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American Spiders and their Spinningwork

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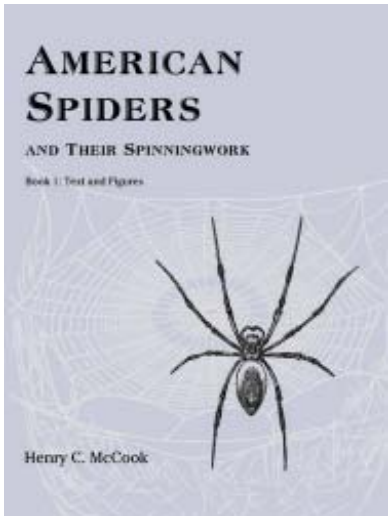

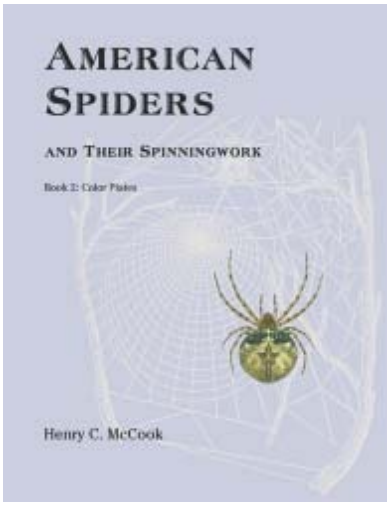

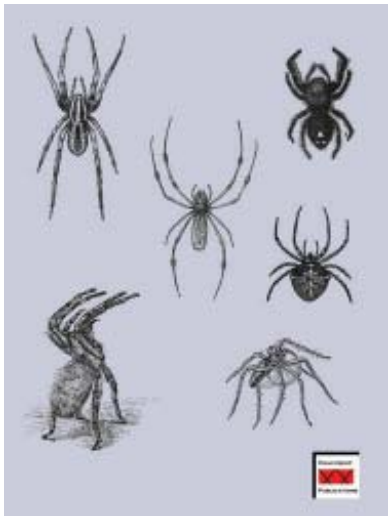

Chapter XI.

Color and the Color Sense.

The popular impression that spiders are extremely ugly is deeply seated. Even specialists in other branches of natural history are apt to express surprise when one speaks of high ornamentation among araneads. Butterflies are commonly thought to have special claims to beauty, and without disputing these one may truthfully say that as fair and brilliant colors may be found among the Araneæ as among the Lepidoptera. I suppose the popular impression to the contrary is largely due to the fact that the spiders which frequent our cellars and outhouses, and straggle occasionally inside our homes, belong to the genera whose colors are rather inconspicuous. Possibly, contact with human beings has tended to demoralize these species, and thus disrobe them of colors which once may have made them attractive!

I.

One does not need to go to the tropics for examples of richly colored spiders. Our indigenous Orbweavers furnish species whose coloring may well challenge the admiration of lovers of the beautiful. This will be abundantly illustrated by the plates prepared for Volume III. of this work, but several examples are presented in this volume, as those on Plates I. and IV. Our two indigenous species of *Argiope* have bright colors, Cophinaria being at once distinguished by her size and prominent black, yellow, and brown markings, and Argyraspis adding to these a metallic white which in earlier stages of her life has a noticeable lustre.

Epeira insularis is well known among familiars of our fields by her attractive yellow and orange colors; and the varied and beautiful robing of the Shamrock spider is well illustrated by the specimens presented in Plate I.

Yet these are far excelled in beauty and brilliancy by the Orchard spider, and the remarkable aranead, *Argiope argenteola* (Plate IV., Fig. 6), which is found in the southwestern portions of the United States. The genus *Acrosoma* also presents several species whose attractive coloring makes them worthy of notice in this connection, and *Gasteracantha* (Plate IV., Fig. 8) is often well decorated.

Many Theridioids also bear beautiful and delicate colors, the varied hues and shades of green, yellow, and brown being particularly noticeable in this group. Some of the genera, as the parasitic species of *Argyrodes*, are covered with burnished silver. Of these two tribes of Sedentary spiders it may be affirmed that they contain, in all portions of the world, and particularly in tropical countries, examples of as delicate and brilliant coloring as may be found elsewhere in Nature.

But the coloring of Orbweavers and Lineweavers is probably even exceeded by that of the Saltigrades, which is as rich as that of hummingbirds or beetles, according to Professor and Mrs.

Peckham. The most brilliant family of this tribe, the Attidæ, especially, contains examples of brilliant ornamentation. Of some of these araneads Wallace says that they are noticeable for their immense numbers, variety, and beauty. They frequent foliage and flowers, run about actively in pursuit of small insects, and many of them are so exquisitely colored as to resemble jewels rather than spiders.[1] Elsewhere he speaks of the abundance and variety of the little jumping spiders which abound on flowers and foliage, and are often perfect gems of beauty.[2] Most travelers in South America who have carefully observed aranead life, agree with Bates that the number of spiders ornamented with showy colors is remarkable.[3] Professor Peckham makes the strong assertion, which my own experience confirms, that a large collection of spiders from the tropics is almost certain to contain as great a proportion of beautifully colored specimens as would be found among an equal number of birds from the same region.[4]

Some of the Laterigrades also are richly colored. We have several species in the neighborhood of Philadelphia that would attract the admiration of any observer. The yellow and brown markings, varied with red and purple, which characterize the familiar *Misumena vatia* (Plate III., Fig. 1), may often be observed in the midst of wild flowers of our fields. A small species, apparently of *Philodromus*, which I am not able to identify, is remarkable for its pleasant grass green hues, with markings of bright red and brown upon the legs and palps. The most brilliant coloring appears to be confined to these four tribes, namely, Orbweavers and Lineweavers among the Sedentaries, and Saltigrades and Laterigrades among the Wanderers. Tubeweavers and Tunnelweavers among the Sedentaries, and Citigrades among the Wanderers, are, for the most part, distinguished by dull and inconspicuous coloring, though it is highly probable that a wider knowledge of the species of these three tribes will uncover many decorated species.

Among Orbweavers and Lineweavers there appears to be a preponderance of yellow hues, and the metallic species of these tribes are generally marked by a metallic white or silver. The Saltigrades have a tendency to somewhat darker colors, the reds and browns being more generally prevalent in this tribe; and where metallic colors occur they are usually metallic green, or occasionally blue. Yellows, greens, and dark browns prevail in the Thomisoids. Uniform browns, grays, blacks, and lead colored or neutral tints are most common among Tubeweavers, Tunnelweavers, and Citigrades.

It will thus be seen that spiders present a sufficient number and variety of facts in coloration to occupy the attention of naturalists. It is to be regretted that these facts have not been so systematized and presented in connection with the habits, industry, and structure of the species as to enable one to consider them with accuracy and satisfaction in their bearings upon many problems that now occupy the thought of scientific observers. Nevertheless, something may be attempted; and even the imperfect contributions of this chapter may, in the future and in other hands, be found helpful.

How shall we account for this variety of coloration? And what underlying causes have influenced the special colors of particular species? In point of fact, color appears to belong to the natural constitution of the spider, being imparted to it at its birth, and preserved through life by the power of heredity. It seems to be an accident or incident of physiological changes which have not been accounted for; and as such it can hardly be considered to have special regard to utility in one direction or another. To quote the language of Mr. Wallace, “Color per se may be considered normal and needs no accounting for. Amid the constant variations of animals and plants it is ever tending to vary, and to appear when it is absent.”[5]

No doubt it is modified by food, habit, environment, variations of heat, cold, moisture, light, and darkness; but the strong hereditary tendency by which it is controlled is dominant, even amidst the abnormal influences which sometimes more or less modify it. Nevertheless, it may be worth while to attempt to present some of the facts in habit, environment, and structure which seem to be most closely related to the colors and color changes of spiders.

Some of the most remarkable and perplexing facts in aranead coloration are seen in *Epeira trifolium*, and these have been represented in Plate I., Volume II., wherein several variously

hued specimens of this species are given, colored from the individuals themselves, as they were collected from one field in Niantic, Connecticut. The locality is described at length in Volume I., Chapter XVII., to which the reader is referred. The specimens were all near neighbors, exposed to the same influences of habitat, food, sunlight, etc., and most of them were taken from bushes of the same plant.

They were all domiciled in nests of clustered leaves or of single leaves rolled and sewed together. Let us examine some of these specimens, all of which are females, as we pluck them from their homes, and note their colors. Beneath this nest is a spider whose feet are black and whose legs are white, ringed with black at the feet and around the joints. The body too is white, with only here and there faint black lines bringing out more distinctly, the trifolium markings. In the next bush is another, differing from the first only in the fact that the annuli of the legs are brown instead of black. Here is another (Plate I., No. 1), pale yellow on the abdomen, deepening into orange towards the spinnerets underneath the body. The trifoil markings on the abdomen are very faint, indeed, scarcely distinguishable. The legs are a pale, transparent yellow, with red brown rings at the joints. Another specimen (No. 2) resembles No. 1, except that the front of the abdomen is orange below and greenish yellow at the top, the face being light brown. This spider is drawn in the position which it usually assumes when sitting in its nest, or when it rests upon a branch, with the knees bunched up against the abdomen. Still another specimen (No. 3) is dark yellow brown on the dorsum of the abdomen, growing into a deep chocolate at the sides and underneath; the trifoil patterns and spots on the abdomen are chalk white. The legs are orange with brown. The next specimen (No. 4) is drawn as viewed from underneath, the abdomen and sides showing there dark orange, with crimson stripes through the centre and yellow hues along the sides. The legs have deep orange rings on transparent pale yellow.

Still another (No. 5) is colored yellow, the top of the abdomen deepening into yellow brown along the sides and beneath, and has the outlines of the trifolium spots distinctly marked and of a pale yellow. Two short, greenish, longitudinal bars mark the tip of the abdomen. The legs are pale yellow with brown rings.

In the next specimen (No. 6) the trifoil spots are yellow on a greenish yellow abdomen, the latter deepening to orange on the sides and beneath. The legs have dull brown rings. Yet another specimen is of a bright strawberry tint, the abdominal patterns being a bright yellow, the legs yellow with red brown rings. It is a beautiful object, certainly, as it lies bunched up in the palm of one's hand, and no one looking upon it could deny that spiders are sometimes attractively clothed. Still another specimen (No. 9) has the dorsum of the abdomen orange, which deepens to crimson red below and at the sides, and has light yellow trifoils and spots. The legs are white, with dark brown rings at the joints. A male, Figs. 10 and 11, which we find in the nest of one of the females, is colored yellow, the legs and cephalothorax having brownish rings and bands, and the abdomen being a lighter yellow with brownish spots.

Thus the colors run, with varieties of tints and hues that confound the observer. Most of these spiders appear to be of one age and at the same period of gestation. Those that are least advanced, perhaps, may be said to have the white colors. The next degree of maturity in motherhood shows the yellow tints. The next the deepening brown, and so as the creature ages the colors seem to deepen and brighten. When the last stage of maturity has been reached, and the spider mother has spun her beautiful silken cocoon, depositing therein her eggs neatly and securely blanketed against assaulting enemies and winter frosts, these colors will gradually merge into the dull, dark hues of the sere and yellow leaf of which her nest is built, and so her life will fade away.

The physiological causes of this change in the colors of Trifolium present an interesting study. Other species known to me are subject to changes. In some the change is quite marked. In some there is a great variety of coloring, and particularly of dorsal patterns, as in the case of *Epeira patagiata* and *Epeira parvula*, but the Shamrock spider exceeds all species which I have ever observed in the puzzling variety and contrasts, as well as beauty, of the colors it assumes in the closing weeks of its life.

II.

The color of young spiders is almost without exception light yellow or green, whitish or livid, tints that blend well with the prevailing greens of foliage and young twigs, and the grays of bark on trees, of rocks and soil. This is probably due largely to the fact that the tissues are at that time translucent. The effect may also be caused by the absence of acquired food in the alimentary tract and lack of distribution throughout the system of other than the prenatal nutriment.

As young spiders advance in age the color deepens, which is caused, no doubt, by gradual hardening of the tissues, thus making them more opaque. Up to this period no food has been taken, hence the absence of food alone is not sufficient to account for the lighter colors of the first stages after exode. Yellows and browns in various tints occur at this period, and in some cases—though not generally, I believe—color patterns which are characteristic of the various species in adult life begin to appear with more or less distinctness, or at least suggestively. It is not until Sedentary spiderlings have established themselves upon their own webs, and, so to speak, have set up housekeeping for themselves, that the characteristic colors and markings of the species begin to appear with positive degrees of distinctness.

The Attidæ, like birds, moult frequently, and at each moult the markings may change, so that some of the older writers have formed several species for the different moults of one. These difficulties are increased by the fact that the adult males and females of a species usually differ considerably in appearance.[6]

This is not entirely in accord with the statement of Mr. Cambridge that the pattern of a spider—that is, the design formed by its colors and markings—differs in general but little in immaturity and maturity, excepting that it is usually more distinct in the young and in the female examples. The first of these statements appears to me to be too sweeping, unless the period of youth referred to be placed well on toward maturity. In some species there are striking differences between the colors and markings of the very young spider and those which it attains after one or two changes of skin. *Epeira diademata* and *Zilla x-notata*, two of the commonest English spiders, are conspicuous examples of this.[7]

According to Peckham, the young spiders often differ from adults, and in many species when the sexes differ when adult, the male being brighter, they are alike until they reach maturity, when the male, along with his sexual development, acquires his brilliant color. Again, soon after hatching, young spiders, probably at the third or fourth moult, begin to show color more decidedly, and the colors are distributed in the patterns characteristic of the species, and as the spiders continue to advance in age and make their successive moults, other and more marked changes may be noted.[8] The truth appears to be that there are differences among species in the degrees of resemblance between immature and adult forms, but that generally the likeness strengthens from the time of hatching onward to maturity.

I give a few observations upon the appearance of spiderlings during and shortly after their cocoon life. These, however, can hardly be fully appreciated by those who do not know the adult species, without consulting the plates in Volume III. But the following species may be compared with figures or descriptions in this volume.

Just after its escape from the egg shell the young of *Argiope cophinaria* is about two millimetres long. The cephalothorax is a grayish white color, translucent, upon the fore part of which the eyes, which are a brownish color, stand out vividly, seeming to form a large part of the face. The legs are white, translucent, as are also the palps; as the spider sits upon a surface both legs and palps are doubled under the body. In this position the palps seem to be a shorter pair of legs, so that as thus viewed the animal really seems to have ten legs. The abdomen is a yellowish color, except that in the places where the peculiar yellowish irregular marks of the dorsum are seen upon the adult, may be seen irregular markings of pure white.

Fig. 305 is drawn from a young Cophinaria just out of the shell, and Figs. 306 and 307 from the same a few days older.

Fig. 305. Young *Argiope cophinaria* after leaving the shell.
Figs. 306, 307. Appearance after first moult.

When the young Cophinarias have advanced in age a few days the folium upon the dorsum of the abdomen assumes a distinct shield shaped outline resembling that which is common upon the adult forms of *Epeira insularis*, *sclopetaria*, etc., the color of the same being a darkish green, and the scalloped margins being surrounded by a white band which extends quite around the fore part of the abdomen. The sides also have a greenish band, the same color prevailing around the spinnerets. The usual aspect of the abdomen is thus green in the centre and lower part of the dorsum, and white along the fore part of the abdomen and the sides. The hairs are quite prominent both on the abdomen and legs. The eyes have a darker hue, and little processes on either side of the base of the abdomen distinctly appear. The abdomen is now in general shape a miniature of the adult form. The legs are covered with greenish bands closely placed. When separated from the mass of its fellow broodlings, a single spider will throw out a thread from which it will hang down, suspending itself by its dragline and weaving a little foot basket, precisely in the manner of the more matured spiders. Three longitudinal bands appear upon the cephalothorax, one in the median line and one on each side. The youngling looks plump, as though well nourished.

The young of *Epeira strix* shortly after its advent from the cocoon (April 14th) often presents a uniform glossy black appearance. After another moult this appearance is somewhat changed, the legs have black annuli around the joints, and the interspaces are of a yellowish brown hue well covered with black spines. The folium upon the abdomen is along its margins jet black, with a median cross like figure of a dark yellowish brown. Bands of the same color surround the scalloped margin along the sides. The cephalothorax has the same general hue of glossy black.

At the time of hatching, the young Gasteracanthas of Africa, according to Dr. Vinson, are round and black, without the pointed spines peculiar to the adult, and with a triangular white spot upon the abdomen. These peculiarities are also characteristic of our California species. Among those sent to me by Mrs. Eigenmann were a number of young in various stages of growth. They are all quite black, and the spines are either lacking or just beginning to push out slight angles upon the otherwise rounded abdomen. (Compare with Plate IV., Volume II., Fig. 8.)

The black color of these young Gasteracanthas is a singular variation from the ordinary color of spiderlings, which is quite light, the colors being nearly always white, or a faint livid, or a delicate hue of pink or yellow. I do not know whether the absence of spines characterizes the young of those species that show these peculiarities in adult life. It may be that the development of these thorn like processes is in some way connected with the development and growth of the young spider, and is only completed at maturity. It would be interesting to know the physiological causes of this vital phenomenon.

Some of those species which have soft conical tubercles upon the fore part of the abdomen show these very early in the young. I have observed them distinctly formed upon at least two of the Angulata group of our American *Epeira*, *gemma* and *bicentennaria*. In the case of *Argiope cophinaria* the spiderling immediately after escape from the egg (the first moult) appears to be without the processes or bifurcations which mark the base of the abdomen of that species, but after the next moult these show plainly. (Compare Fig. 305 with Figs. 306 and 307.)

When the young of *Tegenaria medicinalis* first break from the shell, the legs and palps are white and semitransparent. The eyes stand out brown and distinct upon the face. The cephalothorax in the fore part has a slight bluish or lead colored tint, with a touch of yellow at the posterior part near the abdomen. The mandibles are the color of the cephalothorax, but with the fangs prominent, feeble looking, whitish, instead of the dark, horny appearance of the adult. The abdomen is a uniform yellowish hue, at the apex of which the spinnerets appear lead colored, the long, jointed, pair quite prominent. The spines are quite manifest on the legs, and hairs are seen on the abdomen. The folium or dorsal figure can be traced, together with the transverse bars, on either side of the median line. In a day or two the color of the legs deepens until they have a leaden hue, upon which the black spines stand out more prominently. The abdomen is a little brighter yellow, and the cephalothorax corresponds in color with the legs. In two days more the yellowish tint has faded from the abdomen, the whole spider has a blackish appearance, caused by the dark hairs upon the lead colored body; the transverse markings stand out more prominently upon the abdomen.

The young of *Epeira cucurbitina* (English) when extracted from the egg have the cephalothorax and legs of a pale yellowish white color, that of the abdomen being reddish brown. But after their first change of integument they acquire an olive or brownish green tint, the upper part of the abdomen being metallic with whitish spots on each side, with a longitudinal stripe of the same hue parallel with it. On the upper side there is a series of minute black spots.[9] These examples will be ample, when compared with adult forms, to enable the student to note the color changes that occur during the growth of spiders.

III.

As spiders further advance in age and make their successive moults, various color changes may be noted. Immediately after moulting the color is always lighter, which is probably due to the fact that the harder skin just cast off prevented the passage of light through the tissues. The new skin is thinner and more translucent. Moulting produces changes in color patterns of a decided kind, at least in certain species.

Phidippus rufus when mature is a dark red spider, the male considerably brighter than his consort. When about one-seventh grown and after the third or fourth moult, the young are dark brown with light yellow legs. Some moults later they are reddish, with narrow, oblique, whitish bars on the sides of the abdomen, and two dark bands on the dorsum, on each of which is a row of white dots. The appearance of the spider changes but little during the next four moults, but after the last, the tenth, both male and female become mature, and acquire the adult color. The appearance of the female after the fifth moult is similar to that of many other females in the genus.[10]

The female of *Phidippus johnsonii* has the abdomen red and black with a white base and some white dots, while the male abdomen is bright vermilion red, with sometimes a white band at the base. The young of both sexes resemble the mother, until the last moult, when the males assume their bright livery.[11]

In old age the color changes are often quite decided. In some, as *Epeira trifolium* and *Epeira thaddeus*, the changes give added brilliancy to the color at certain parts of the body. Some of the color changes of Trifolium are remarkably beautiful, and the same is true of Thaddeus. But advanced age, as a rule, brings darker colors. Orange and brown then have a ruddier hue; yellows darken into orange and brown. Sometimes the yellow patterns are entirely lost, and the spider becomes dark, almost black. There is a grizzled appearance about the animal in this stage which reminds one of vertebrate animals at the corresponding period. These last named changes are manifest in the female spider after the final deposit of eggs.

In gravid females changes of color are sometimes noticeable. Some of the bright colors upon Trifolium and Thaddeus are doubtless due to this condition. However, other and perhaps

most species during gestation have a lighter color, which may be the result of mechanical changes in structure. The skin becomes distended and more transparent, the pigment is thereby distributed, and thus centres of color are broken up and the coloring matter diffused. Not only the skin, but other parts of the abdomen are distended during gestation, and this distension produces changes in the color of the animal, it may be by modifying in some way the various secretions from the liver and other organs, and in some cases, perhaps, widening the intervals between color centres and color hairs, and breaking up groups of the same.

The little pits or dark spots upon the dorsum of the abdomen, which mark the attachment of the muscles within, seem to me to be centres for the aggregation of coloring material. At least the dorsal patterns appear to be grouped in some regular way around these muscular attachments. Thus the action of the muscles on the skin and chitinous shell or walls seems to compel certain aggregations along the lines of use that form these colors and patterns. It might be important in this connection to consider what is the ordinary effect of muscular action upon the distribution of pigment and colored hairs in vertebrate animals.

The color rings or annuli around the joints of the legs of spiders may be influenced by action of the muscles. The tendency of these darker and more vivid colors is towards the ends of the joints, as though by the attachments and prevailing outward action of the muscles the pigment were forced mechanically or otherwise attracted toward these points. The foot or terminal joint is usually dark, and often black. In the cephalothorax may be noted the same tendency of color to group itself somewhat symmetrically around the points of muscular attachment, particularly the central depression.

IV.

Color and markings are undoubtedly influenced by sex. Peckham, after summarizing the Attidæ of France from the studies of M. Simon, finds that in thirty-nine species the male is plainly unlike the female, being in twenty-six instances much more conspicuous, while in fifty-five the sexes are similar, or, if they differ, the male is no more conspicuous than the female. These facts make it clear that the sexes commonly differ, the male being brighter than the female. Peckham considers it not too much to say that in the Attidæ at least two-fifths of all the species have the male more conspicuous than the female.[12]

Menge, in referring to the greater brilliancy of the male of *Micromata ornata*, says that it only assumes its bright color as a bridal adornment, and in this connection makes a statement that in the Thomisidæ and Saltigradæ the males are generally more beautifully colored than the females.[13]

Philæus militaris, a common American Attoid, is another illustration. In the male the cephalothorax and abdomen are bright bronze brown, the former with a wide, pure white band on each upper side and a white spot on the centre of the head, the latter with a wide white band around the base and sides. The female has the brown all covered over with white and gray hairs, which form a more or less distinct pattern of lines and spots.[14]

In *Habrocestum splendens*, while the young males are not exactly like the adult female, they resemble her much more closely than they do the adult male. This is one of our most beautiful male Saltigrades. The highly iridescent scales which cover the entire body make it impossible to give in a painting a correct idea of its brilliancy, since the color changes in every light. The male only gets his gorgeous livery at the last moult, just as he becomes mature, though in some species the nuptial moult is acquired one moult before maturity.[15]

This prevalent condition of the relative brilliancy of coloring between the sexes of the Attidæ is entirely reversed among Orbweavers. In this tribe there is a strong tendency to inconspicuous colors in males, and frequently in the degree that the females are conspicuous for size and coloring, the males are diminutive and dull.

We have already seen (see Chapter II., page 303), from our examination of the interesting studies of the Peckhams upon the courtship of Saltigrade spiders, that there is a close relation between mating habits and the brilliant colors prevalent among males. In other words, the favors desired from the female are solicited with such a display of the ornamented parts of the male body, as to justify the conclusion that the ornamentation is pleasing to the female, and is presented in the way of soliciting her favors. Of course, if we accept this fact, we also admit that there must be, on the part of both sexes, a consciousness of the presence of color, and the fact that the female at least is so sensitive to the differences in color ornamentation as to be moved towards this wooer or that according to the splendor of his physical finery.

That climate and favorable environment sometimes exert modifying influences upon the general facies and, to some extent, the industry of spiders, is illustrated by *Epeira labyrinthea*. I have specimens of this species from almost every part of the United States where collections of araneads have been made. It is distributed from the far Northeast to the southwestern portion of California. I have also received specimens in collections forwarded to me by Professor Peckham from several South American States. These southern representatives of the species are larger and decidedly more vigorous looking animals than the northern specimens. The industry of the spider experiences no essential change as far as I can learn. The snare is, perhaps, larger with tropical examples. Specimens of cocoons sent to me from southern California have all the characteristics of our northern species, but are decidedly larger. No marked influence appears to have been exerted upon the coloration of the spider itself. But other collections indicate contrary conditions.

The species was collected pretty freely by the naturalists of the U. S. S. "Albatross," in its explorations along the shores of the southern Atlantic and the Pacific, showing an immense distribution over the entire Western Hemisphere. Dr. Marx remarks that specimens collected at the Straits of Magellan are hardly recognizable, for its color has greatly changed. The dorsal folium is nearly obliterated. Only two lighter spots at each side remain, and the whole body is covered with a long, dense pubescence.[16]

If Dr. Marx is correct in his surmise that *Epeira cooksonii* Butler, which lives in great abundance on the Galapagos Islands, is related to our *Epeira domiciliorum*, and that the latter spider has undergone on the Pacific coast so great a change in form and coloration as to be identical with my *Epeira vertebrata*, this species will afford another example of the influence of climate upon color.[17] I am not satisfied, however, that the last two named species are identical. On the other hand, certain species, as notably *Argiope cophinaria* and *argyraspis*, have undergone a transcontinental distribution, covering wide extremes of climate and conditions, without experiencing any notable change in general appearance.

These examples will be sufficient as illustrations of the fact that the influence of climate must vary according to species. The fact is that some of the species probably are more elastic and impressionable in their natural constitution, and thus are more sensitive to radical changes in environment, while others are able to resist such changes more vigorously, and thus retain their characteristics through extreme changes.

Spiders that live upon plants, as a rule have colors that are harmonious with the prevailing greens and yellows, and admixtures thereof, of branches, leaves, and flowers. Spiders that nest in stables, houses, on fences, and like locations, ordinarily have dusky colors, harmonious with the environment; as, for example, *Theridium tepidariorum*, *Agalena nævia*, *Tegenaria medicinalis*. However, I do not find that any great difference in color is observable in the above species when they nest in foliage, as is often the case, at least with *Agalena* and *Theridium*. It might be said, perhaps, that there is a slight tendency to darker hues and a more uniform color when the spiders are found in the first named locations.

Ground spiders, as the Lycosids, generally have colors of neutral grays that blend well either with the soil, with rocks, or with stalks of grass and weeds, especially when the latter are somewhat dry. Lycosids found in the neighborhood of streams do not seem to be especially influenced

by the natural color of water; but *Dolomedes sexpunctatus*, which is so constantly found on the water, sometimes has a tint that at least well harmonizes with that of the stream itself.

Saltigrades follow the rule of the Lycosids; their colors, being chiefly black, gray, and brown, harmonize with the surfaces of rocks, trunks of trees, etc., upon which they habitually seek their prey. Many of them are freely marked with yellow, and thus are also sufficiently harmonized with the color of the leaves. The metallic green and blue on the fangs of some Saltigrades seem almost like a leaf ambush to the body of the creature as it is observed stalking its prey. This suggests the strategy most familiar from its association with the lines of Shakespeare:—

> "Macbeth shall never vanquished be, until
> Great Birnam wood to the Dunsinane hill
> Shall come against him."

It is, perhaps, a not wholly untenable theory that some insects are made less wary by the resemblance to surrounding foliage and the play of iridescent hues from the mandibles of a stalking *Phidippus morsitans*, for example, as it stealthily moves upon its prey. But independent of the indifference of the ordinary insect to spider presence, the Peckhams have taught us to find the chief service of these gorgeous frontlets in courtship. But what can be their use in the female Morsitans? She is such a ferocious virago that we might suspect in her an example of warning coloration as towards her own lovers.

According to Emerton,[18] in one species of *Linyphia* from Weyer's Cave, Virginia, the colors and markings of some specimens are as bright as on spiders of the same family living in cellars and shady woods. The other five species are pale in color. On the supposition that all these species drifted from the outside world into the caverns, we must reason from such a fact either, that the species retaining a normal color had been domesticated in the caverns at a much more recent date than the others, or that it was possessed of greater power to resist the changes consequent upon its changed environment.

The influence of cave life upon *Anthrobia mammouthia* appears to be manifest in this lack of color. Two young Anthrobias were hatched May 3d for Professor Packard, who describes the whole body, including the legs, as snow white, with the legs much shorter than in the adult state. The adult in life is white, tinged with a very faint flesh color, with the abdomen reddish. In some specimens the abdomen has beneath several large transverse dusky bands. *Linyphia subterranea* as observed living in Wyandotte Cave is pale pinkish, horn brown on the thorax and legs, while the abdomen is dull honey yellow.[19]

Two specimens of *Linyphia weyerii* in my possession, collected by Dr. Joseph Leidy in Luray Cavern, Virginia, are of a light honey yellow, the abdomen of one individual being darkish brown. As this is a common color for spiders of all conditions, after they have been in alcohol a little while, I am not able to say what may have been the original color of these, particularly as they are not adult.

In the case of *Lycosa arenicola*, whose habits were studied by me on Coffin's Beach, near Annisquam, Massachusetts, the undue presence of sunlight and heat appears to have produced precisely the same results as the absence of sunlight in Mammoth Cave. The eastern shore of the bay opposite Annisquam consists in part of a stretch of sand hills known as Coffin's Beach. The sand is a bright white color, and is massed at places into elevations of considerable height. The fragrant Bay bush grows in clumps along the edges and summits of these irregular sand hills, and this is intermingled with patches of tough grass, among which are numerous burrows of the Turret spider. These Lycosids are domiciled in the sand, and spread very generally over the dunes. The burrows are dug straight downward, penetrating the upper layer of loose sand, and striking the more compacts and moist strata below the surface. The spiders captured were of a light hue, as compared with the same specimens found in meadows, fields, and like environment in the interior. Specimens almost identical with these in color were found by Dr. Joseph

Fig. 308. *Lycosa arenicola*. (A dark specimen.)

Leidy, and subsequently by myself, in the sand at Beach Haven, New Jersey. This pale coloring appears in all other littoral specimens examined. The influence of environment, as manifest in these spiders, was also seen in a grasshopper or locust which is quite abundant on Coffin's Beach, and is almost as white as the sand over which it was found hopping.[20]

It is certainly confusing to one who studies the influence of light upon aranead coloration to find such contradictory facts as these, viz., that the absence of light results in albinism in the spider fauna of caverns, while the excessive sunlight which beats upon and is reflected by the white sea sand produces the same condition. Evidently something more than the direct influence of sunlight must contribute to these results.

But confusing elements do not stop here. Any one who is familiar with our ordinary cellar spider fauna must have observed among them a strong tendency to black or dark colors. The most common cellar spider in the neighborhood of Philadelphia is probably the Tubeweaver *Tegenaria medicinalis*. It is a quite dark lead color, which is as near black as any of our indigenous spiders. So also *Agalena nævia*, when it nests in dark places, as it often does, seems to me to add to the somewhat sombre colors which it bears in arboreal and sunny sites, several additional tints of darkness.

It should be noted that in the case of the Turret spider of Coffin's Beach a large portion of the year must be spent in a torpid condition by such individuals as survive the winter, which is severe and long in that vicinity. On the other hand, the white spiders of Mammoth Cave live in a uniform and pleasantly warm temperature. The same, to some extent, is true of the Medicinal spider, which is kept reasonably warm when living in our cellars and other unfrequented places in human habitations, but, unlike the Mammoth Cave Anthrobias, are black. Thus similar conditions of temperature, as well as of light, appear in these cases to issue in opposite conditions of color.

V.

I have already considered the theory of Peckham that the bright ornamentation of the male Saltigrade spider serves to attract the attention of the female, and to secure him her favor in preference to duller colored rivals. In the case of Orbweavers, where the conditions are reversed and the female is the more highly ornamented, we may suppose that the point of utility is also reversed, and the brighter colors of the female serve to attract to her the attention of the male. In the case of Orbweavers and Lineweavers, there would seem to be some necessity for this, inasmuch as the females for the most part occupy the centre of their webs, which are often of considerable size, and thus they would require to be marked in such wise that the vagrant male on his courtship excursions could discern his mate at the distance of at least several inches. It seems not an overstrained supposition that both the increased size and excessive coloration of the female would make her a more conspicuous object and thus facilitate the union of the two sexes.

Again, in a large number of species which are influenced by what we might call mimetic harmony, and to which allusion has already been made, we can readily see how highly useful the general resemblance of environment would be in protecting spiders from various enemies. All the Wanderers, and some of the Sedentary spiders, appear to be subject to those influences which harmonize their color with the surroundings of their daily life. This subject may be more fully considered in the chapter on Mimicry, but it has been necessary to allude to it in this

connection. Here, perhaps, we have a view of the greatest influence exercised by color and, as one may say, the absence of color, upon the life of araneads.

When we come to consider the more highly colored species, particularly in their relation to their habits, the question of utility is complicated by many apparently contradictory facts. Such large and well marked species as those of the genus *Argiope*, *Acrosoma*, *Gasteracantha*, and such brilliant species as the Orchard spider, are found well nigh invariably hanging at the centre of their webs in full view of all enemies and assailants. One who is pursued by the theory of utility can scarcely fail to ask whether these species are protected by their color from any enemies, and, if so, in what manner are they protected? It is certainly natural to suppose that they are more exposed thereby to raiding birds, digger and mud dauber wasps.

Another question may be mooted, have these species, thus highly colored, and thereby exposed to enemies, any industrial protection which may be considered a compensation? I refer to a few examples bearing upon this inquiry. *Argiope cophinaria* and Argyraspis sometimes have protective wings of retitelarian lines thrown out on each side of their nets, which guard the dorsal parts of their bodies, and a thick shield like sheeting, which protects the under side. (See Volume I., Figs. 96 and 89.) These spiders are highly colored and conspicuous by size. They dwell in shrubs, bushes, grasses, low trees, and commonly are stationed in the centre of their round webs, having no domicile or tent to which they retire. No doubt, the protective wings are serviceable in warding off attacks of raiding wasps, as well as helping to secure insect food for the occupant. But I find that in a large number of cases these fenders are omitted. The tendency to omit them, if I am not mistaken, strongly increases as the spiders mature in age; Perhaps in this case the size of the animal may be considered as sufficient protection. At all events, I think that the protective wings are rather characteristic of the immature state.

The Insular and Shamrock spiders, which are among the most brightly colored of our fauna, do not hang habitually in the centre of their webs during the day, but live in leafy tents, and their habitat is among bushes, shrubs, and trees. The Insular spider inclines to groves much more strongly than Trifolium. *Epeira thaddeus* has the same habit. Indeed, it may be asserted generally that many of our most highly colored Epeiroids belong to tentmaking species, a fact which is true not only of the American, but of the European, spider fauna. The facts here seem to point to a special development of industrial protection as a compensation for the exposure of bright colors.

On the other hand, *Epeira strix*, which is not a bright colored spider by any means, is one of the most secretive Orbweavers in its habits, dwelling in a domicile of rolled leaves, shrinking away into cavities and holes of bark, in angles of walls, and like positions, occupying at times a well made leafy tent, after the manner of Insularis and Trifolium, and only occupying its snare during the night. It is one of the rarest things to find a Furrow spider, unless it be quite young, suspended upon its orb, trapping flies, in daytime. Notwithstanding its seeming protective color, and the additional protection of its secretive habits, it is mercilessly pursued, in the vicinity of Philadelphia, by the steel blue wasp, which stores numbers in its clay cells.

Epeira domiciliorum and cinerea are also spiders of rather inconspicuous colors, the last named particularly so, and both of them screen themselves in tents, though the Domicile spider at least not as habitually as some others.

The Labyrinth spider and *Epeira triaranea* are among the most strongly protected of our fauna by their industry, having, besides their orbs and thick retitelarian snare, a dome shaped silken tent as a domicile. In addition, Labyrinthea roofs her tent with a dry leaf, or uses it as a shelter for her body. These spiders are strongly marked as to their patterns, and are not inconspicuously colored, but do not have the bright hues which characterize *Argiope*, *Epeira insularis*, and some others.

The Orchard spider is one of the most brilliantly colored of our indigenous species, although its hues harmonize well, particularly its green and yellow, with its leafy surroundings. It rests beneath its horizontal orb, where it is abundantly exposed to attack from above, but has straggling,

Fig. 309. Leaf nest of *Epeira*.

pyramidal retitelarian lines beneath it, which form some protection. It dwells mostly in wooded places, or among shrubs and thick, leafy bushes. *Epeira gibberosa* is also a brilliantly colored spider. Its industrial protection is more manifest, for it dwells beneath a sort of hammock or structure of lines woven between the edges of a leaf. This hammock protects it above, while the leaf affords good security from beneath (Volume I., Chapter IX.), and its green color completes the protection.

Our three indigenous species of *Acrosoma*, viz., Rugosa, Spinea, and Mitrata, are all, particularly the first two, well marked and brightly colored spiders. They are protected, Mitrata least conspicuously, by spinous processes, if such can be called protections. They live in the centre of their orbs as a rule, and their webs are most frequently found stretched between the trunks of young trees, in openings of groves, woods, and like spots. They seem to me more directly exposed to assault than almost any other of our native Orbweavers, unless, indeed, their preferred site within the shaded walks of groves and woods may be considered a protection.

Gasteracantha, with its strongly developed spines, has much the same habit as *Acrosoma*, but the spines appear to be wanting in the young of this genus, the very age, one would think, at which they are most needed. However, the young of *Gasteracantha*, at least with numerous specimens sent from the Pacific coast, are almost black in color, a feature which must certainly be regarded as protective, if bright colors best invite the observation of enemies.

On the whole, the conclusion seems to be justified that many spiders which appear to be more exposed to enemies by reason of bright colors or greater size, possess special variations in industry and habits that in some degree are protective; but there are so many apparent exceptions to this, which require more careful study, that no generalization can now be warranted.

If we come finally to consider the bearing of what has been called “warning coloration” upon spiders, there is little to be said. In the case of those numerous species which belong to the Wanderers, the colors cannot be considered as warning, but, as we have seen, are rather protective. As to Sedentary species, I cannot think of any animal that would avoid them as inedible on account of their color, or of any influence that their color could have in warning insects of danger. In point of fact, the colored spiders appear to be as delicate morsels to those that feed upon them as any other sort, and they are just as frequently, and perhaps I may say even more frequently, though by no means exclusively, selected for such purposes.

That a warning should be conveyed to insects by the color of a spider at the centre of its web seems to me wholly imaginary, since Sedentary spiders do not capture food directly, but by means of their manufactured trapping instruments. Indeed, I have little faith in the opinion that insects are capable of experiencing anything like a warning, from color or other causes, against the presence of spiders. I feel sure that this is the case with flies, the insects which perhaps more than any other form the staple food of the various aranead tribes. I have often been witness of the absolute indifference of various species of flies to the presence of spiders. One remarkable example is recorded (Vol. I., Chapter XV.), in which, during an entire season, I observed numbers of a little black Diptera settling and feeding upon the carcasses of large blue bottle and house flies which had been trapped and trussed within the orbs of *Argiope*. In several cases these little creatures were observed stationed within the open jaws of their gigantic enemy, sipping juices which the spider was expressing from the fly on which she was feeding.

A fly which had been put into a box with *Epeira strix* tempted her in vain to make a breakfast upon it. Three times it flew into or against the spider’s jaws and escaped. Twice it crept between

the front pair of legs; once it lit upon and crept up the hindermost legs; and all the time was walking everywhere around her, utterly unconscious of the presence of an enemy. The spider remained motionless, except when the fly flew into her face, when she made an effort to seize it. At the time she was seated upon the bottom of the box, separate from any snare or web, and thus without ordinary means by which the presence and locality of insects are determined. We may suppose that the spider was confused by the unusual circumstance of separation from her web, and her vision momentarily impaired; but the fly, at least, was in normal condition, hunting food and otherwise acting in a natural way.

In numerous other cases when flies have been placed within boxes where spiders have been confined, I do not remember a single individual that showed the slightest sense of fear, but on the contrary they would run all around, and even settle upon the spider, apparently no more conscious of its presence or of any peril therefrom, than if it had been a clod or chip. The same is true of grasshoppers, hundreds of which have been fed to the large tarantulas that from time to time, during a number of years, I have kept in confinement. Of such insects, at least, it would be highly absurd to argue anything of service in the way of "warning coloration." Bright or dull, large or small, they seem to be absolutely without consciousness of the presence, or fear of the power, of spiders.

In taking a summary view of the facts above recorded it may be said, in general terms, that the influences which appear to modify the color of spiders, in various degrees more or less known, are the following: Moulting changes; the effects of advancing age and approaching dissolution; the disturbance of gestation; the distribution of pigment and color hairs by muscular action; the effects of food, environment, and general habit; sexual differences and the excitements of courtship and mating; and, possibly, inimical influences, such as natural enemies and weather changes.

VI.

How far are spiders conscious of the color elements in their surroundings? They are found among leaves, flowers, and blossoms of all the varied kinds and colors in the vegetable kingdom. Sedentary spiders hang their webs to the branches and leaves of trees, and weave them amidst flowers, often selecting for them sites which strike the observer as choice and notable for beauty. One may find, for example, the pretty web of *Linyphia* communis hung within an opening upon a morning-glory vine, the bright colored flowers of which encircled the web like a charming frame to a picture.[21] Again, one may see the round webs of *Epeira* spun among lilies,[22] and hung within full blossoming sprays of honeysuckle. Indeed, at every point in Nature where flowers appear, there also appear spiders erecting their domiciles, weaving their snares, and spinning their cocoons.

In like manner many of the wandering tribes spend their lives in arboreal situations, continually stalking their prey, and plying the varied industries characteristic of their species among grasses, shrubs, blossoming trees, vines, and beds of flowers. Are they utterly unconscious of the color effects among which they continually move? Or if, on the other hand, they have some sense of color, in what degree is it possessed? These are interesting questions, and to some extent they have been solved, although much remains to be proved.

It cannot, of course, be known that the light waves of various lengths, whose vibrations result in color, produce upon the spider's organ of vision effects similar to those known to man and many of the higher mammals. But that some effect is produced seems clear, and that this is analogous to the color sense in man, we may perhaps safely assume; for we can only think and speak of the sensations of spiders in terms of our own conscious states.

The late Prof. Paul Bert claimed that all animals see the rays of the spectrum as we do; that beyond this they see nothing that is unseen by us, and that, in the extent of the visible region,

the differences between the illuminating powers of the different color rays are the same for them as for us.[23] He rests these conclusions on experiments made on a small fresh water crustacean belonging to the genus *Daphnia*. Sir John Lubbock dissents from this generalization as too sweeping and based upon an insufficient foundation,[24] but, as the result of numerous experiments with *Daphnia pulex*, concludes that while it would be impossible to prove that these crustaceans actually perceive colors, to suggest that the rays of various wave lengths produce on their eyes a different impression other than that of color, is to propose an entirely novel hypothesis. At any rate, he thinks that he has shown that they do distinguish between waves of different lengths, and prefer those which to our eyes appear green and yellow.[25]

On the other hand, M. Merejkowski denies to the crustaceans any sense of color whatever. He thinks that they distinguish very well the intensity of the ethereal vibrations, their amplitude, but not their number. In the mode of their perception of light there is a great difference between the lower crustaceans and men, as well as between those animals and ants. While we see the different colors and their different intensities, the inferior crustaceans neither behold any color or the different variations of intensity therein. We perceive colors as colors, they perceive them only as light.[26]

Mr. Alfred R. Wallace does not admit that the fact that the lower animals distinguish what are to us diversities of color, proves that their sensations of color bear any resemblance to ours. The insects' capacity to distinguish red from blue may be and probably is due to preceptions of a totally distinct nature.[27]

We have much testimony that insects have a decided color sense. Most important and decisive are, perhaps, the remarkable investigations of Sir John Lubbock, whose experiments indicate that ants are sensitive to the ordinary colors of the solar spectrum. It becomes probable, moreover, that the ultra violet rays must make themselves apparent to ants as a distinct and separate color, of which we can form no idea, but as unlike the rest as red is from yellow or green from violet. He adds, that as few of the colors in Nature are pure, but almost all arise from the combination of rays of different wave lengths, and as in such cases a visible resultant would be composed not only of the rays which we see, but of these and the ultra violet, it would appear that the colors of objects and the general aspect of Nature must present to ants a very different appearance from what it does to us.[28]

Lubbock has also shown that bees have a decided preference between colors, and that blue is distinctly their favorite, although yellow is much liked.[29] He also demonstrates that wasps are capable of distinguishing color, although they do not seem to be so much guided by it as bees are.[30] The fact having thus been established, that among two classes of the Arthropods, namely, the Crustacea and the Insecta, there are found genera which show a decided color sense, prepares us to expect the same fact in the case of the Arachnida, and indeed of all other Arthropods.

The best sustained and most conclusive experiments upon spiders themselves, of which I have knowledge, were made by Professor and Mrs. Peckham in the neighborhood of Milwaukee, Wisconsin.[31] Their method of procedure was as follows: A cage was constructed, formed of four differently colored compartments, all made of glass and opening freely into one another. The cage was placed on a table on a covered porch, with the wall of the house on one side, while the other sides were exposed to light. A spider was then admitted to the cage and, after having become sufficiently domesticated, was gently driven into a specially colored compartment, say the blue. It was then left without interference to select such position as it might prefer in any one of the four differently colored compartments. When the spider had changed its position and remained therein a sufficient time to indicate a preference for the color under which it rested, it was again disturbed and moved to another color. If, for example, it settled within the red compartment, it was transferred to the yellow, and so on, a record being made of the various changes and preferences. This process was continued during several days, in which several hundred experiments were made. As a result it was found that among all the spiders experimented

with 181 preferred the red, 32 the yellow, 11 blue, and 13 green. The preference of the spiders for red was thus decidedly marked, resembling, although in a more marked degree, the preference of ants for the same color, as demonstrated by Sir John Lubbock's experiments,[32] which appear to have suggested those of Professor Peckham.

A test case was made which gave a striking result, quite in confirmation of the experiments as above described. An individual of *Lycosa nigroventris*, which had shown a strong preference for red, choosing that compartment 33 times out of 41, was temporarily blinded by covering its eyes with paraffin. When put within the cage it was found that the spider remained quiet in whatever compartment it was placed until it was driven out. If placed in the blue compartment, with its eyes as close as possible to the red, it showed no inclination to enter, although this color had before proved so strongly attractive. Its preferences, or rather its locations, during the resulting experiments, are recorded as follows:—

Preferences after blinding: Red 6, yellow 6, blue 6, green 5.

Preferences before blinding: Red 33, yellow 5, blue 0, green 3.

Such results leave scarcely any room for doubt that in some way the spider had been influenced by a color sense, since, while it possessed normal vision it expressed a most decided preference for the red color, but when temporarily deprived of vision settled indifferently and about equally in all the colors represented in the series, there being no stronger preference for red than there had been in previous experiments for the blue compartment, which it had entirely shunned. These results seem to justify the conclusion that there exists a color sense in certain spiders.

It is to be remarked, however, that in all the cases recorded, and apparently in all experimented upon, the individuals were chosen from the Lycosids alone. These spiders undoubtedly have a keen sense of sight, although I am inclined to think that in this respect they are inferior to some other groups. Their habit keeps them during much of their life concealed within earth burrows, or little caves excavated and fitted up by them under stones, logs, and like surroundings. They move over the ground or water, where they stalk their prey, and are not as apt to be found in arboreal situations among flowers, blossoms, and leaves, as other tribes of the Wanderers, the Saltigrades and Laterigrades.

There is one well known species of Laterigrade spider, *Misumena vatia*, whose habits have awakened in my mind the query whether it might not be influenced by a decided color sense in the selection of certain sites. Most araneologists have observed this species stationed upon yellow flowers, as the golden rod and the brown daisy which is popularly known in our section as "black eyed Susan." *Misumena* lurks upon this flower with its legs spread out within the very centre, and so closely corresponding in color to its floral site that one must look closely ere he discovers it. The yellow centre of the common ox eyed daisy is also a lurking place for this spider. I have found the same species nestled within the petals of a half opened tea rose, and then its color also corresponded with its environment, being white, with various delicate shades of green and pink. (Plate III., Fig. 2.) In these cases we are forced at least to face the question, was the spider moved in such selection by the color of the flower? If we say yes, then we are also constrained to the conclusion that, in some way, the aranead must have been conscious of the fact that its peculiar color harmonized with the color of the flower which it sought as a stalking point for the capture of its prey.

It is doubtless true for the most part that light is perceived by spiders, and arthropods generally, by the eyes, and not chiefly by the skin. Sir John Lubbock has shown, by a series of ingenious experiments, that ants perceive the ultra violet rays with their eyes, and not, as suggested by Graber, by the skin generally. These experiments have been repeated and the conclusions verified by an observer so careful and experienced as Dr. Auguste Forel.[33] Nevertheless, it seems to me probable that there is some, and it may be considerable, perception of light by the skin of spiders.

The abdomen of spiders is included within a soft integument which is frequently covered heavily with hairs. May it not be that this soft skin is far more sensitive than the hard chitinous

enclosure of the abdomen of insects? May it not, therefore, be that such a spider as *Misumena vatia* is led to settle within those flowers which correspond in color to itself, by that comfortable feeling which results from the harmony of an individual with its environment, and which may be caused, for all we know, by the fact that the yellow rays of the flower are perceived by and agreeable to the sensitive skin of the spider? In thinking of the power of spiders to distinguish the various hues, may we not be justified in calling into play this sensitiveness of the entire skin, instead of limiting the perception to the eyes alone?

There is indeed another theory which may be suggested, namely, that the color surroundings of the spider, in some manner not now explicable, so rapidly influence the organism of the creature that a change of color is produced in harmony with its environment. Can we suppose, in this case, that the spider possesses the power to influence at will the chromatophores or pigment bodies, so that they may change her color with changing site?

There is another explanation of the above peculiar habit of *Misumena*. Many insects are strongly attracted by yellow colors, and as insects are the chief food of spiders, it is natural that the familiar resorts of insects should be the places most affected by spiders. That insects have such attraction to colors has already been shown, and that they are drawn to yellow colored flowers has been fully established by Müller in his remarkable volume on Alpine flowers.[34] This author gives a table recording the numerous visits of various insects to flowers of different hues; and a study of the table shows that butterflies, bees, flies, and gnats, and other insects manifest a strong preference for yellowish white and for yellow flowers. With such a fact as this in view, we may, perhaps, conclude that the habit of *Thomisus* and *Misumena* to frequent flowers of the character above described, resolves itself into the well known instinct of all animals to seek their food in those resorts where the supply is most abundant and accessible. This explanation does not, of course, exclude the fact that the spider, in seeking such favorable site, may be guided by its sense of color, but it reduces it to a subordinate rank.

VII.

Walckenaer[35] advanced the idea that the form of the cocoon corresponds with that of the abdomen of the mother. This is in some measure correct, for the abdomens of spiders have most frequently an oval shape, and this is substantially the shape of the cocoon. But when one comes to compare the shapes of the abdomens of individual spiders with the shapes of their cocoons, the exceptions are so numerous and decided that no such generalization can be accepted.

The same author suggested that some correspondence exists between the color of the cocoon and that of the mother's abdomen. The facts, however, at least as far as American spiders are concerned, will not sustain this theory, except in a general way. For example, the colors of the abdomen of *Argiope cophinaria* are yellow, black, white, and brown.

The colors of her cocoon are yellow, white, and brown. *Argiope argyraspis* has yellow, black, and silvery white upon her abdomen. Her cocoon is yellow and white. *Argiope argenteola* has an abdomen whose colors are metallic white or silver, yellow, and black. Her cocoon is green or yellow, or a combination of green and yellow on the outside with a white tuft within. The Insular spider has for its abdominal colors yellow, orange, and brown. Her cocoon is a uniform yellow. The Bifid spider has for its prevailing colors a light greenish hue intermingled with a livid yellow and a little brown. Her cocoon is a dull green color.

The prevailing colors of Orbweavers' cocoons may be said to be yellow and white. Sometimes the yellow shades into green, sometimes into brown. The dark or blackish cocoons, when examined carefully, are found to owe their shade to the compactness of the threads of which they are spun and the presence of gum. The above colors, namely, yellow and white, are the prevailing ones among Orbweavers themselves. The yellows sometimes shade into green, oftener

into brown, livid, and orange. The white frequently becomes metallic, having a silver sheen. There is, therefore, some basis for suggesting a correspondence between the color of a cocoon and that of the spider, or abdomen of the spider, which spins it. The harmony is more apparent, as far as my observation extends, among Orbweavers than other araneads; but there are not enough facts in hand to justify a generalization.

Turning from the Orbweavers to other tribal groups, we find that the exceptions are so many and striking that they appear at once to wholly disparage the theory. Most Citigrades and Tunnelweavers, and many Tube-weavers, are dark colored, but their cocoons are quite uniformly white. For example, the well known American tarantula, whose large cocoon is a white ovoid ball three inches long, has a dark reddish brown and black coat.

Tegenaria medicinalis is a quite dark, almost black spider, but she spins a white cocoon. The same is true of Tegenaria persica, whose clustered cocoons are white when originally spun, although the mother covers them with dirt, and thus soils the appearance. The Speckled Tubeweaver is a dull creature, yet she spins a beautiful white cocoon, although she also mars its whiteness by adding extraneous material. With many of the Drassids the same rule obtains. Without multiplying examples, this may be said fairly to represent the color relations of American araneads to their cocoonery.

An examination of the colors of European cocoons, as given by Walckenaer, Blackwall, or Simon, or by Staveley,[36] in her tabular arrangement of cocoons and eggs, will show that the same fact obtains among the spiders of Great Britain and Ireland. We learn from this table that a great majority of British cocoons are white; green or greenish, yellow, and yellow brown being the other colors represented. These colors are distributed quite indifferently of the maternal colors.

The color of the silk extruded from the spinnerets of spiders of all tribes in the construction of snares is, with few exceptions, white, sometimes having a steel blue tint, and often a lustre which gives it the appearance of spun glass. There are some exceptions to this rule, as, for example, the round web of *Nephila* is uniformly woven with yellow silk; and perhaps a wider study of the spinningwork of araneads will show that there are other exceptions, and perhaps many of them.

The differences of color in the spinning silk of araneads appear in the construction of the cocoon. Many cocoons are composed of white silk, perhaps it may be said the majority of them, but others again show some pretty varieties of color, and in some species several hues of silk will be used in weaving one cocoon.[37]

Among Orbweavers the colors used in cocooning are principally white; but one frequently finds yellow in various shades, green, and sometimes brown. A few Lineweavers make colored cocoons, and among Tubeweavers may be found a few species whose cocoons are various shades of red, sometimes quite bright. I often find these cocoons in the shape of little plates, with the convexity upward, attached to bark and stones, and showing a very dainty appearance, but have not been able to fully identify them with the species making them.

An examination of the spinning glands of spiders under the microscope will show, in some species at least, as *Argiope cophinaria*, several colors represented in the liquid contents. The causes controlling the secretion of these specially colored silks are, of course, physiological, but one cannot presume to guess even what they may be.

VIII.

The forms in which the coloring materials are arranged constitute the various patterns or marks that characterize spider species. These patterns are most varied and prominent upon the dorsum of the abdomen, although the venter and the sternum are also sometimes highly colored. While there is much variety in the arrangement of these patterns, there is, on the whole, a

general tendency to form a folium or leaf shaped outline, scalloped on the outer margin. This folium outline appears to have some orderly relation to the little pits or points of muscular attachment, and, in a general way, may be said, to be regulated by those sections of the abdomen which have commonly been held to indicate a segmentation. In other words, some writers are disposed to consider the abdomen as segmented, and, in a rough way, the symmetrical divisions in the pattern folium may be said to outline the articulations of the segments.

The cephalothorax is most frequently uniform in its color, commonly with longitudinal stripes of different shade. It follows, in a general way, the coloration of the legs, which it resembles in its chitinous character, the entire fore part of the body having the hardness which is characteristic of the enclosing walls of insects. The abdomen, on the contrary, is enclosed in a soft skin, a fact which exposes it to injury, and causes its rapid decay after death, one of the principal difficulties in the way of preserving specimens of spiders. On the cephalothorax there are often several longitudinal bands, one on each side, near and indeed quite surrounding the margin, and two drawn from the suture of the caput backward. There is also frequently a band of color in the median line from the middle of the eye space backward. The legs are usually colored like the cephalothorax, and are generally uniform in hue, except that at the joints there are rings of color usually darker than the rest of the leg. The feet are nearly always black or blackish.

In order to determine if possible the structural causes producing color in spiders; I made studies from a number of dissections of various species chosen with special regard to variety and brilliancy of colors. Among these are *Argyroepeira hortorum*, *Argiope argyraspis*, *Argiope cophinaria*, *Argiope argenteola*, *Epeira insularis*, *Gasteracantha cancer*, and *Phidippus morsitans*.[38] I do not speak of the results positively, for the studies are in a field where trained histologists alone are competent to decide. But I venture to give some indications of what appeared to me, in the hope that others may follow the path suggested, and reach positive determinations.

The metallic white upon the cephalothorax of *Argiope argyraspis* is produced chiefly by a vast number of white hairs. These are packed closely one upon another and reflect white light, the combined reflections forming the metallic appearance of the object. The metallic hues of the abdomen of Argyraspis are produced in part by closely thatched white hairs that reflect white light in the manner of those upon the cephalothorax. The black transverse bands on the abdomen are produced by amorphous granules of black pigment just beneath the skin, which thin out towards the margin of the band, becoming yellow as they diminish. There appears also to be a diffused yellow stain in the chitine, and, in addition, white pigment bodies which resemble the chromatophores that give the color in frogs and lizards; for example.

In *Argiope cophinaria* the metallic color of the cephalothorax is produced by hairs in the same way as with Argyraspis. These hairs are wavy; there appear to be two kinds, one flattened, with a wavy outline, having somewhat the appearance of cotton fibre, which may, however, be produced by irregular cavities or spaces within the hairs. Others again, present a similar appearance, but are cylindrical. On the abdomen of Cophinaria the colors are produced chiefly by pigment granules beneath the epiderm, the chitinous layers of which are arranged in beautiful undulating lines.

The pretty orange color upon the thigh of *Epeira insularis* is produced chiefly by vast numbers of pigment granules lying beneath the epiderm, the secreted layers of which are arranged in diamond shaped figures.

Argyroepeira hortorum, the most beautifully colored of our indigenous spiders, makes a fine object for mounting in order to show colors. The hairs have little or nothing to do in producing these varied hues, which are due to green and yellow pigment granules, and to what appear to be chromatophores. These chromatophores are white for the most part, though some of them are yellow tinted, and they yield a strong white reflection, which, it seems to me, is a chief agent in producing the brilliant silvery white of this aranead.

In the case of *Phidippus morsitans* the color of the abdomen is due to several causes. The black shades with dark green metallic reflection on the sides are produced chiefly by dark green

pigment granules underneath the skin, and in part by black hairs. The white spots on the sides of the dorsum are composed of peculiar white lanceolate hairs laid one upon another. They are marked by longitudinal striations on the surface, which give it, under the lens, the appearance of a minute ear of Indian corn. The little yellow lunettes of color on the dorsum near the apex appear to be composed of somewhat similar hairs, of nearly the same shape, but a little more elongated, yellow in color, and these, instead of longitudinal grooves, have slight feather like projections or papillæ irregularly distributed over the surface.[39]

The remarkable metallic green on the mandibles of this species is produced by a method quite different from any of those above named. The surface of the mandibles is broken up into a number of rugosities, arranged, though somewhat irregularly, in arcs of circles. These ridges appear to act as prisms, refracting the light; and to this evidently is due the brilliant metallic color which has attracted the attention of all observers of the species. Under a microscope the minute lunettes and waves of green light are readily distinguished; but the natural eye does not separate the several groups of refracted rays, and perceives them as an unbroken band of metallic green color.

These cursory examinations appear to suggest that the structural causes of color in spiders are probably the following: First, color stains diffused throughout the tissues; second, pigment granules of various hues distributed beneath the skin; third, pigment bodies or chromatophores; fourth, the reflection of light from the surfaces of thickly overlaid or thatched hairs; fifth, by hairs of various colors and peculiar forms, in some degree analogous to the scales of the Lepidoptera; sixth, certain colors, particularly the brilliant metallic colors, are produced by refraction of light from broken or ridged surfaces of the epiderm, that appear to act as prisms.

Little attention has been paid to the structural causes of color in spiders, and scarcely more to the form of the color hairs, and the manner in which they are grouped and overlaid in order to form the various color spots and pattern outlines produced exclusively or in part by them. The subject might well repay the careful study of the microscopist, and it may often be found that these color hairs will show many varying forms, corresponding with genera, or even species.

Mr. Emerton says[40] that the hairs or "scales" usually found on the Drassidæ and Agalenidæ are feathered.[41] Each scale, as far as he had noticed, is uniformly colored. Along the edges of the red spot in *Geotrecha crocata*, for example, red and black scales are mixed, but each scale is either all red or all black. The scales of *Micaria longipes*[42] are either white or brown. The iridescence of the abdomen, which is very marked in certain lights, he had seen on the individual scales. In general form these hairs resemble those which I have seen on *Phidippus morsitans*.

Micaria longipes.
Figs. 310 and 313. White scales from spots on abdomen.
Fig. 311. Scale from hinder half of abdomen.
Fig. 312. Scale from front of abdomen. (After Emerton.)