote from Mr. Frank Cowan's interesting and valuable "Curious Facts."[23] "On Sunday, October 1st, 1826, a phenomenon of rare occurrence in the neighborhood of Liverpool was observed in that vicinage, and for many miles distant, especially at Wigan. The fields and roads were covered with a light filmy substance, which, by many persons, was mistaken for cotton; although they might have been convinced of their error, as staple cotton does not exceed a few inches in length, while the filaments seen in such incredible quantities extended as many yards. In walking in the fields the shoes were completely covered with it, and its floating fibres came in contact with one's face in all directions. Every tree, lamp post, or other projecting body had arrested a portion of it. It profusely descended at Wigan like a sheet, and in such quantities as to affect the appearance of the atmosphere. On examination it was found to contain small flies, some of which were so diminutive as to require a magnifying glass to render them perceptible. The substance so abundant in quantity was supposed by the writer who described the phenomenon to be the gossamer of the garden or field spider, often met in fine weather in the country, and of which, according to Buffon, it would take 663,552 spiders to produce a single pound."

An English writer[24] describes what he calls a "Visitation of Spiders," which occurred at Newcastle-on-Tyne. Three miles of iron railing in the writer's neighborhood was covered with

the little creatures. They were equally numerous about one mile north of Newcastle, and, in fact, covered the entire town. A gentleman from Hexham, a town twenty miles from Newcastle, reported that they were abundant there also. The spiders were unknown up to that time, Mr. Blackwall not having described them in his elaborate work on the "Spiders of Great Britain and Ireland," only having noticed them in the "Annals of Natural History" in 1863, previous to which time they had not been observed in England. No one had observed this spider in the neighborhood of Newcastle up to the time of their appearance, and they disappeared as suddenly as they came. According to Mr. Blackwall, the spider is an aeronautic species, *Neriene dentipalpis*.

One of the most temperate descriptions of a gossamer shower I quote from Mr. Blackwall. A little before noon on an October day which was remarkably calm and sunny, with the thermometer in the shade ranging from fifty-five to sixty-four degrees, Mr. Blackwall observed that the fields and hedges in the neighborhood of Manchester, England, were covered over with a profusion of fine, glossy lines, intersecting one another at every angle and forming a confused kind of network. So extremely numerous were these slender filaments that in walking across a small pasture his feet and ankles were thickly coated with them. It was evident, however, notwithstanding their great abundance, that they must have been produced in a very short space of time, for early in the morning they had not attracted his notice.

A circumstance so extraordinary could not fail to excite the curiosity of so keen an observer. But what more particularly arrested his attention was the ascent of an amazing quantity of webs of irregular and complicated structure, resembling raveled silk of the finest quality and clearest white. They were of various shapes and dimensions, some of the longest measuring upwards of five feet in length and several inches in breadth in the widest part, while others were almost as broad as long, presenting an area of a few square inches only. Mr. Blackwall quickly perceived that these gossamer threads were not formed in the air, as was generally supposed at that time (1826) even among naturalists, but at the earth's surface. The lines of which they were composed being brought into contact by the mechanical action of gentle airs, adhered together, until by continual additions they were accumulated into flakes or masses of considerable magnitude. On these masses of spinningwork the ascending current, occasioned by the rarefaction of the air contiguous to the heated ground, acted with so much force as to separate them from the objects to which they were attached, raising them in the atmosphere to a perpendicular height of at least several hundred feet.

About midday Mr. Blackwall collected a number of these webs as they arose, and again in the afternoon, when the upturned current had ceased to support them and they were falling. Scarcely one in twenty contained a spider, though on minute inspection he found small winged insects, chiefly aphides, entangled in most of them. This flight of gossamer appears to have been quite general throughout Great Britain, as it was noticed in England, Wales, and even in Ireland.[25]

Mr. Blackwall is undoubtedly correct in the suggestion which he makes as to the origin of gossamer showers. My own observations, at least, are precisely in the direction of his conclusion. As has already been said, the aerial excursions of spiders in the United States usually occur in the soft, balmy days of early autumn, during the months of September and October, although they occur in a less degree during the first warm days of June. The reasons for this are manifest. In the first place the conditions of the atmosphere are favorable. The balmy weather invites the spiders to issue from their hiding places and attempt aerial flight. The wind is not high enough to disturb their excursions, and yet the temperature is sufficiently high to cause ascending currents of air. Were the weather cold or rainy spiders would not venture forth. Were the wind high its violence would greatly interfere with their excursions. Were the air perfectly still it would be impossible for them to mount above the earth. But the conditions being favorable, as they generally are in the halcyon days of our American autumn, immense numbers of spiders, but particularly the young, may be found upon all manner of elevated objects—blades of grass, weeds, bushes, fences, and what not—essaying an aeronautic flight.

In many, and I would venture to say in the great majority of cases, before a successful ascent is accomplished many unsuccessful attempts are made. A spider will assume the proper position and spin out a long thread. For various reasons, which we are not able to explain, it fails to mount aloft. The thread floats in the air until it is whipped off by the breeze. One, two, or a dozen attempts of this sort produce as many floating filaments. These while waving to and fro in the eddying air are sometimes tangled together before they are loosened. Others, again, are united in the air after release. If now we think of the unnumbered myriads of young spiders who are abroad at this season, all moved by the common impulse to fly away from their present site, and all making the unsuccessful efforts described, we can imagine the enormous quantity of loose filaments of gossamer threads which would thus be set afloat within a short period of time.

These, no doubt, ascend to a certain height, at which they become more or less united into a loose, flocculent mass, and from which, in the cool of the evening, or on the cessation of the air currents, they slowly descend, and add to the quantity already fluttering from all points of the herbage on the surface.

This is a natural, and undoubtedly is the true, explanation of gossamer showers. The theories which have attributed them to electrical phenomena, or to the shooting out of threads from the spinnerets by the physical power of spiders before their ascent, must be dismissed as having no foundation in fact. They are really no more worthy of credit than the popular superstition that these fleeing cobwebs are

> "Caused by the autumnal sun,
> That boils the dew that on the earth doth lie."

The French naturalist Mr. Virey made certain observations and experiments which led him to conclude that spiders "swim in the air" by approximating their limbs and striking the air as birds or insects do their wings. Moving the feet with incredible agility, they are able by means of the vibration to propel themselves through the atmosphere.[26] In this bold but fanciful conjecture, as Blackwall properly terms it, Mr. Virey was anticipated by Dr. Lister. "Certainly this is a rope dancer," he writes, "and itself effects its ascent and sailing. For, by means of its legs, closely applied to each other, it balances itself, as it were, and promotes and directs its course no otherwise than as if Nature had furnished it with wings or oars."[27]

Notwithstanding the importance which such names give to the supposition, it is thoroughly unworthy of belief. The only movement which I have ever perceived on the part of spiders is a momentary adjustment of their bodies, so as to swing them between the two floating rays of threads that constitute their balloon; and, also, to spin the little foot basket or support for their feet, which I have heretofore described. Otherwise they appear to remain perfectly quiet until they reach the ground and escape from their aeronautic threads.

It is hardly worth while to more than mention the theory of Murray that the ballooning ascents of spiders are caused by electricity.[28] The theory was much mooted at one time, and had some worthy names to endorse it. It is, of course, not impossible that a material composed of silk, as is the spinningwork of spiders, may be influenced more or less, and in one way or another, by electricity. But as the result of careful, long continued, and wide observation and study I have no hesitation in saying that electricity has nothing (or next to nothing) to do with the ballooning of spiders, and that the ascending and moving currents of air are entirely responsible for aeronautic phenomena.

There appears to be a special tendency on the part of certain species to undertake aeronautic flight, and certain species appear to be destitute of the power, or at least the wish, for such excursions. Among the latter Blackwall[29] ascertained that *Tegenaria civilis* and *Ciniflo atrox* are to be reckoned; among the former, the most skillful balloonists observed by him were *Thomisus cristatus* and *Lycosa saccata*. The largest individuals of the first named species seen to take aerial journeys measured one-sixth inch between the extreme points of the head and abdomen,

one-tenth inch across the broadest part of the abdomen, and weighed about a quarter of a grain. The largest individuals of *Lycosa saccata* seen floating in the air were of similar weight and dimensions.

IX.

Most readers of general and theological literature possess some knowledge of the position held by Dr. Jonathan Edwards as a philosopher. His work on "The Will" still ranks as one of the greatest books written by an American; but the fact that Jonathan Edwards is entitled to a place among the pioneers of natural history has heretofore been limited to a small number of persons specially interested in science. To that little band it gives particular pleasure to note the recognition of that fact which the last few months have brought. In the first volume of this work I have already alluded to the observations of Master Jonathan Edwards upon spiders, and have credited him with anticipating by at least one hundred and sixty years some of the most interesting observations which I have made and published under the supposition that they were original with myself.[30]

It is proper at this point to call attention to some facts in the aeronautic habits of spiders which this lad made known. Dr. Sereno E. Dwight, the editor of the "Life and Works of Jonathan Edwards," appears to have been the first to publish a letter written by him, when a boy of twelve or thirteen years old, to an English correspondent of his father's, in which letter he describes what he has seen of the habits of "flying spiders." The scientific world was made acquainted with the matter as early as 1832 by the editor of "Silliman's Journal,"[31] who published in full the above named letter as printed by Dr. Dwight.

The January number of the "Andover Review" takes up this subject anew, and in a valuable paper[32] Professor Smyth covers the whole ground of Edwards' studies, and permits us to look into the operations of the young mind while pursuing his remarkable observations and experiments. An unpublished manuscript is therein edited, which appears to have been the original record of the boy's studies, from which record the letter of the English correspondent was probably constructed.

Young Edwards appears to have made a rude division of various tribes of spiders, which, as far as it goes, is accurate, at least sufficiently so for all popular purposes. In a general way this lad as early as A. D. 1716 had hit upon the foundation principle of classification of the distinguished naturalist Latreille, who, just a century later, divided spiders into seven groups, based upon those very habits which young Edwards notes, although, of course, with more careful characterization.[33]

Edwards had found that on a dewy morning towards the end of August or beginning of September one has the best opportunity to study field spider webs. He had further discovered that spider webs which are ordinarily unobserved may readily be brought into view by putting one's self into such position that the rays of the sun shall fall upon them against some opaque body.

Once more, the boy naturalist had discovered that the aeronautic habit of spiders is closely associated with those bridge lines which are continually observed in

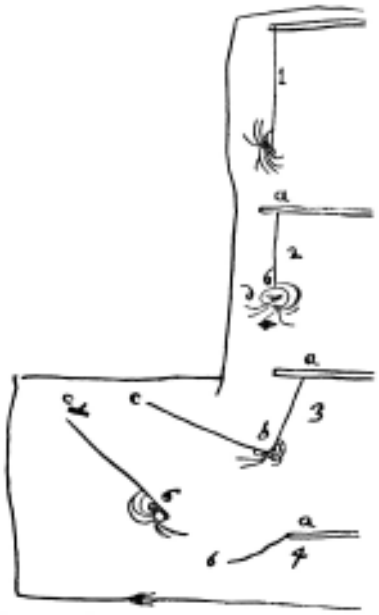

Fig. 281. Edwards' Ballooning Spiders. 1, dropping from twig; 2, swinging from line; 3, sending out threads, b c; 4, a, abandoned thread; c b, spider in flight.

summer stretched from tree to tree across roads, between fences, and in like position. Again, he appears to have discovered that the spider, while engaged in casting out these bridge lines, often swings itself in a little basket of lines held between the bunched feet. I have particularly alluded to this in Volume I., page 51, when speaking of the use of what I have called the swinging foot basket, a habit of which I had supposed that I was the original discoverer. The drawing in Volume I., Fig. 65, was taken from what I supposed to be an accurate facsimile in "Silliman's Journal;" but, in point of fact, Edwards' drawings, as given by Professor Smyth, are far more accurate than those, particularly in the outline of the spider's body and legs, and I therefore reproduce them here, after the drawings in the "Andover Review."

Again, Edwards defined correctly the manner in which the spider's thread is formed. He could make no studies of the interior structure of the animal. It was reserved for the age of the microscope to do this, but this boy of thirteen years old reasoned that the spinning stuff must be contained in liquid form within certain appropriate organs in the abdomen, from which it is expressed, escaping from the spinnerets as a liquid, and immediately hardening by contact with the air. I quote his language: "Seeing that the web while it is in the Spider, is a certain cloudy liquor with which that Great bottle tail of theirs is filld which immediately upon its being Exposed to the Air turns to A Dry substance, and Exceedingly Rarifies and extends it self" .... "Now if it be a liquor it is hard to Conceive how they should let out a fine Even thread without Expelling a little Drop at the End of it but none such Can be Discerned, but there is no need of this."

Young Edwards also perceived that the spider had no direction of its frail aerial vessel after it had once embarked, but was compelled to go at the will of the wind, and to disembark and settle wherever its balloon might find an entanglement. He correctly discerned and explained the theory of equilibrium by which the spider navigates the air. This is his explanation: "If there be not web more than enough Just to Counterbalance the gravity of the Spider the spider together with the web will hang in equilibrio neither ascending nor Descending otherwise than as the air moves but if there is so much web that its Greater Rarity Shall more than Equal the Greater Density they will ascend till the Air is so thin that the Spider and web together are Just of an equal weight with so much air." This statement substantially expresses the opinion of all students at the present day.[34]

This review of the studies in natural history of the boy Edwards will suffice to justify the language used nearly sixty years ago by Prof. Benjamin Silliman, one of the most eminent of America's men of science: "The observations recorded by him present a very curious and interesting proof of philosophic attention in a boy of twelve years, and evince that the rudiments of his great mind were even at that immature age more than beginning to be developed." Even with the more perfect light of the present there will be found few to question the further words of the same distinguished authority, that "had he devoted himself to physical science, he might have added another Newton to the extraordinary age in which he commenced his career; for his star was just rising as Newton's was going down."[35]