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OBSERVATIONS ON SEXUAL SELECTION

—IN—

SPIDERS OF THE FAMILY ATTIDÆ.

BY

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OBSERVATIONS ON SEXUAL SELECTION IN SPIDERS OF THE FAMILY ATTIDÆ.

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Introduction.

Mr. Wallace, in his well known essay on *Colors of Animals*, remarks that color *per se* may be considered normal and needs no special accounting for; that amid the constant variations of animals and plants color is ever tending to vary and to appear where it is absent; and that natural selection is constantly eliminating such tints as are injurious to the species while it preserves and intensifies such as are useful; and in opposition to Darwin he has argued that the sexual diversity of color, common in many animals, has its primary cause in the special need of protection for the female, which represses in her the bright colors that are normally produced in both sexes by general laws. Or, to put it in another way, he starts with the fact of the variability of color in animals of both sexes and says that in the female, where greater protection is needed, the color is toned down or eliminated, while in the male, the need for protection being less, the color may be preserved and intensified. Mr. Wallace has supplemented this theory by another factor; he now holds that the frequent superiority, to use his own words, of the male bird or insect in brightness or intensity of color, even where the general coloration is the same in both sexes, is primarily "due to the greater vigor and activity and the higher vitality of the male. * * * This intensity of coloration becomes most developed in the male during the breeding season when the vitality is at a maximum. * * * The greater intensity of colors in the male, which may be termed the normal sexual difference, would be further developed by the combats of the males for the possession of the

females. The most vigorous and energetic usually being able to rear most offspring, intensity of color, if dependent on or correlated with vigor, would tend to increase. But as differences of color depend upon minute chemical or structural differences in the organism, increasing vigor acting unequally on different portions of the integument, and often producing at the same time abnormal developments of hair, horns, scales, feathers, etc., would almost necessarily lead also to variable distribution of color and thus to the production of new tints and markings. These acquired colors would * * * be transmitted to both sexes, or to one only, according as they first appeared at an early age, or in adults of one sex; * * * but in all cases where an increasing development of color became disadvantageous to the female, it would be checked by natural selection; and thus produce the numerous instances of protective coloring in the female only, which occur in these two groups, birds and butterflies."[1]

We have here two theories offered to explain sexual differences in color: the first is, that natural selection modifies color in the female for purposes of protection; and the second, that color may be produced or intensified where there is a surplus of vital energy, as in male animals generally, and sometimes in the females, and more especially at the breeding season. We will here consider the second theory, since Mr Wallace regards this as the more important in making intelligible cases of more brilliant coloring in the male as compared with the female.

What is meant by an excess of vital energy is not quite clear. Does this term imply that the colored modifications of the integument represent the excess of nutriment over expenditure? This seems scarcely probable, and yet what other interpretation is to be put upon such a statement? Supposing this interpretation to be correct, if the color or development of plumage represents the surplus over ordinary expenditure, should not the least active animals, rather than the most vigor-

1 *Tropical Nature*, pp. 187 and 193–196.

ous, have the greater surplus and consequently the richer ornamentation?

Grant Allen, in his *Colour Sense*, remarks, concerning the ornamental appendages of animals: "Whatever we may think of their functions, we must agree that they are, on the whole, products of a high vitality. They represent part of the excess of nutriment over expenditure. But these dermal adjuncts do not probably take away anything from the effective energies of the organism."[1] He evidently understands Mr. Wallace to mean that these color adjuncts are by-products, or waste, from the other tissues. In this connection he quotes from Mr. Lowne to the effect that "the dermal appendages of reptiles and the feathers of birds, rich in pigment and nitrogen, are probably entirely excrementitious to the other tissues, and, without doubt, depend in great part for their origin on the solid nature of the excretion of the kidneys. Birds especially, leading a very active life, excrete material rich in nitrogen; and the feathers, which are shed periodically, enable them to throw off that element without overtaxing their renal organs."[2] "Hence," says Mr. Allen, "we can understand why the more active and energetic sex should possess a greater number of highly developed dermal adjuncts, and should often display much brighter colors than the females." This, however interesting it may be as a speculation, has, so far as we are aware, no direct evidence to support it; and knowing so little as we do at present of the functions of the kidneys in birds, and of

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1 P. 188.

2 The fact that closely related species annually undergo a double moult and others only a single one, and that even in the same species the sexes sometimes differ in their moulting habits, renders this proposition improbable. The habits being usually identical, why should one species depend upon moulting for the disposal of its surplus nitrogen, while in another the burden is borne by the excretory organs alone? Is there a single anatomical fact to countenance such a supposition? Darwin says that there is reason to believe that with certain bustards and rail-like birds, which properly undergo a single moult, some of the older males retain their nuptial plumage throughout the year. In the birds of paradise some have a single moult, some a double, and others, after the moult of the first year, do not cast their feathers again. For other facts bearing on this habit, see *Descent of Man*, Am. Ed., pp. 391–394.

the nature of the pigment in their feathers, it would be premature to discuss it in this connection.

Let us see how far the hypothesis that brilliant coloring is correlated with high vitality is supported by facts. Wallace makes the activity and pugnacity of an animal the criterion of its vitality; and where the male bird takes charge of the eggs and incubates them, he considers this change of habit, along with the pugnacity of the female, a proof that in such cases she possesses the higher vital energy, pugnacity being the important factor. "Of the mode of action of the *general principles of color-development among animals*,"[1] he says, "we have an excellent example in humming-birds. * * * The more vivid colors, and more developed plumage of the males, I am now inclined to think may be wholly due to their greater vital energy, and to those general laws which lead to such superior developments even in domestic breeds; but in some cases the need of protection by the female while incubating, to which I formerly imputed the whole phenomenon, may have suppressed a portion of the ornament which she would otherwise have attained." In view of the importance of this point the following evidence, offered in its support, seems rather meagre. "The extreme pugnacity of humming-birds has been noticed by all observers, and it seems to be to some extent proportioned to the degree of colour and ornamentation in the species. Thus Mr. Salvin observes of *Eugenes fulgens*, that it is 'a most pugnacious bird,' and that 'hardly any species shows itself more brilliantly on the wing.' Again, of *Campylopterus hemileucurus*,—'the pugnacity of this species is remarkable. It is very seldom that two males meet without an aërial battle,'—and 'the large and showy tail of this humming-bird makes it one of the most conspicuous on the wing.' Again, the elegant frill-necked *Lophornis ornatus* 'is very pugnacious, erecting its crest, throwing out its whiskers and attacking every humming-bird that may pass within its range of vision;' and of another species *L. magnificus*, it is said that 'it is so bold that the sight of man

[1] The italics are ours.

creates no alarm.' The beautifully coloured *Thaumastura Cora* 'rarely permits any other humming-bird to remain in its neighborhood, but wages a continual and terrible war upon them.' The magnificent bar-tail, *Cometes sparganurus*, one of the most imposing of all the humming-birds, is extremely fierce and pugnacious, 'the males chasing each other through the air with surprising perseverance and acrimony.' These are all the species I find noticed as being especially pugnacious, and every one of them is exceptionally colored or ornamented; while not one of the small, plain, and less ornamental species are so described, although many of them are common and well observed species."[1]

Here we have *six species* of humming-birds, given as all that are noticed as especially pugnacious, to establish the wide generalization that there is a causal relation between high vital activity, as shown by fierceness and pugnacity, and brilliancy of coloring, in the family *Trochilidæ*, containing 118 genera and 390 species, of which 340 are brightly colored.[2]

The large family of pigeons gives evidence that makes strongly against the theory. Many of them are conspicuously colored—indeed Mr. Wallace remarks, "in the Malay Archipelago and Pacific islands, they occur in such profusion and present such singular forms and brilliant colors that they are sure to attract attention. Here we find the extensive group of fruit-pigeons, which, in their general green colors, adorned with patches and bands of purple, white, blue, or orange, almost rival the parrot tribe; while the golden-green Nicobar pigeon, the great crowned pigeons of New Guinea as large as turkeys, and the golden-yellow fruit-dove of the Fijis, can hardly be surpassed for beauty."[3] If the high vitality of the humming-birds will

1 *Tropical Nature*, pp. 213, 214.

2 Baird, Brewer and Ridgway, *N. A. Birds*, say that about fifty species are plainly colored.

3 *Loc. cit.* p. 103. All the pigeons build open nests and the males take part in incubation. In the case of the humming-birds, which also build open nests, Wallace has abandoned, in part, the factor of protection to the female during incubation, since, in a number of the most beautiful species, the sexes are alike, and, as Darwin says, "in the majority the females, though less brilliant than the males, are brightly

explain the unusual development of color in both sexes, and will sometimes override the action of natural selection in keeping down the brightness of the female, this is evidently not the case where the pigeons are concerned, since they are not remarkable for activity nor pugnacity, and are notoriously liable to destruction by many enemies. The further fact that the male is more highly ornamented than the female, and yet assists in incubation, is still more out of harmony with the hypothesis. That the presence of ornaments or gaudy tints is not necessarily correlated with high vitality in birds is shown by the Barbets, which are "rather clumsy, fruit-eating birds," and are clothed in green, diversified by the most vivid patches of yellows, reds and blues.[1]

Again, in the birds of paradise there seems to be no relation between pugnacity and color. Mr. Wallace, in speaking of the splendid Great Bird of Paradise, which he studied in the Aru Islands, says that they congregate at "*sácaleli* or dancing parties," held in certain trees in the forest. "On one of these trees a dozen or twenty full-plumaged male birds assemble together, raise up their wings, stretch out their necks, and elevate their exquisite plumes, keeping them in a continual vibration. Between whiles they fly across from branch to branch in great excitement, so that the whole tree is filled with waving plumes in every variety of attitude and motion."[2] Although these birds were carefully observed not a word is said of their fighting nor of any display of pugnacity. In regard to the Red Bird of Paradise, he mentions having kept a number of the magnificent male birds in the same cage; this he could not have done had they quarreled to any extent.[3] He also mentions "the large cage" of two specimens of the Les-

colored." Does not the same reasoning hold good with the pigeons and a host of other birds where the nest is open and the female conspicuous? A fair consideration of the facts seems to us to confirm Darwin's supposition that the habit, common with bright colored birds, of using covered nests was acquired after, rather than before the development of the color.

1 *Tropical Nature*, p. 165.

2 *Malay Archipelago*, p. 446.

3 *Loc. cit.*, p. 536.

ser Bird of Paradise, which he took with him to England, as though he kept them together.[1] If the trait of pugnacity is so closely related to brilliant ornamentation in the hummingbirds, why should it not not be so in the birds of paradise? And why do we find brilliant color in many birds that have no more—indeed rather less—vigor than the soberly dressed birds of prey? Since, of all living naturalists, Mr. Wallace is undoubtedly the most competent to discuss this theory of the correlation of great vitality and bright color, it is surprising that he can find so little evidence in its favor.

Perhaps the most difficult fact to reconcile with the theory is the absence of ornamentation and bright color in the bats. They have wide expanse of integument, and great activity, the conditions specified by Mr. Wallace for the development of gaudy pigment, and nothing, apparently, in their habits to keep it down; but, except in the frugivorous bats, we find little difference between the sexes, nor is there any appreciable approach to bright colors. As Darwin remarks, it deserves attention as bearing on the question whether bright colors are serviceable to male animals from being ornamental, that only in frugivorous bats is the sense of sight well developed, and it is only in this group that we find any color.[2]

In the Araneides the great number of species and the wide differences between the several groups in habits and in amount of ornamentation, offer unusual facilities for testing Wallace's two theories of sexual color.

There is a common impression that among spiders there is little development of ornamentation, and that they are, as a rule, inconspicuous and dull. This is far from being true. Wallace, in his *Tropical Nature*, says: "The small jumping spiders are also noticeable from their immense numbers, variety and beauty. They frequent foliage and flowers, running about actively in pursuit of small insects; and many of them are so exquisitely colored as to resemble jewels

1 *Loc. cit.*, p. 537.
2 *Descent of Man*, p. 534.

rather than spiders."[1] In the Malay Archipelago, also, he was struck by the "abundance and variety of the little jumping spiders, which abound on flowers and foliage, and are often perfect gems of beauty."[2] Bates, too, in *The Naturalist on the Amazon*, says that "the number of spiders ornamented with showy colors was somewhat remarkable."[3] A large collection of spiders from the tropics is sure to contain as great a proportion of beautifully colored specimens as would be found among an equal number of birds from the same region. Let us, then, endeavor to apply to them the hypothesis, that the brighter color of the male is due to his greater activity and vital force.

Beginning with the most brilliant family, the *Attidæ*, we find that the females are, with few exceptions, larger, stronger and much more pugnacious than the males. Some four years ago we placed two females of *Phidippus morsitans* together in a glass jar. No sooner did they observe each other than both prepared for battle. Eyeing each other with a firm glance they slowly approached, and in a moment were locked in deadly combat. Within a few seconds the cephalothorax of one was pierced by the fang of the other, and with a convulsive tremor it relaxed its hold and fell dead. We placed together, in all, four females, and in each instance the fight was short but even to the death. Subsequently, we put in a well-developed male, which, though smaller, was compactly built and apparently strong enough to bring the virago to terms; but, to our surprise, he seemed alarmed and retreated, trying to avoid her; she, however, followed him up, and finally killed him. We have observed the same habits in *Phidippus rufus*. In *Dendryphantes elegans* the female is nearly a third larger than the male. During the past summer we kept a number of this species, males and females, together in a large mating-box, and were much struck by the greater quarrelsomeness of the females; they would frequently go out of their way to chase each other, and they were much more circumspect in approach-

1 P. 97.
2 *Malay Archipelago*, p. 437.
3 P. 54.

ing each other than were the males. In *Icius mitratus* neither sex was especially pugnacious, but the male was as little so as the female. In *Synagelcs picata* the females never came near each other without some display of hostility, though they did not actually fight.

In several species of *Xysticus*—as *ferox* and *gulosus*—the females are savage and ready to attack anything that comes in their way, while the males are smaller and more peaceable. De Geer tells of a male spider that, "in the midst of his preparatory caresses was seized by the object of his attentions, enveloped by her in a web, and then devoured, a sight which, as he adds, filled him with horror and indignation."[1] The Rev. O. P. Cambridge holds that the greater ferocity on the part of the female in the genus *Nephila* has led, through the action of natural selection, to the extreme reduction in the size of the males.[2] In each of two species of *Lycosa*, whose mating habits we were endeavoring to discover, two males were destroyed by a single female.

Not all female spiders are savage and quarrelsome. In some genera, as *Linyphia*, the two sexes live happily together in the same web; but Hentz, after twenty years' study of North American spiders, says that "there is less ferocity in the spiders of this division than in any other of the family. It is the only sub-genus in which the male and female may be seen harmoniously dwelling together."[3] Although subseqnent investigation has made it necessary to qualify this statement, the

1 Kirby and Spence, *Entomology*, Vol. I, p. 280, 1818.

2 *Proc. Zool. Soc.* 1871, p. 621. Simon has the following interesting remarks on sexual differences in size in Epeiridæ: "Dans les genres où l'inégalité est faible, le nombre des mâles paraît égal à celui des femelles, car à l'époque de l'amour ces *Epeiridæ* se rencontrent régulièrement par paires; mais, dans les genres où il y a grande disproportion, le nombre des mâles est beaucoup plus considérable, car il n'est pas rare de voir quatre on cinq individus de ce sexe courtiser une seule femelle. Ces petits mâles sont adultes les premiers, mais la durée de leur vie paraît très-courte, car après l'époque de la reproduction ils disparaissent complètement; ils ne construisent point de toile propre; mais ils se tiennent à proximité des endroits habités par la femelle, attendant le moment propice pour l'accouplement, qui a lieu au milieu de la toile de celle-ci est qui est toujours précédé de longues hésitations. *Les Arachnides de France*, I, p. 20.

3 *Spiders of the United States*, p. 132.

broad fact remains that, as a rule, the females are more powerful and more pugnacious than the males. Walckenaer, Menge, Hentz and others give numerous instances where the male meets his death through the fierceness of his mate; in fact, the danger is so imminent that after mating it is the habit in several genera (*Epeira* and *Tegnaria* are mentioned by Walckenaer) for the male to retire with precipitation from the web of the female, as a reasonable precaution. The relations between the sexes have been admirably characterized by Romanes in *Animal Intelligence*, where he says: "In many species the male spider in conducting his courtship has to incur an amount of personal danger at the hands (and jaws) of his terrific spouse which might well daunt the courage of a Leander. Ridiculously small and weak in build, the males of these species can only conduct the rites of marriage with their enormous and voracious brides by a process of active manœuvering, which, if unsuccessful, is certain to cost them their lives. * * * There is no other case in the animal kingdom where courtship is attended with any approach to the gravity of danger that is here observable."[1]

It might be supposed that in spiders the usual conditions are reversed and that, as in some birds, the females are more beautifully colored as well as more pugnacious than the males. This, however, is not the case. Even where the coloration of the two sexes is similar the tints of the male are usually brighter; and in many cases, especially among the *Attidæ*, the female is dull-colored, while the weak and unaggressive male is extremely brilliant.

There is a family of spiders, the *Gasteracanthidæ*, comprising a number of genera and several hundred species, widely distributed and very rich in individuals. In the whole order of spiders there is no group where the females are so universally remarkable for inactivity and sluggishness of movement. After the web is made she remains, nearly all the time, standing motionless in the center. The males, so far as they are

1 P. 204.

known, are smaller and much more active in their habits. Contrary to what we should expect on the theory, however, the males are, as compared with the females, inconspicuous and plainly colored; the females being almost always strikingly and often very brilliantly adorned with black, yellow, red, blue and white. If it be objected that the *Gasteracanthidæ* do not entirely meet the point in question, since their colors have been developed as a warning of their inedibility, there are scores of edible species among the web-building spiders which are brilliantly colored and, at the same time, are very inactive; as in the genera *Epeira*, *Meta*, *Tetragnatha*, *Theridium*, *Linyphia* and others.

Turning to the family *Lycosidæ*, with its numerous species, just the reverse appears, since it is among these vagabond or wolf-spiders that we find the most vigorous species, ever running about and full of restless activity. We know a good deal of their habits and of the courage of the females in defending their young; but, contrary to what we should expect, this family presents very little color development, dull grays, browns and blacks prevailing. The *Agelenidæ* are very active in their movements, throwing themselves upon their prey with great vigor, and depending upon their strength, and not upon web-lines, to hold it, even when it is large and powerful. These spiders are also dull colored.

The spiders, then, seem well adapted to disprove the proposition that there is a causal relation between vital activity and color development, since in the sedentary groups, while many of the species are plainly colored, there are nearly as many that present the most beautiful tints; and, on the other hand, some of the wandering and very active groups are, for the most part, clothed in sombre hues.

Turning to the other question, how far have the females had their color toned down, as compared with the males, for purposes of protection during the nesting period? If we examine the *Attidæ*, where there are marked differences in the coloration of the sexes, we find that all the females remain under

a thick, web-like covering, with their cocoons, until the eggs are hatched—that is to say, all the species of this family have covered nests. Many of these covered nests are occupied by dull-colored females, the males of the same species being showily attired. The same is true, to a great extent, among the *Thomisidæ*, where the females, often protectively colored, remain near the eggs in a covered nest. The protectively colored *Lycosidæ*, it is true, have practically open nests, as they usually carry the eggs about with them. In other families the habits vary, some leaving the eggs to their fate as soon as the cocoon is formed, while others give it much or little attention, as the case may be. A general survey of the facts shows no relation between color development in the females and their nidifying habits, and it is highly probable that in spiders, as in birds, the color was developed prior to the formation of these habits.

We must, then, seek further for an explanation of sexual coloring in spiders, since here we have present to account for it neither special vitality on the part of the male, nor need of protective coloring, while nidifying, in the female.

MOULTING HABITS.

There is no group of facts that brings out the remarkable similarity between birds and spiders in color development more prominently than that which is gained from a study of the moulting habits of the two classes. In spiders, as in birds, the young very often differ from the adults, and in many species where the sexes differ when adult, the male being the brighter, they are alike until they reach maturity, when the male, along with his sexual development, acquires his brilliant color. Cuvier formulated, under several rules, the various changes that the plumage of birds undergoes from the nestling to the adult. These rules were extended by Blyth; and Darwin, in *The Descent of Man*, not only amplified and added to them, but also submitted them to a thorough analysis and discussion in order to discover the causes of the phenomena. In

looking over systematic works we unfortunately obtain little or no information about the moulting habits of spiders. Most of the species have been described by workers living in the large cities of Europe, from collections coming to them from distant parts of the world, so that an observation of habits was impossible. Then, too, such collections contain only adult or nearly adult forms, since both systematists and collectors have thus far given their attention only to these. There are, therefore, accessible on this subject, little more than the impressions of several high authorities in arachnology as published by Darwin. For some years past we have been accumulating data as to the differences in form and color between the young and the adults, and also between the two sexes in the adult stage in the same species.

Before giving the facts that we have thus far obtained it may be well to remind our readers that spiders, shortly after hatching, cast the skin, and that this moulting of the integument, including the outer coat of the eyes, is repeated, the number of times varying in the different species and possibly in the two sexes. It is probable that the *Attidæ* moult from seven to eleven times before reaching maturity. In *Dendryphantes capitatus* we have counted ten moults and the spider was still immature. If one examines any of our spiders soon after they are hatched he will verify Dr. McCook's generalization that "the color of young spiders is almost without exception bright yellow or green, whitish or livid."[1] Soon after this stage, probably at the third or fourth moult, colors appear, distributed in patterns characteristic of the species, and as the spiders continue to advance in age and make their successive moults, still other and more marked changes may be noted.

Let us now pass to the consideration of the classes of cases under which the differences and resemblances, in color and form, between the young spiders and the adults of one or both sexes may be arranged. It is true among spiders as among birds, that the several classes pass into each other; and that

1 Proc. Acad. of Nat. Sci. of Phila., 1888, p. 172.

when the young resemble their parents, the resemblance, although very strong, is not so complete as to render them exactly alike.

CLASSES OF CASES.

I. When the adult male is more conspicuous than the adult female the young of both sexes in color and form closely resemble the adult female.

II. When the adult female is more conspicuous than the adult male the young of both sexes, in color and form, more closely resemble the adult male than they do the adult female, especially in the earlier moults.

III. When the adult male resembles the adult female the young of both sexes resemble the adults.[1]

In Darwin's discussion of the subject of sexual selection, he considered in great detail how far the moulting habits of birds tended to support his theory that the differences between the two sexes are attributable to female selection, rather than to natural selection acting upon the greater need for protection on the part of the female. In his profound discussion of the laws of heredity he formulates two general propositions. *First:* That variations appearing early in the life of an organism would tend to be transmitted to the offspring of both sexes. *Second:* That variations appearing late in life would be limited to the sex in which they first appeared, and would tend to appear at a corresponding age; the exception being that they might appear at an earlier age in the offspring than they did in the first instance. When the great complexity of the subject is considered, and the way in which natural selection must have sometimes modified sexual selection is taken into account, it is remarkable how fully the moulting habits of birds confirm his generalizations; and it is of the highest interest to inquire how far the moulting habits of spiders are also consistent with them.

Class I includes the cases where the adult male spider is

1 These classes are slightly modified from Darwin, *Descent of Man*, p. 466.

more conspicuous than the adult female, the young of both sexes resembling the adult female, both in color and form—or, at least, resembling her much more than they do the adult male. A good example of this class is *Phidippus johnsonii*, where the female has the abdomen red and black, with a white base and some white dots, while that of the male is bright vermillion 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. *Philæus militaris*, a very common *Attus*, 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 center of the head, the latter with a wide, white band around the base and sides; the female has a brown body covered over with white and gray hairs, which form a more or less distinct pattern of lines and spots. To give a better idea of this difference, let us suppose a male bird with the body, neck and head bright bronze brown, and the wings and a patch on the head pure white, with a female having mottled white and brown plumage.

Hentz described the female of his *Plexippus puerperus* as a different species under the specific name *sylvanus*, so little do the sexes resemble each other. *Dendryphantes capitatus* is another species in which there are great sexual differences. As in the last instance, the male and female were described by Hentz as different species. We may suppose that the sexual peculiarities of the male have been only recently acquired in *capitatus*, since he sometimes retains the markings and color of the female, these being proper to him in the immature stage. In *Icius palmarum* the sexes are very different. We shall, later on, describe the differences in the face and falces, so that here it is enough to say, that in the male the whole body is bronze brown, covered with short, golden down, while in the female the color is rufus, with black and white markings.

For *Habrocestum splendens* the colored figures of the moults and the adult forms (Plate I) bring out the fact that while the

young 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 males. 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 this gorgeous livery at the last moult, just as he becomes mature, though in some species the nuptial robe is acquired one moult before maturity.

The family *Attidæ*, from which these illustrations have been taken, is by common consent, placed at the head of the order, and contains among its 1,500 species the greatest amount of sexual difference and the highest development of ornamentation; indeed, as we have seen, Wallace speaks of them as resembling jewels rather than spiders, and Walckenaer says that their species are well marked by the rich diversity of their colors and the variety of the designs which ornament their abdomens.[1]

In the seventy-eight species described in our work on the *Attidæ* of North America we have both male and female in only forty; or, to be more accurate, we have felt warranted in placing males and females together in only forty instances. Doubtless in many cases we have separated the two sexes, making two species out of one, but the difference in color is so great that, without knowledge of their habits, no other course was possible.[2] Of the forty species, we know the moults of thirty-two, and of these, nineteen species form a group characterized by marked sexual differences, the males being very generally conspicuously colored as compared with the females, while in others only the falces are different. Since the nineteen species represent twelve important genera[3] it would seem that so far as the North American *Attidæ* are concerned, the generalization is

1 *Hist. Nat. des Insectes Aptères*, I, p. 481.

2 We have, in the genus *Phidippus*, sixteen species, four pairs, four single males and eight single females. *P. cardinalis*, male, is of a splendid, uniform, cardinal red; to which of the eight plainly attired females he belongs we do not know; and we have the same difficulty in other cases.

3 *Phidippus*, *Philœus*, *Plexippus*, *Dendryphantes*, *Icius*, *Habrocestum*, *Astia*, *Zygoballus*, *Synageles*, *Menemerus*, *Lyssomanes*, and *Epiblemum*.

well established. If we may add to these a large number of bright-colored, undescribed species from our own Guatemala collection, in which the young closely resemble the female, the generalization is materially strenghtened.

In order to estimate to what extent the sexes differ in the *Attidæ*, we tabulated the species, in a number of works, giving the number of species in which both sexes, and also the number in which one only are described. If it may be assumed that a collector ordinarily takes as many of one sex as of the other—and our numerous collections from different parts of the world confirm this supposition[1]—if the sexes were fairly alike they would be identified as one species and placed together; if, on the contrary, the sexual differences were great (the habits being unknown) many species would be founded on a single sex.

TABLE OF SPECIES DESCRIBED BY DIFFERENT AUTHORS, ACCORDING TO SEX. TOTAL 930.

AUTHOR.	LOCALITY.	♂ & ♀	♂	♀
Koch and Keyserling	Australia	48	47	57
Taczanowski	South America	60	27	26
C. Koch	World, except N. Am. and Europe	3	49	46
Cambridge	Various	16	27	16
Lucas	Algiers	8	13	36
Thorell	Burmah and Indian Archipelago	17	62	42
Simon	Various places, not France	8	47	22
Walckenaer	World, except N. Am. and Europe.	3	11	17
Peckham	North America	40	17	21
Simon	France	94	28	11
Vinson	Madagascar, Mauritius, etc.	..	..	8
		297	328	306

The table shows that in a total of 930 species from all parts of the world the single males just about balance the single

1 That this is not always true in other families is shown by Stoliczka, who says: "In collecting *Epeiridæ* I was particularly struck with the very great scarcity of male specimens; for, among about 200 specimens belonging to about thirty species, there were not more than five or six males." *Indian Arachnida*, Proc. Asiat. Soc., Vol. XXXVIII, p. 234. This was probably due to his having collected either before or after the mating season, when the males are always more rare.

females, and that the same is true, with a few exceptions, in the individual collections. Excepting when the spiders are well-known, as in the case of Simon's *Attidæ of France*, a comparison of the description of the two sexes, when they have been put together, would only serve to show a similarity between the males and females, since it would be only in the species where there was little or no sexual difference that they could be placed together. Where they are well-known, as in the *Attidæ of France*, we find by such a comparison 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 are given to make it clear that the sexes very commonly differ, the male being brighter than the female. It is probably 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.

Menge[1], 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 the statement that in the families *Thomisidæ* and *Salticidæ* the males are generally more beautifully colored than the females. We have, in North America, several *Thomisidæ* that are like Menge's species in the difference in color between the sexes, and also in that the young males are like the female, and only assume their bright color at the last moult. Darwin remarks on the fact that "the female of *Sparassus smaragdulus* is dullish green, whilst the adult male has the abdomen of a fine yellow, with three longitudinal stripes of rich red;" while young this male resembles the female. The obvious conclusion from these facts is that it is the male that has varied, and this, too, late in life, so that his peculiarities, having been limited to one sex, do not appear in the young. We are not embarrassed in this group by any need on the part of the female for plain colors to protect her during incubation, since, without exception, the cocoon

1 *Preussische Spinnen*, II, p. 396.

is so placed as to be concealed, or, as in the *Attidæ*, is covered with a thick layer of web, under which the mother spider remains until the young appear, seldom leaving the nest to obtain food. On the whole, the explanation of sexual differences of color in spiders which is most conformable with facts, is that the males have departed from the usual colors of the genus,[1] and that most probably this departure has been brought about by sexual or female selection.

Thus in the *Habrocestum* group the general coloring of the genus is represented by the females of *cristatum* and *auratum*, which are gray, with oblique whitish bands; in *viridipes* there is a tendency to greater concentration of color, and consequently to stronger contrast, the color being blackish with yellowish white bands. In *peregrinum* and *auratum* we find that the males have gone still further in the same direction, the ground color being deep black and the bands pure white. (Plate 1.) In *splendens* the male has made a still greater departure from the typical coloring of the genus, while the female, also departing therefrom, though not in so great a degree, shows the strongly contrasting black and white that is found on the males of *peregrinum* and *auratum*.

Class II. When the adult female is more conspicuous than the adult male, the young of both sexes, both in color and form, more closely resemble the male than they do the female, especially in the earlier moults.

This class, while it is found both in spiders and birds, differs widely in the two groups, both in the number of instances and in the causes that have produced them. While in birds the number of cases in which the females are brighter is

1 This is the opinion of Blackwall and of Canestrini. Thorell, in speaking of the genus *Erigone* (of the family *Theridiidæ*, a genus that contains an immense number of species, says: "The study of the spiders belonging to this interesting genus has hitherto been comparatively neglected, and this neglect is no doubt to be attributed partly to their diminutive size, and partly to the great similarity prevailing among the *females* of the different species. * * * Many a female is sometimes mated with one, and sometimes with another male; * * * the following lists of synonyms must, unless the contrary be directly stated, be considered as applying only to the *males*, which are comparatively easily distinguishable." *Remarks on Synonyms of Europ. Spiders*, p. 97.

inconsiderable, and while even in these cases the female is but little more conspicuous than the male, in spiders there are numerous species in which the female is decked in the most gaudy hues, her body being at the same time protected by strong, sharp spines, while the smaller male is unarmed and comparatively inconspicuous.[1] (Figs. 1 and 2.) The spiders to which we refer belong to the genera *Gasteracantha*, *Acrosoma*, *Phoronocidia* and others, including possibly 250 species distributed over all parts of the world. The differences between the males and females are shown in Plate III. Only a few males are described in this group, but they all agree in the peculiarities mentioned.

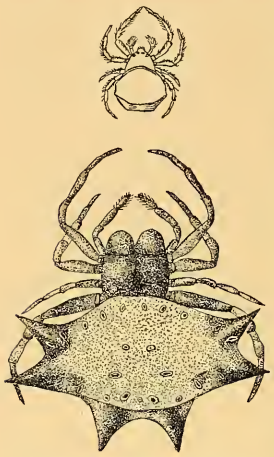

Fig. 1.—Gasteracantha rufospinosa. Upper figure, male enlarged seven times; lower fignrer female, enlarged four times (from Marx.)

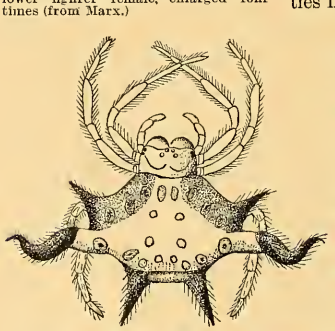

Fig. 2.—Gasteracantha crepidophora, female (from Cambridge.)

The perplexing fact in this connection is that while the females at first resemble the males, it is only while they are quite young, since when they are from a quarter to a third grown they begin to assume the adult form and color, and it seems as though characteristics developing so early should have been transmitted to

1 A seeming exception to this rule is G. Cowani, ♂, described in *Proc. Zool. Soc.*, 1882, p. 766. As this case was sufficient to invalidate our generalization we wrote to Mr. Butler, asking him to re-examine the spider in question to make sure that it

both sexes. After a good deal of consideration we are inclined to believe that in the early history of the group the male and female both possessed some such form and color as is now seen in the adult male, and in the first few moults of the female; and that afterwards the adult female, probably on account of some change in habits, varied toward her present size, form and color under the action of natural selection. "As variations occurring late in life," says Darwin, "and transmitted to one sex alone, have incessantly been taken advantage of and accumulated through sexual selection in relation to the reproduction of the species; therefore it appears, at first sight, an unaccountable fact that similar variations have not frequently been accumulated through natural selection, in relation to the ordinary habits of life. If this had occurred the two sexes would often have been differently modified, for the sake, for instance, of capturing prey or of escaping from danger. Differences of this kind between the two sexes do occasionally occur, especially in the lower classes. But this implies that the two sexes follow different habits in their struggles for existence, which is a rare circumstance with the higher animals."[1]

The other supposition open to us, namely, that the variation from the male form began in young females and were sexually limited from the first, is improbable, in view of the mass of evidence that variations before maturity are inherited by both sexes equally. The habits of the female, standing nearly all the time exposed in the web, give the clue to the occasion of her modification. The habits of the male being different, he is left unmodified; he is usually found in less exposed posi-

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was a male and not a female. Mr. Pocock, who is now in charge of the *Arachnida* in the British Museum, responded as follows:

BRITISH MUSEUM (Natural History), LONDON, March 23, 1889.

* * * * * * *

You are quite right in supposing that Mr. Butler fell into error in describing his specimens of this species as being males. They are in reality females. The distal segments, however, of the palpi are considerably wider than the preceding, and no doubt the mistake arose from a superficial examination of this appendage.

1 *Descent of Man*, p. 241.

tions, and only for a few days, at the mating time, is to be seen in the web.

Class III. When the adult male resembles the adult female the young of both sexes resemble the adults.

The greater number of species in this class have dull colors, which seem to be protective, as in the *Lycosidæ*, many of the *Drassidæ*, *Epeiridæ*, *Thomisidæ* and others. The same problems are presented here that are so ably discussed by Darwin in the case of birds belonging to this class. It seems likely that in the orb-weavers a large part of the courtship is conducted by vibrating the web lines, and that the males depend upon their skill in this direction, and not upon color alone, in attracting the female. The modifications of the first pair of legs, so common in the male spiders of the group, might be explained as useful in producing variations in these vibrations. We have some little evidence on this point, but defer consideration of it until treating of mating habits. In the *Attidæ*, when the male is not strikingly colored, it is more than probable that the choice of the female is determined by his antics and grace of movement. *Saitis pulex* is a good example. While in the greater number of instances in this class the colors are dull, we have many species which are brilliant. Thus, in the genus *Homalattus*, many of the species have metallic greens or lovely iridescent blues or violets, while others are soft brown, mottled with white. We have not enough data to throw any light on the very intricate problems here presented, and can only refer the reader to Darwin's work,[1] where the whole subject is admirably discussed. If, therein, he will substitute *spider* for *bird*, whenever the latter word appears, he will see how full of difficulty is the whole subject.

We have other cases that come under several classes, but as the instances are few, we will simply describe them individually. In *Hasarius hoyi* the adult male is more conspicuous than the adult female, which, indeed, was first described as a separate species under the name *pinus*. The young, very early,

1 *Loc. cit.*, p. 481.

differ from each other according to sex, the young males resembling the adult males, and the young females the adult females. In this case the law of inheritance at corresponding ages must be supposed to have failed, the young males inheriting their differential peculiarities at an earlier age than that at which the variation first appeared in their male ancestors.

Phidippus rufus, when mature, is a brick-red spider, the male being considerably brighter than his consort. When about one-seventh grown, and after the third or fourth moult, the young are very 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 meaning of the fifth moult—that with the uniform brown body and yellow legs—we are unable to explain. The appearance of the female after the fifth moult is similar to that of many other females in the genus, and her final change is probably due to a transference to her of the male color, which, judging from the moults, must have appeared late in life.

All the cases under the first and third classes are intelligible if we suppose that the females have selected the more conspicuous males, and that when variations occurred late in life they were limited to the sex in which they first appeared. There are, however, many cases in which it is probable that the color variation of the male has modified the female in a greater or less degree, and this accounts for the instances in which the female, as well as the male, is showily colored, especially since the showy color in these females usually tends to approach the coloring of the males, and to depart, in the same proportion, from the normal coloring of the genus. The second class, in which the females are more brilliant than the males, is the only one in which the moulting habits of spiders are not strikingly similar to those of birds; and it seems in the highest

degree probable that where there is so close a resemblance between two such complex sets of phenomena, in widely separate classes, they can only have been brought about by a common cause.

SECONDARY SEXUAL CHARACTERS.

It is a noticeable feature in the secondary sexual peculiarities of spiders, beside those of color, which have already been sufficiently dwelt upon, that they are very commonly found in the falces, clypeus, palpi and first pair of legs—that is to say, in those parts of the animal that are plainly in view when the male is paying court to the female; and it is a fact of great significance that even in the species where sexual differences are reduced to a minimum we usually find a modification of one or more of those parts which serve to render the male somewhat more conspicuous or showy than the female. *Synageles picata* is a case in point, the sexes being nearly alike, but the male having the first legs flattened and brilliantly iridescent. In several species of the genus *Lyssomanes* the sexes only differ in the length of the falces and that of the first pair of legs or palpi.[1]

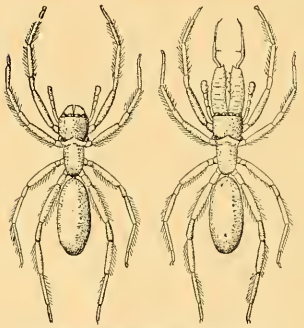

Fig. 3.—Salticus formicarius (from C. Koch.) Right-hand figure, male; left-hand figure, female.

The ant-like spiders are notable for differences in the falces of the two sexes. *Salticus formicarius*, (Fig. 3), a common European species, is a good illustration, the female having short, vertical, reddish black falces, while those of the male are horizontal, much enlarged, and copper green in color. In an ant-like spider from Australia, *Synemosyna lupata*, (Fig. 4, see p. 27), Dr. Koch describes a very curious development in the falces of the male; their great length, their teeth, and their branching

1 *Lyssomanes viridis*, *jemineus* and *amazonicus*.

fangs, reminding one of the great mandibles in certain male *Lucănidæ*. The female is undescribed, but we know, in this genus and in others closely related, so many males that have enlarged falces while those of the female are short, that this, too, is doubtless a sexual characteristic.[1]

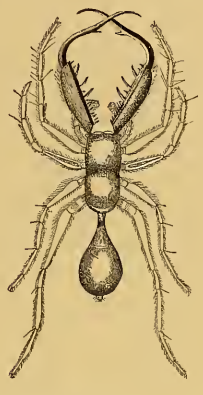

Fig. 4.—Synemosyna lupata. Male (from L. Koch).

Cambridge has described two spiders from Ceylon[2] which are remarkable for the great elongation of the male falces, these being in both species longer than the cephalothorax, while the fangs are toothed and equal in length to the falx. In both species, too, the falces seem to be attractively colored, as in one they are "dark black-brown and shining," and in the other "very slightly and transversely rugose, and shining in some lights with an opaline hue." It is true in many males that the falces are not only greatly enlarged but are also brilliantly colored; and in this connection it is of high importance to note that the brightly colored hairs or metallic scales, as well as the protuberances, are either on the anterior surface, or in some way so placed as to be plainly in view from in front.

In a common spider of the Southern and Eastern United States *Icius palmarum* Hentz we have a good illustration. In the male the falces are compressed and horizontal and are three times as long as the face, the fang equaling the falx in length. The front surface of the falces is dark bronzy rufus and on each outer edge is a wide band of snowy white hairs. In

1 We have examined 49 species of ant-like spiders, but in no instance have we found a female with long falces, while we know of 19 males in which they are much lengthened. One might have expected to find that an occasional female had inherited the modification from the male, but it seems to be, in this group, strictly limited to one sex.

2 *Ann. and Mag. of Nat. Hist.*, 1869, pp. 68-70.

the female the falces are vertical and only as long as the face, the fang being equally reduced, and the white hairs are absent. The male is rendered still more striking by the long, snowy white hairs which cover his clypeus, while the forehead and a space just below the first row of eyes is covered with bright red hairs. All this ornamentation is lacking in the female, and the contrast between the showy male and his modestly attired mate is very striking. In the little cosmopolitan zebra spider, *Epiblemum scenicum* we find the same difference in the size of the falces of the two sexes, the male having them four times as long as the face, while in the female they are only one-and-a-half times as long. Dr. Koch, in his magnificent work *Arachniden Australiens*, figures and describes an Attus *Opisthoncus abnormis* (Fig. 5), with curiously formed falces. Their general color is yellowish brown, but the front surface is coppery red, and toward the inner edges they are of a pretty, iridescent, bronzy green; but nature, less generous to the female, has given her only some white hairs over her small and unmodified yellowish brown falces. For purposes of offense or defense, however, the female fang is the more effective of the two, and our fine fellow doubtless hopes more from his beauty than his strength.

Fig. 5.—Opisthoncus abnormis (from L. Koch). Upper figure, face and falces of male; lower figure, face and falces of female.

In the sub-family *Tetragnathinæ* the falces are long in both sexes, but longer and much more ornamented with various processes and bunches of hair in the male than in the female.[1] (Figs. 6 and 7, see p. 29.) The two figures fairly represent this greater development in the one sex than in the other.

Canestrini remarks on the sexual differences in the falces, saying: "Sometimes they are long and strong, with fine teeth,

1 This point has also been noted by J. H. Emerton, *New England Epeiridæ*, p. 298. He says of the *Tetragnathinæ*: "The mandibles, especially in the males, are very long, and toothed on the inner edge."

in the male, while in the female they are short, weak and without teeth."[1] He also speaks of the entirely different colors of the male and female falces of the same species. Not infrequently there are two forms among the males of a species, one with long and modified falces, and another having them short, and more like those of the female. In *Pensacola signata*, an Attus from Guatemala, we have two such forms. To quote from a former paper of our own: "In the first, which is a little the larger, the falces are more than twice as long as the face, slightly retreating, narrow at the base and extremity, but dilated in the middle when looked at from in front. Near the anterior inner edge, in the middle, is a strong apophysis or spine in each falx, which reaches nearly to the end of the fang; fang long and slightly bent. In the second form the falces are relatively shorter, and are but very little dilated in the middle, so that the curve on the inner edge is not marked, and the spine is less than half as long as in the first form. We find others intermediate between these two extremes.[3] Canestrini also refers to the existence of two male forms, and explains them by the supposition that we here see these secondary sexual characteristics, as it were, in process of development.[4]

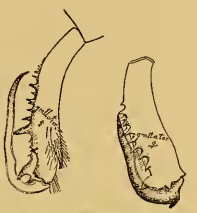

Fig. 6.—Tetragnatha gralator (from Emerton). Left-hand figure, falx of male; right-hand figure, falx of female.

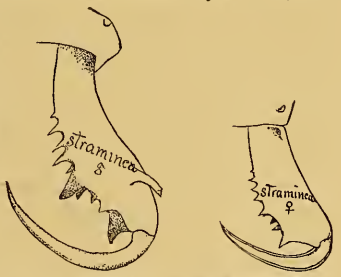

Fig. 7.—Tetragnatha straminea (from Emerton). Left-hand figure, falx of male; right-hand figure, falx of female.

Another curious modification is found in *Icius cornutus*,

1 *Caratteri sessuali secondarii degli Arachnidi*, Atti della Soc. Vento—Trentina di Sc. Nat. Padova, I, Fasc. 3, 1873.

2 *Loc. cit.*

3 *On Some New Genera and Species of Attidæ*, G. W. and E. G. Peckham, Proc. Nat. Hist. Soc. of Wisconsin, 1887, p. 84.

4 This occurs in *Philœus militaris*, *Icius palmarum*, and *Zygoballus bettini*. Canestrini mentions the genera *Linyphia*, *Theridium* and *Dysdera*,

from Madagascar, where there is long projection from the anterior face of each falx, the two processes extending forward and looking a little like a pair of horns; they are more than half as long as the cephalothorax.[1]

The height of the clypeus[2] was formerly used in the classification of *Attidæ*, but it has more recently been found to be so entirely a sexual peculiarity, as to be of little or no taxonomic value. It is frequently adorned by colored hairs, which fall over the falces, or is diversified by curious patterns formed by bars and patches of down. The very striking appearance that a spider presents with this feature well developed is shown in *Titanattus sævus*, a male from Guatemala. In a common North American spider, *Dendryphantes capitatus*, (Fig. 8), the clypeus of the male is conspicuously marked by several white bands; one passes up between the anterior middle eyes from the base of the falces; and two on each side pass back over the cephalothorax. The contrast between these snowy white bands and the dark color of the rest of the face is exceedingly striking. The female has the whole clypeus whitish and is not at all conspicuous. In two species of *Habrocestum*, *coronatum* and *cæcatum*, the clypeus is covered with bright red hairs. In describing *H. coronatum*, Hentz says that "the bright scarlet spot on its front gives to this spider a whimsical air of fierceness, which is heightened by its attitudes and singular motions."[3] In *Thorellia ensifer*, the male has two bunches of stout dark hairs projecting forward from just above the insertion of the falces, which are not present in the female.[4] *Hyllus pterygodes*[5] has the clypeus, or rather what might be called the cheeks, drawn

Fig. 8.—Dendryphantes capitatus. Male, face, falces and palpi (from nature).

1 *On Some New Genera and Species of Attidæ from Madagascar*, G. W and E. G. Peckham, Proc. Nat. Hist. Soc. of Wisconsin, p. 31.

2 The *clypeus* is all of the face above the insertion of the falces and below the first row of eyes.

3 *North American Spiders*, p. 65.

4 Koch and Keyserling, *Arachniden Australiens*, p. 1353.

5 *Id ibid.*, p. 1339.

out and gradually coming to a point on each side, so that the face looks, from in front, very much swollen and enlarged. This surface, in both sexes, is covered with bright scales which are somewhat rosy in tint, and the points at the sides are furnished with some stout dark hairs.

In examining the upper part of the face, just above or below the first row of eyes, a number of interesting features may be observed. In one section of the sub-family *Lyssomanæ* most of the species have, for the general color of the body, a tender grass green. In this group the clypeus and the region around the first row of eyes is nearly always adorned with a covering of red hairs, which are sometimes dull, sometimes very bright; this ornamentation is not usually confined to one sex, but in *L. amazonicus* the red is perceptibly brighter in the male, while though in *Asamonea puella* the eye-region of the female shows no red hairs, the male has the forehead covered in the middle by thick, silvery white, and on the sides by reddish hairs, his clypeus, also being unusually high.

The other section of this sub-family often presents dark colors, and here the clypeus and eye-region are more frequently marked with white pubescence or metallic scales than with red hairs; thus in *A. tenuipes* the dark clypeus of the male is covered with highly iridescent scales, and that of the female is light yellow, covered with thick, snowy white hairs.

The bright markings in some of these species have evidently been transmitted to the females through the males. Looking at the group as a whole, it is important to note how frequently the adornment is so placed upon the body as to be brought into view when the spiders face each other.

Fig. 9.—Amycus micans. Male, face and falces (from L. Koch).

In *Amycus micans*, (Fig. 9), of which only the male is known, the face is very high, and all its parts are covered with glittering violet, green and golden scales; above the first row of eyes is a transverse band of scale-like hairs, some few longer hairs growing out between; this band is shining, colored

like the rest of the face.[1] *Amycus tristriatus* has a high face, the hairs around the eyes being white in the lower half and yellowish red above.[2]

In the nine species of the genus *Amycus* described by the two Kochs, we have only males; in the South American spiders of this genus described by Simon and Taczanowski,[3] we have both sexes in four species, and in three of these the clypeus of the female is low; in the fourth it is said to be "rather high." The great height of the clypeus in *Amycus* is, in fact, a sexual peculiarity, although in some instances it may have been transmitted to the female.

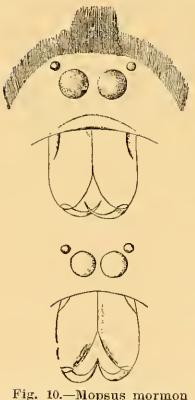

Fig. 10.—Mopsus mormon (from L. Koch). Upper figure face and falces of male, showing ridge of hairs; lower figure, face and falces of female.

By far the most remarkable instance of facial adornment is to be found in *Mopsus mormon*[4] (Fig. 10.) The face of the male is dark brown, covered with steel-blue scales; around the eyes are both brown and yellowish red hairs; the front of the long falces is also dark brown, covered with bright metallic scales; and to add to his beauty there is a high vertical ridge of variously tinted hairs extending over his forehead. The part above the middle eyes is brown, but on either side it changes to pure white, gradually becoming yellowish as it passes back on to the sides. In the female, while the general coloration is the same, the most striking ornament—the band of hairs—is entirely absent. In this species we are reminded of the wonderful crests found in hummingbirds and fruit pigeons. In *Dendryphantes elegans* the male alone has two oblique converging ridges of short hairs extending from the eyes of the second row to the anterior middle eyes; and in

1 Koch and Keyserling, *loc cit.*, p. 1173.

2 *Id ibid.*, p. 1181.

3 A. rufifrons, Simon; A. fusco manus, A. mystacalus, A. scops, Taczanowski.

4 *Arachniden Australiens*, p. 1319, described as *Ascyltus pencillatus*.

the black male form of *Astia vittata* there are three long tufts of black hairs on the eye-region, which are absent not only in the female but also in the other male form.

Leaving the *Attidæ*, there are several genera described by Menge, Cambridge, Simon, Thorell, Emerton and others that illustrate curious sexual modifications of the upper part of the face. For example, in the genus *Argyrodes*, (Fig. 11), of Simon, while the head of the female is often high and somewhat notched in front, in that of the male each of these divisions of the front part of the head gives rise to a horn, covered at the extremities with hairs. The drawing shows the parts in the two sexes. Emerton in *New England Theridiidæ*, when speaking of the genus *Ceratinella* says: "The heads of the males are usually higher than those of the females, and in some species are very large and raised into humps;" and of the genus *Corniculuria* he says that "the males have a hump or horn on the front of the head between the eyes, usually ornamented by flat, stiff hairs. In several species there are two horns, the lower one being small and partly concealed by the upper." There are many other genera in this family, with large numbers of species distributed over different parts of the world. Most of these species are small, but close inspection shows a great deal of sexual difference in the head parts and often also in the falces.

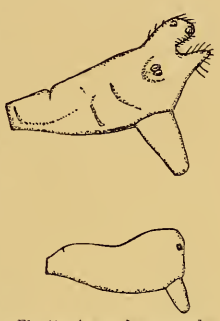

Fig. 11.—Argyrodes argyrodes (from Simon). Upper figure, cephalothorax of male; lower figure, cephalotharax of female.

In male spiders the palpi are modified and serve as organs for the conveyance of the sperm cells to the epigynum of the female. Beside this direct use in the reproductive act they often play an important part as ornamental appendages. The female palpi, are, speaking generally, cylindrical, five-jointed outgrowths of the maxillæ, covered with hairs and varying somewhat in length and color; but throughout the order there

is but little difference among the various species. Passing over the many and great differences of structure in the last or tarsal joint of the male palpus, which are primary sexual characters, we find, in this organ, many curious modifications of form and of ornamentation the only use of which is to please the female.[1]

In some species they are greatly elongated (*Lagnus longimanus*); in others there are curious enlargements and apophyses on one or more of the joints (*Plexippus puerperus*); but the most frequent and by far the most striking form of decoration is a covering of long white or yellowish hairs which gives them a plume-like appearance (*Pensacola signata*).

In many spiders the sexes differ not only in the beautiful plumose palpi of the male, but also in the locomotive organs. The legs of the first pair are lengthened, in many males, and the several joints are enlarged and brilliantly colored, or furnished with long hairs or iridescent scale-like setæ. In no family of spiders does sexual selection seem to have been more effective than in the *Attidæ*. Many of the species, as we have seen, are furnished with remarkable falces, elaborate head ornaments and plume-like palpi, and we have now to give an account of a further modification which has apparently been gained for the sake of ornament, or possibly through the sham battles between the males.

In an ant-like species, *Synageles picata*, the female has legs of the ordinary form; but in the male the tibia of the first leg is enlarged and flattened, and the anterior face of the enlargement is of a brilliant, steel-blue metallic color, as glossy as the breast of certain pigeons. In *Philæus metallescens*, from Australia, the legs of the first pair in the male are 11 mm. long, while those of the female are only 9 mm.; those of the male are of a very brilliant steel-blue color, and are ornamented with rings, spots and fringes of short, scale-like hairs, and of

1 Koch and Keyserling in *Arachniden Australiens* describe in the family *Attidæ* thirty-four males having well developed fringes or tufts of hair on the palpi, while there are only five females so ornamented, and several of these to only a moderate extent.

long, white hairs; those of the female are but slightly iridescent, and lack all further ornament. In *Dendryphantes elegans* the first leg in the male has on the lower half of the tibia a wide fringe of hair, which is very conspicuous as he waves his legs while courting; while the legs of the female are plain. These leg modifications have been frequently transmitted to the female, so that not uncommonly we find both sexes presenting striking forms, which are, however, proportionately less remarkable in the females than in the males. For example, in *Diolenius phrynoides*, where the first legs are wonderfully lengthened and modified, those of the female measure 12¼ mm., and those of the male 20½ mm., being nearly twice as long. The curious change in the legs of this species so impressed Walckenaer as to make him suggest that the spider must walk on the water, since in no other way could such legs be useful. As it is a land species his explanation must be abandoned, and we are constrained to look upon these legs as secondary sexual organs, useless for locomotion, but of high importance while mating. To gain a clearer idea of this lengthening of the first legs one has only to imagine that in some group of human beings the arms of the men were doubled in length, while in the women they remained as before. There are numerous species in this genus, all characterized by their long legs (Fig. 12). It is not unusual for female as well as male beetles to possess well developed horns and knobs, so that there is nothing anomalous in the elongated legs of both sexes of the *Diolenii*. In *Chirothecia*, a South American genus of *Attidæ*, we meet with other instances of modified legs, but here there is a marked

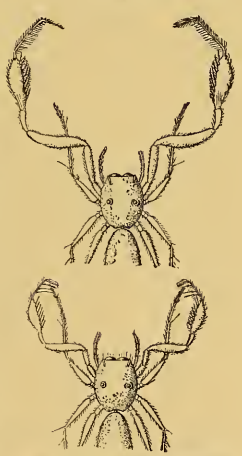

Fig. 12. — Diolenius venustus (from nature). Upper figure, male; lower figure, female.

difference between the sexes, the males having the legs longer, more robust, and more ornamented than the females. This is also true in the North American species *Icius palmarum*. *Saitis barbipes* has the third leg of the male fringed with hairs on either side, which gives it quite a plume-like appearance, while that of the female is entirely plain. In an undescribed species of *Habrocestum* from Arizona the first leg of the female is plain, while that of the male has on the tibia a fringe of long, silky, yellow hairs, mingled with which are other hairs, which are enlarged and flattened at the end. These spatulate hairs also appear on the first legs of *Habrocestum hirsutum*; in this species we have only the male.

Walckenaer remarks that his earlier division of *Attidæ* into *Sauteuses*, or short-legged, and *Voltigeuses*, or long-legged, is vicious, since in many species of *Sauteuses* the males have very long legs, and are, therefore, if we have not seen the female, placed in the *Voltigeuses*, while the females must be put into the *Sauteuses*.[1] We may go further than this, and say that all these modifications of the legs are sexual and of little or no importance in taxonomy.

The instances which we have given of secondary sexual differences might have been indefinitely multiplied, but we have only thought it necessary to give examples of each kind or class of modification; these will serve, we trust, to establish the fact that these differences are not less numerous among spiders than among birds and insects.

MATING HABITS.

For a number of years prior to 1888, we had been much impressed by the many important differences between the sexes of our jumping-spiders, and since we thought it most probable that they had come about through sexual selection, we had often tried to watch them during their courtship, but up to that time with very little success. We had occasional glimpses of their habits, but they were so incomplete as to con-

1 *Loc. cit.*, p. 482.

tribute but little to a thorough knowledge of the subject. Last year, we determined that, if possible, we would work out this subject so far as concerned the species in our locality. For this purpose we had made a number of mating-boxes. The larger ones were 15 inches long by $11\frac{1}{2}$ wide and 3 deep; the smaller, $7\frac{1}{4}$ long by $5\frac{3}{4}$ wide and $2\frac{1}{2}$ deep. The sides of each box were marked off into inches so that the distance of the spiders from each other could be easily noted. The floor was made of coarse cotton cloth, for the purpose of ventilation, while the top was of glass, so that the inmates of the cage could be kept fully in view at all times; this top could be opened and closed. As a usual thing we move into the country toward the last of June, but this year we went out on the 22d of May, in order to be in time for those species that mature early.

The courtship of spiders is a very tedious affair, going on hour after hour. We shall condense our descriptions as much as possible, but it must be noted that we often worked four or five hours a day for a week in getting a fair idea of the habits of a single species.

SAITIS PULEX.

On reaching the country we found that the males of *Saitis pulex* were mature and were waiting for the females, as is the way with both spiders and insects. In this species there is but little difference between the sexes. On May 24th, we found a mature female and placed her in one of the larger boxes, and the next day we put a male in with her. He saw her as she stood perfectly still, twelve inches away; the glance seemed to excite him and he at once moved toward her; when some four inches from her he stood still and then began the most remarkable performances that an armorous male could offer to an admiring female. She eyed him eagerly, changing her position from time to time so that he might be always in view. He, raising his whole body on one side by straightening out the legs, and lowering it on the other by folding the first two pairs of legs up and under, leaned so far over as to be in danger of losing his balance, which he only maintained by sidling

rapidly toward the lowered side. The palpus, too, on this side was turned back to correspond to the direction of the legs nearest it. (Fig. 13.) He moved in a semi-circle for about two inches and then instantly reversed the position of the legs and circled in the opposite direction, gradually approaching nearer and nearer to the female. Now she dashes toward him, while he, raising his first pair of legs, extends them upward and forward as if to hold her off, but withal slowly retreats. Again and again he circles from side to side, she gazing toward him in a softer mood, evidently admiring the grace of his antics. This is repeated until we have counted 111 circles made by the ardent little male. Now he approaches nearer and nearer and when almost within reach whirls madly around and around her, she joining and whirling with him in a giddy maze. Again he falls back and resumes his semi-circular motions, with his body tilted over; she, all excitement, lowers her head and raises her body so that it is almost vertical; both draw nearer; she moves slowly under him, he crawling over her head, and the mating is accomplished.

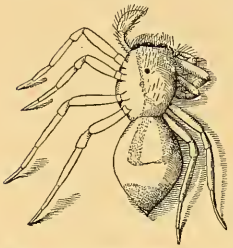

Fig. 13.—Saitis pulex. Male dancing before female (from nature, by Mr. Ludwig Kumlien).

After they have paired once, the preliminary courtship is not so long. When this same pair mated a second time, there were no whirling movements, nor did the female lift her body, as at first. We watched this species a great deal during the three weeks that the mating lasted. Once we saw a female approach a very glum-looking male, waving her palpi and making herself agreeable, but in vain. He was pushed a little from without, so as to make him look toward her, when she turned about, holding her abdomen high and her head low. Finally he grew excited enough to dance a little, and then they whirled round and round together in the usual manner; but she appeared the more eager of the two. This was true, however,

of only this one female. All the others were more retiring, and were never more than half willing to be wooed.

The males, while very excitable in the presence of the female, do not seem to be especially quarrelsome. When excited, they pursue and leap upon each other, but do not exactly fight. During the display of the male before the female, she is no inattentive observer, but watches him intently, turning frequently to keep him in view as he dances from side to side, and, finally, if she approves of him, yields to his desires. Often, however, the male fails to make an impression upon her, even after dancing before her for a long time, since upon his too near approach, she runs away.

EPIBLEMUM SCENICUM.

On the afternoon of the 10th of June we found two males of this species fighting on a brick wall. They held up the first pair of legs and moved rapidly in front of each other, now advancing and now retreating, in a half circle, distant from each other about four and a half inches. There was little real earnestness in the affair, and it reminded one of the bluster of two boys, each threatening the other and daring the other to strike, but neither willing to be the aggressor. In a few minutes they both wandered away. During the next two days we found eighteen males and four females on this wall, which was about 20x12 feet in size. The performances of the male are not so complicated and interesting in this as in the preceding species, nor do the males seem to be so persistent.

We placed twelve spiders, of both sexes, in one of the boxes. Soon they were all moving about, the males making advances to the females, who seemed to endeavor to escape. After about two hours, we found that three pairs had come to an agreement and mated, the male, in each case, getting his female into a corner of the box and spinning a cover over and around her. Sometimes, while the male was working, the female would wander off several inches, but when the house was nearly completed, he would follow her, and half lead and half drive her home, when he would get her into the nest first,

and then follow himself. Here the mating would be accomplished, after some slight preliminaries. The females seemed to have some difficulty in choosing from among the males, but, after a decision had been reached and a male accepted, there appeared to be complete agreement, and the male, thereafter, commenced to build his house. On the next morning we found all the pairs together in different tents.

The male, when prancing before the female, stood quite high on the three posterior pairs of legs; the first pair, the palpi, and the long falces, were stretched out stiffly in an oblique direction, the spider moving rapidly from side to side.

ICIUS SP.

This species, still undescribed, we discovered last summer, in large numbers, on rail fences at the edge of woods. We had worked over the place time and again, for many years past, but had overlooked them, not only on account of their admirable protective coloring, but from the fact that they only congregate, in this way, until they have mated, and afterward wander back into the woods and are then rarely met with. This is a habit with several *Attidæ*[1] and reminds one of the "*sicaleli*" or dancing-parties of certain birds, or of our own partridge dances. We were fortunate in discovering them just at the mating season. A dozen or more males and about half as many females were assembled together within the length of one of the rails. The males were rushing hither and thither, dancing opposite now one female and now another; often two males met each other, when a short passage of arms followed. They waved their first legs, sidled back and forth, and then rushed together and clinched, but quickly separated, neither being hurt, only to run off in search of other and fairer foes. We watched them for hours, and then, our patience being exhausted, filled all our bottles and carried them home. We placed them in the smaller boxes, since we have learned that propinquity is quite as effective in hastening the courtship of

1 In the genus *Dendryphantes*, *capitatus and elegans* are examples. Going to their favorite bushes we have caught 40–50 males in a few hours' sweeping, but after the season the same locality would not yield more than 2–3.

these little creatures as it is said to be among the higher races. For several days, in visiting this fence, we found goodly numbers on each rail, but after a little they grew scarcer and scarcer and at last we were unable to find one where a short time before they had been so common.

It was much more comfortable to study them after they had been put into the mating boxes and within the next few days we had seen many of them pair. The males were very quarrelsome and had frequent fights, but we never found that they were injured. Indeed, after having watched hundreds of seemingly terrible battles between the males of this and other species, the conclusion has been forced upon us that they are all sham affairs [1] gotten up for the purpose of displaying before the females, who commonly stand by, interested spectators. This is entirely contrary to what we had expected, and early in the season we, on several occasions, forcibly parted the combatants, fearing that they would kill each other. The falces in many of the males are, it is true, much lengthened, but as weapons of offense the shorter fangs of the female are much more deadly. In twelve species, in which we witnessed numberless fights, we could never discover that one of the valiant males was wounded in the slightest degree.

In this new species the position of the female while watching the male is unlike that of any of the others. She lies close to the ground with her first legs directed upward and forward, while her second legs are held on the ground and stretched forward in front of her face (Fig. 14). The male, when approaching her, does not throw his legs high over his head, as he does before another male, but raises his body on his six hind legs;

Fig. 14.—Undescribed species. Position of female when approached by male (from nature by L. K.)

1 Cuvier remarks that "the males sometimes engage in contests in which their manœuvres are very singular, but which do not terminate fatally." *Animal Kingdom*, trans. by Carpenter and Westwood, London, 1863. p. 464.

Hentz (*N. A. Spiders*, p. 133) saw two males of *Linyphia communis* fighting an

the first legs are held down toward the ground, diverging slightly near the head, and are bent inward at the middle so that the tips turn toward each other and meet. (Fig. 15.) At times he turns the apex of his abdomen down; at other times he keeps it straight, as he moves from side to side; the palpi are folded under. He sometimes varies his attitude by lying flat on his venter, keeping the tips of the legs touching as before.

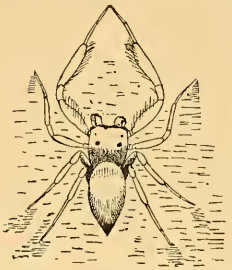

Fig. 15.—Undescribed species. Position of male approaching female (from nature by L. K.).

HASARIUS HOYI.

The sexes are very different, so much so that we at first described them as two species, the male being the more conspicuous of the two. The males are ready in the early days of June, and the females a little later. In his dance the male has several movements; most commonly he goes rapidly from side to side with his first legs obliquely up; (Fig. 16); at other times he twists the abdomen to one side and bending low on the other, something as *pulex* did, goes first in one direction for about two inches, and then, reversing, circles to the opposite point. The females are very savage, especially with each other; and even the members of the sterner sex are not always free from danger when paying their preparatory addresses. Once we saw a female eagerly watching a prancing male and as he slowly approached her she raised her legs as if to strike him, but he, nothing daunted by her unkindly

Fig. 16.—Hasarius hoyi. Position of male approaching female (from nature by L. K.).

obstinate battle; he did not watch it to the close, but believes that it was "without bloodshed."

Vinson, on the contrary, mentions a fatal combat between two males of *Epeira niger* that he had shut up in a bottle with a female. *Araneides de La Reunion, Maurices et Madagascar*, p. 190. We have a cousin of this species, *Argiope cophinaria*, and though we have seen the two or three little males that were courting a female manœuvre together the results were never serious.

reception of his attentions, advanced even nearer, when she seized him and seemed to hold him by the head for a minute—he struggling. At last he freed himself and ran away. This same male, after a time courted her successfully.

SYNAGELES PICATA.

These are small ant-like spiders. The most important sexual difference, is the greater thickness of the first legs of the male. These are flattened on the anterior surface and are of a brightly iridescent steel-blue color. Unlike most of the *Attid* males this species keeps all his feet on the ground during his courtship: raising himself on the tips of the posterior six he slightly inclines his head downward by bending his front legs, their convex surface being always turned forward. His abdomen is lifted vertically so that it is at a right angle to the plane of the cephalothorax. In this position he sways from side to side. After a moment he drops the abdomen, runs a few steps nearer the female, and then tips his body and begins to sway again. Now he runs in one direction, now in another, pausing every few moments to rock from side to side and to bend his brilliant legs so that she may look full at them. We were much impressed by the fact that the attitudes taken by the males served perfectly to show off their fine points to the female. We had never known the male of this species until the day that we caught this one and put him into the mating-box, and it was while studying his courtship that we noticed how he differed from the female in his iridescent first legs. He could not have chosen a better position than the one he took to make a display. We had six females in the box, and saw him mate with all of them; and each, after a time, made a cocoon containing three large eggs.

MARPTUSA FAMILIARIS.

This is a rather plainly marked *Attus*, well protected by its coloring of gray and black, on the bark of trees and on fences, where it is most frequently found. There is little difference between the sexes. We placed the two together. She saw him

as he entered at the opposite side of the box, some thirteen inches away. Eyeing him attentively, she slowly changed her position to keep him in sight, and kept her palpi moving rapidly, a characteristic action with the species. As he neared her, he stretched the first and second pairs of legs sideways, but, after a moment, backed away. (Fig. 17.) These manœuvres were repeated many times. Occasionally he would bend the tip of the abdomen down, lifting the body up on the last joints of the two hindermost legs. The female always paid the greatest attention to his movements, lying on the ground, with all the legs flattened out and the palpi slightly raised, the only movement visible being the vibration of the palpi. There is a certain slowness and dignity about the wooing of this species that is almost ludicrous.

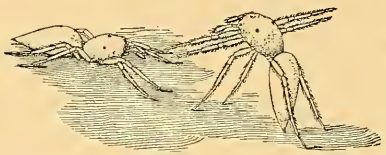

Fig. 17.—Marptusa familiaris. Positions in courtship; left-hand figure female, right-hand figure male (from nature by L. K.).

PHIDIPPUS RUFUS.

The sexes are alike in general coloring, but the male has much the brighter tint. In the early days of July we found them mature and brought them together. The female standing still, the male, while some five inches away, stood high on the six back legs, turned the first pair forward and upward and crossed them at the tips; the palpi were held widely apart, parallel with the second legs. The effect of this position was to bring directly before her, as she stood watching him, the beautiful white hairs on the lower part of the palpi.[1] At the same time the abdomen dropped so that it touched the ground. In this way he advanced, with a swaying motion. The female ran away, but after a time he renewed his attentions. The

1. These white hairs, in contrast with the bright iridescent green falces, are very striking; the female, although her falces are green, is without the white hairs.

female *rufus* is a ferocious creature, having a great advantage in size, and so it happened that our assiduous male, in an unguarded moment, was pounced upon and eaten up.

PHIDIPPUS MORSITANS.

On this species we have but few notes. The single female that we caught during the summer was a savage monster. The two males that we provided for her had offered her only the merest civilities, when she leaped upon them and killed them. The sexes are quite alike in color and marking, but while the female has the fourth leg longest, the male has the first pair not only much the longer, but thickly adorned with white hairs, some of which are long and others short and scale-like. It was while one of the males was waving these handsome legs over his head that he was seized by his mate and devoured. The tibia of the palpus is also covered with white hairs, which make a strong contrast with the general black color, and this is held out in such a way as to make a display as he approaches the female.

DENDRYPHANTES CAPITATUS.

The sexes are entirely different. In the male the bronze brown face is made very conspicuous by some snowy white bands, as is shown in the drawing. These are wanting in the female, her face being rufus with some few scattering white hairs. The males of *capitatus* are very quarrelsome, sparring whenever they meet, chasing each other about, and sometimes clinching. It is a very abundant spider with us, so that we often put eight or ten males into a box to see them fight. It seemed cruel sport at first, but it was soon apparent that they were very prudent little fellows, and were fully conscious that "he who fights and runs away will live to fight another day." In fact, after two weeks of hard fighting we were unable to discover one wounded warrior. When the males are approaching each other, they hold the first legs up in a vertical direction. Sometimes they drop the body on to one side as they jump about each other. These movements are very quick, and they

are always ready for a passage at arms. When courting the females they have another movement. They approach her rapidly until within two to five inches, when they stop and extend the first legs directly forward, close to the ground, the legs being slightly curved with the tips turned up. (Fig. 18.) Whether it be intentional or not, this position serves admirably to expose the whole of the bronze and white face to the attentive female, who watches him closely from a little distance. (Fig. 19.) The males also give their palpi a circular movement, much as a person does when washing his hands. As he grows more excited, he lies down on one side with his legs still extended. These antics are repeated for a very long time, often for hours, when at last the female, either won by his beauty or worn out by his persistence, accepts his addresses.

Fig. 18.—Dendryphantes capitatus. Position of male approaching female (from nature, by L. K.).

Fig. 19.—Dendryphantes capitatus. Face and palpi of male (from nature, by L. K.).

DENDRYPHANTES ELEGANS.

The male of the species, like many other animals, has received a number of names. Hentz called the female *elegans*, and the male *superciliosus*. C. Koch called him *cristata*, and we ourselves, *ibialis*, on account of the fringe of hairs on the tibia of his first leg. Both sexes are beautiful. The male is covered with iridescent scales, his general color being green; in the female the coloring is dark, but iridescent, and in certain lights has lovely rosy tints. In the sunlight both shine with the metallic splendor of humming-birds. The male alone has a superciliary fringe of hairs on either side of his head, his first legs being also longer and more adorned than those of his mate. The female is much larger, and her loveliness is accompanied by an extreme irritability of temper which the male seems to regard as a constant menace to his safety, but his eagerness being great, and his manners devoted and tender,

he gradually overcomes her opposition. Her change of mood is only brought about after much patient courting on his part. While from three to five inches distant from her he begins to wave his plumy first legs in a way that reminds one of a wind-mill. She eyes him fiercely and he keeps at a proper distance for a long time. If he comes close she dashes at him and he quickly retreats. Sometimes he becomes bolder and when within an inch, pauses, with the first legs outstretched before him, not raised as is common in other species; the palpi also are held stiffly out in front with the points together. Again she drives him off, and so the play continues. Now the male grows excited as he approaches her, and while still several inches away whirls completely around and around; pausing, he runs closer and begins to make his abdomen quiver as he stands on tip-toe in front of her. Prancing from side to side, he grows bolder and bolder, while she seems less fierce, and yielding to the excitement lifts up her magnificently iridescent abdomen, holding it at one time vertically and at another sideways to him. She no longer rushes at him, but retreats a little as he approaches. At last he comes close to her, lying flat, with his first legs stretched out and quivering. With the tips of his front legs he gently pats her; this seems to arouse the old demon of resistance, and she drives him back. Again and again he pats her with a caressing movement, gradually creeping nearer and nearer, which she now permits without resistance until he crawls over her head to her abdomen, far enough to reach the epigynum with his palpus.

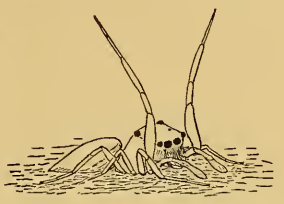

Fig. 20.—Zygoballus bettini. Position of male approaching female (from nature, by L. K.).

ZYGOBALLUS BETTINI.

The sexual differences in this species are well marked. The male has much more silvery white on the face; the first

legs and falces are much longer, and on the side of the abdomen the general color is darker and the lateral bars of a much more glistening white. All the colors are far more brilliant in the male than in the female. (Plate II.) In courting the male lies flat near the female, wriggling his abdomen and frequently turning from side to side. His first legs are held up over his head, slightly diverging, and are often twisted and turned about. (Fig. 20, see p. 47.)

Two males that were displaying before one female, rushed savagely upon each other and fought for twenty-two minutes, during one round remaining clinched for six minutes. When fighting, the abdomen is held nearly at a right angle with the cephalothorax. (Fig. 21.) The combatants appeared tired at the close of the battle, but after a short rest were perfectly well and fought a number of times subsequently. There are two forms of male in this species, one being twice as large as the other.

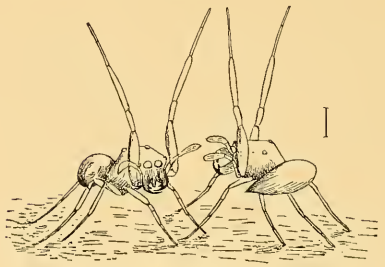

Fig. 21.—Zygoballus bettini. Position of males when fighting (from nature, by L. K.).

HABROCESTUM SPLENDENS.

The colored plate gives a good idea of the sexual difference in this species. The male, a magnificent fellow, when we first caught him, displayed for a long time before the female. He began by advancing a few inches toward her and then backing off again, this being repeated many times. After a while he settled down under a little web in the corner. The female, troubled by this indifferent treatment, advanced toward him; he came out and she fell back. This play was kept up for some time, but at length the male began his courting in earn-

est. When within a few inches of her he began a rapid dance from side to side, raising the whole body high on the tips of the legs, the first pair being directed forward and the palpi clasped together, with the abdomen turned to one side and lifted up. After a short dance he stood motionless, striking an attitude, as shown in the figure, remaining quiet for half a minute. (Fig. 22.) Then he turned his back on her, moving irregularly about with his legs forward and his palpi vibrating. Again he dances sideways before her, strutting and showing off like a peacock, or whirling around and around. When he turned his back we often thought that the female seemed disappointed, since she would then commonly move nearer to him and appear much excited herself. We at first supposed that this turning around was accidental, but it happened so regularly at a certain stage of the courtship that we concluded it was an important part of his display, serving to better show off his brilliant abdomen. Our artist, Mr. Kumlien, while watching the antics in order to draw the spider, called our attention to this habit, not knowing that we had observed it. The fact that among spiders the males take such attitudes as display their best points recalls this passage in one of Darwin's letters: "I am very glad to hear of your cases of the two sets of *Hesperiadæ*, which display their wings differently, according to which surface is colored. I cannot believe that such display is accidental or purposeless."

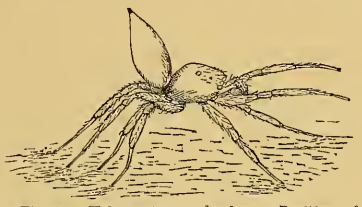

Fig. 22.—Habrocestum splendens. Position of male approaching female (from nature, by L. K.).

ICIUS MITRATUS.

The male is quite different from the female, especially in his slender, tapering body and in his long first legs. While in *splendens* the female was remarkable for the attention that she

gave the male, seeming at times to coquet with him, in this species she was remarkable for her indifference. She takes less interest in the display of the male than any spider that has come under our observation. Another peculiarity of *mitratus* is the large amount of time and strength given up by the males to fighting. They do not seem so fierce as other species, but they cannot endure each other's proximity. A male will leave a female in the midst of his caresses to drive off another male that comes too near. We once saw a male jump on to the back of another that was pairing with a female. The latter turned on the intruder and drove him to a distance of five or six inches, and then returned and renewed his addresses. In courting and in fighting the position of the male is the same. The body is somewhat raised; the first legs are held at a right angle to the cephalothorax, and the abdomen is twisted to one side, and, as he dances before the female, is changed now to the right, now to the left. (Fig. 23.) In mating, the male does not usually crawl over her, but jumps upon her from a distance of one or two inches, in this respect agreeing with the following species, *militaris*. Whether or no this habit in the two species is due to the savageness of the female—the females of both species sometimes attack the males—we are unable to say.

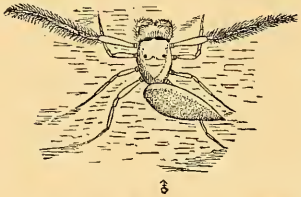

Fig. 23. — Icius mitratus. Male dancing before female (from nature, by L. K.).

PHILÆUS MILITARIS.

This is the only species in which we saw males take possession of young females and keep guard over them until they became mature. There is a good deal of difference in the size of the males, some being larger and some smaller than the females. We commenced our experiments by putting half a dozen mature males into a box. They at once began to chase each other about and to threaten each other with upraised legs.

The addition to the company of a number of nearly mature females considerably increased this tendency to quarrelsomeness, the males thereafter spending all the time that they spared from courtship in fighting. In approaching the female they seemed very eager, and fairly quivered with excitement. The first two legs were raised over the head and curved toward each other, so that the tips nearly met and the palpi were moved up and down. (Fig. 24.) One of them was much larger than any of the others, and from the first showed plainly that he had a strong sense of his own superiority. He drove all the others about at his pleasure, constantly interrupting their attempts at courtship. This big fellow seemed to be especially attractive to the females, of which there were always two or three standing in an admiring circle around him. When he approached them, however, they slipped away. After a time, he singled out the largest of the females, half coaxed and half drove her into a corner, and there kept her secluded, chasing away every spider that approached, irrespective of sex. He once interrupted a courtship which was going on six inches away, driving the male to a distance and then pursuing the female for a long time. This seclusion of the female was kept up until evening of the next day—a period of twenty-four hours—but on the following morning the pair had separated and he was hidden among some leaves. None of the females were yet mature. We now put into the box another male, which was nearly as large as the first. This second one adopted the same bullying manner to the smaller members of his sex that the first had done. After driving them about for a time, he secured a gnat, and was peacefully devouring it, when number one emerged from the leaves, caught sight of the new-comer, and at once approached, bristling with pride and ire, his first legs raised high, as if to strike, his palpi vibrating with excitement, and

Fig. 24.—Phîlæus militaris. Position of male approaching female (from nature, by L. K.).

his abdomen dragging, first on one side and then on the other. Number two was evidently of good courage, for he held his ground, and, not relinquishing the gnat, raised his legs and clinched with his antagonist. The battle raged for five minutes; finally number one pulled the gnat from the other, and then chased him away.

For several days following life in the mating box was robbed of its monotony by perpetual battles among the males. The females, in eluding them, jumped and hung from a thread. At one time a small one guarded a female for some hours in a corner; she once slipped away and ran a few inches, but when another male began to pay court to her, she ran back and crept under the body of her protector. After two or three days each of the two large males took possession of a female, spun a web over her, and spinning a second sheet above as a cover for himself, remained quiet in the little nest thus formed for a week. During this time every spider that approached was driven away. They went out occasionally for food, but were not seen to carry any to their mates.

At the end of a week number one was observed to be pairing with his female, which had moulted and was now mature. The two were separated, when the male went hunting about and finally sprang upon an unmated female, three inches away from the other nest, whereupon number two ran out, attacked him violently, drove him away, and then returned to his nest. Number one, while wandering about, caught sight of his own mate and sprung upon her without any of the preliminary attention before noticed. From this time forward, the big, wandering male, his occupation gone, became a very thorn in the flesh to the other, whose female had not yet matured. Not only did he continually approach the nest, thus arousing a jealous fury in its owner, which was not called out by any of the other spiders, but whenever the rightful owner was away from home, chasing intruders or procuring food, this disturber of domestic peace made his way into the nest. The first time this happened, the owner, returning, ejected him

without ceremony; the second time they had a prolonged struggle, clinching, and falling, thus locked together, a distance of about twelve inches—the height of the box (Fig. 25); the third time number one was not discovered until he had cut the still immature female out of the web which enclosed her. She ran away, and after that the two males wandered about, fighting whenever they met. The defrauded male, as well as the other one, now courted every female in the box, although so long as they had their own mates they had paid no attention to other females, except to drive them away.

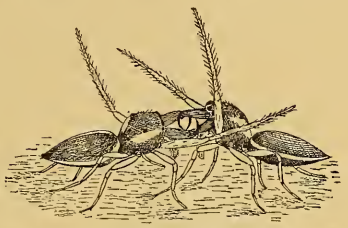

Fig. 25.—Philæus militaris. Position of males when fighting (from nature, by L. K.).

The following extract from our notes shows that the guarding of young females is a habit of the males in this species, and was not the result of artificial conditions:

"Aug. 17. Found a mature male *militaris* standing guard, in a tent, over an immature female (one moult from maturity). They seemed very friendly when taken out and put into a bottle. The webs and positions were as we had seen them in our mating-boxes.

ASTIA VITTATA.

There is a good deal of interest connected with the study of this species, for the reason that there are two well marked male forms; moreover, their love antics are unusually curious. A description of the two males is unnecessary, since they are well represented on Plate II. The two forms grade into each other, excepting that the three hair tufts are only found in the fully developed *niger* form. The *vittata* form, which is quite like the female, when he approaches her, raises his first legs either so that they point forward or upward, keeping his palpi stiffly outstretched, while the tip of his abdomen is bent to the

ground. This position he commonly takes when three or four inches away. While he retains this attitude he keeps curving and waving his legs in a very curious manner. Frequently he raises only one of the legs of the first pair, running all the time from side to side. As he draws nearer to the female he lowers his body to the ground, and, dropping his legs also, places the two anterior pairs so that the tips touch in front, the proximal joints being turned almost at a right angle to the body. (Fig. 26.) Now he glides in a semi-circle before the female, sometimes advancing, sometimes receding, until at last she accepts his addresses. The *niger* form, evidently a later development, is much the more lively of the two, and whenever the two varieties were seen to compete for a female, the black one was successful. He is bolder in his manners, and we have never seen him assume the prone position, as the red form did, when close to the female. He always held one or both of the first legs high in the air, waving them wildly to and fro, or, when the female became excited, he stood perfectly motionless before her, sometimes for a whole minute, seeming to fascinate her by the power of his glance. (Fig. 27, see p. 55.) A female that was full of eggs was looked at critically from a distance of four or five inches by several ardent males, but received no further attention. Although the males were continually waving their first legs at each other, their quarrels were harmless. It was quite otherwise with the females, since they not only kept the other sex in awe of them, but not infrequently, in their battles, killed each other. We thought it rather remarkable that the *niger* variety should not have the same antics as the *vittata;* but since closely related species often differ greatly in color, form

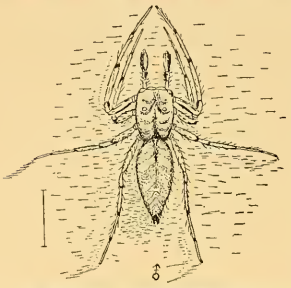

Fig. 26.—Astia vittata. Position of male approaching female (from nature, by L. K.).

and habits, we should not be surprised at finding like differences between distinct varieties.

The very meager knowledge that we have of the mating habits of the *Epeiridæ* has been gained at the expense of numerous hours of watching. The courtship of *Attidæ* is often very tedious, but it does not compare in this respect with that of the *Epeiridæ*, perhaps because the members of the former family are constantly in motion and thus hold out a hope to the observer that he is going to see something worth seeing, while the orb-weavers make nothing of remaining motionless for six or eight hours at a stretch; the observer, in the meantime, being afraid to let his attention flag for a moment lest he lose some small but significant movement on their part. We have watched the males and females of several species, but our only notes pertain to two species of *Argiope*, *cophinaria* and *fasciata*, in which the males are much smaller than the females. In the mating season each female has three or four of these little males hanging about the outskirts of her web.

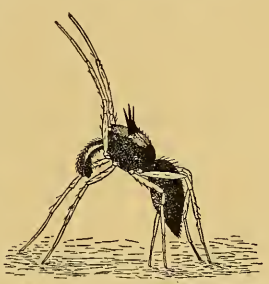

Fig. 27.—Astia vittata, var. niger. Position of male approaching female (from nature, by L. K.).

In *cophinaria*, when two of these males meet, they throw up their first legs and back away from each other, without striking or clinching as in the *Attidæ*, and then one of them drops at the end of a line. When advancing toward the female, the male seems to pause and pull at the strands of web, as though to notify her of his approach. When he comes toward her from in front she imparts a slight motion to the web with her legs, which seems to serve as a warning, as he either moves away or drops out of the web. When he comes from behind she pays no attention to him until he begins to creep on to her body, when she slowly raises one of her long legs and unceremoniously brushes him off.

We passed one afternoon in watching a female of *fasciata* in her web, around the edge of which were perched four little males. The proceedings were briefly as follows:

One of the males ran lightly over the web toward the female, approaching her from behind. Before he reached her she, seemingly conscious of his approach, gave the web a violent shake, whereupon he retreated. He made three or four trials of this kind and then seemed to give up hope. His place was taken by one of the other males, which acted in exactly the same way, with no greater success, and then gave place to a third. The female was always approached from above and behind, she hanging head downward, and she usually gave her warning shake before the male came very near, although once or twice he came close enough to touch her. The males showed no ill feeling toward each other. The most interesting part of it was that she seemed to recognize from the character of the vibration that a male was approaching, not taking the motion of the web to signify that an insect was entangled in it, as in this case she would at once have turned to secure her prey.

From these slight observations we were inclined to believe that the courtship in the *Epeiridæ* was carried on, to some extent at least, by a vibration of web lines. Dr. McCook subsequently confirmed that opinion, and we quote from his work on *American Spiders and their Spinning Industry* the following extract, which bears directly on the subject:

"The first stages of courtship have already been indicated. Having found the snare of his partner, the male stations himself upon the outer border and awaits results. It is not difficult for him to communicate his presence. Indeed, he must take his place deftly and keep it very quietly upon the snare, or he will quickly bring down upon him the voracious lady of the house. A touch of his claw upon a radius would telegraph to the female the fact of his presence; and I believe, from what I have seen of the operations of the male in this preliminary stage of courtship, as well as from the recorded observations of others,

that he does thus intimate his presence, and that the first stages of the engagement are consummated by these telegraphic communications back and forth between male and female over the delicate filaments of the silken snare.

"If matters be favorable, the male draws nearer, usually by short approaches, renewing the signals at the halting places. Sometimes this preliminary stay is very brief; sometimes it is greatly prolonged. I have observed it to be continued during several days, in which the male would patiently wait, sometimes, but not always, changing his position until his advances were favorably received, or were so decidedly repulsed that he was compelled to retire. With Labyrinth spiders I have generally seen the male stationed upon the maze, or that part of the snare which consists of crossed lines. Here he would make for himself, as he hung back downward, a little dome of spinning work, which spread above him like a miniature umbrella. The male of *Argiope cophinaria* feels the web with his feet for some time before the final approach. The male of *Linyphia marginata*, as he cautiously approaches, pulls upon the threads connecting his own with his lady's bower. The period of approach or courtship is generally terminated by a sudden rush which brings the partners into union."

The same idea was advocated many years ago by Termeyer, as follows:[1]

"The *diadema* spider was that which I examined. * * * He never appears in the center of the beautiful webs, and even when I saw him he was, as to abdomen and palpi, so different from the female, which in other respects he resembled, that I should not have supposed him of the same species. He never spins webs except in the time of his amours. * * * He approaches little by little, with much caution, doubtful of the reception with which he is to meet in the web of the female, who occupies the center, intent only on her prey. He commences

1 Researches and Experiments upon the Silk from Spiders and upon their Reproduction. Raymond Maria de Termeyer. Revised by Burt G. Wilder. M. D. Proceedings of Essex Institute, Vol. V, pp. 71–73.

by touching with one leg a thread of her web; the female approaches him; he flies, allowing himself to hang. Then he rises, winding up the thread, when he is assured, by I know not what movement, that he will not be ill-received; then he approaches her and with one of the palpi touches her stomach quickly many times. Then he returns, repeats the same act and departs, if he succeeds in leaving. I say if he succeeds, because I wish to relate what came under my observation in 1798. * * * I put a male and female of the *diadema* spider together in a box like a drum, closed with a veil at both ends. The male began by making various movements, as if to draw the attention of the female, who pretended not to perceive him, but only from time to time touched some thread of the web. He boldly approached, directing one of his palpi to her abdomen, and she extending this toward the palp. * * * But I saw also with surprise and indignation that, the work hardly finished, the male not being able to fly on account of the confinement, the female enveloped him in her thread, and having thus deprived him of every means of defense, devoured him. Perhaps overpowering hunger compelled her to it, but the act was very ferocious."

SUMMARY AND CONCLUSION.

In this paper we have considered the two theories by which Mr. Wallace explains sexual color differences in animals—primarily the greater vitality of the males, especially during the breeding season, and secondarily the greater need of protective coloring on the part of the females; and we have found that however satisfactory they may be where birds and butterflies are concerned, they fail in each important particular when applied to spiders.

In our study of moulting habits we have seen that among the *Attidæ*, where the sexual differences are strongest, males are commonly more brilliant than the females; that the young males nearly always resemble the adult females; that the males, when they differ from the females, depart from the general coloring of the group; and that when the females depart from the coloring of the group they approach, in the same degree,

the coloring of the males. Mr. Wallace's theory would only partially explain these facts since although the increased vitality at the breeding season might produce variations which would tend to be inherited at that age, the assumption with which he starts out—that the male animal is constitutionally more active than the female—is not true in regard to spiders.

While studying the secondary sexual characteristics of spiders we came upon several large groups of facts which seem entirely inconsistent with Mr. Wallace's view. First, we found no evidence that the male spiders possess greater vital activity; on the contrary, it is the female that is the more active and pugnacious of the two. Second, we found no relation, in either sex, between development of color and activity; the *Lycosidæ*, which are among the most active of all spiders, having the least color development, while the sedentary orb-weavers show the most brilliant hues. Third, we found that in the numerous cases where the male differed from the female by brighter colors and ornamental appendages, these adornments were not only so placed as to be in full view of the female during courtship, but that the attitudes and antics of the male spider at that time were actually such as to display them to the fullest extent possible. Moreover, we noticed that the males were much more quarrelsome in the presence of the females, and that they, to a great extent, lost their tendency to fight when the mating season was over.

With these facts in mind let us examine Mr. Wallace's two strongest objections to the theory of sexual selection.

First: "There is a total absence of any evidence that the females admire or even notice the display of the males. Among butterflies there is literally not one particle of evidence that the female is influenced by color or even that she has any power of choice, while there is much direct evidence to the contrary."[1] In butterflies and in birds, with their rapid flight, it is difficult to determine how much one sex is watched by the other; but in the *Attidæ* we have conclusive evidence that the

1 *Tropical Nature*, pp. 199–200.

females pay close attention to the love dances of the males, and also that they have not only the power, but the will, to exercise a choice among the suitors for their favor.

Second: The fact that every male bird finds a mate "would almost or quite neutralize any effect of sexual selection of color or ornament; since the less highly colored birds would be at no disadvantage as regards leaving healthy offspring." In spiders, as the females gradually become adult, they have a choice from among a number of males, as these mature several days earlier. The males will pair as often as they have the opportunity and as the mating season lasts for two or three weeks the more brilliant males may easily be selected again and again.

The fact that in the *Attidæ* the males vie with each other in making an elaborate display, not only of their grace and agility but also of their beauty, before the females, and that the females, after attentively watching the dances and tournaments which have been executed for their gratification, select for their mates the males that they find most pleasing, points strongly to the conclusion that the great differences in color and in ornament between the males and females of these spiders are the result of sexual selection.

Note.—Since finishing the above we have seen, in the February number of the Popular Science Monthly, T. H. Morgan's article on *The Dance of the Lady Crab*. The observation therein noted is full of interest, showing, as it does, that sexual display in the invertebrates is not confined to spiders.

PROTECTIVE RESEMBLANCES IN SPIDERS.

ELIZABETH G. PECKHAM.

Introduction.

There are, among spiders, two forms of protective modification: the first, including all cases of protective resemblance to vegetable and inorganic things—that is, all modifications of color or of color and form that tend to make them inconspicuous in their natural relations—I shall call direct protection. The second form, which I shall call indirect protection, includes two classes, the spiders which are specially protected themselves and those which mimic other creatures which are specially protected.*

Spiders are specially protected when they become inedible through the acquisition of hard plates and sharp spines. The modification of form is frequently accompanied by conspicuous colors, which warn their enemies that they belong to an unpalatable class.†

The second class of indirectly protected spiders—those that mimic specially protected creatures—presents some difficulties, since it is not always easy to determine whether the purpose of mimicry is protection or the capture of prey. The resemblance may, as is frequently the case in direct protection, serve both purposes.

In looking for instances of protective form and color among spiders we encounter one difficulty at the outset. The

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* Wallace classifies the colors of animal organisms as follows:

1. Protective colors.
2. Warning colors. { *a*. Of creatures specially protected. *b*. Of defenseless creatures mimicking *a*.
3. Sexual colors.
4. Typical colors.

Tropical Nature and Other Essays, p. 172.

† Under special protection would also fall cases, such as are common among other animals, of the development of some nauseous taste or odor; but we know of no such case among spiders.

meaning of a protective peculiarity can be determined only when the animal is seen in its natural home. The number of strangely modified forms depicted in descriptive works on spiders is enormous. Bodies are twisted, elongated, inflated, flattened, truncated, covered with tubercles or spines, enclosed within chitinous plates, colored like bark, like lichens, like flowers of every imaginable hue, like bird droppings, like sand or stones, and in every one of these modifications there is doubtless an adaptation of the spider to its surroundings which, when it is studied out of its natural relations, we can only guess at.

It has been well said that in these protective resemblances those features of the portrait are most attended to by nature which produce the most effective deception when seen in nature; the faithfulness of the resemblance being much less striking when seen in the cabinet.*

Before entering upon a consideration of protective modifications, I wish to give some account of the enemies of spiders and also to call attention to the remarkable variations in the fertility of the different species.

ENEMIES OF SPIDERS.

The enemies of spiders are numerous and vary greatly in different countries. Among them we may enumerate birds, wasps, lizards, snakes, monkeys, ichneumons, some kinds of ants, and spiders. They are also eaten in inconsiderable numbers by beetles and by fishes.

Outside of the Trochilidæ comparatively few of the North American birds feed to any extent upon spiders, although they form an insignificant part of the food supply of many species.†

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*H. W. Bates, in *Lepidoptera of the Amazon Valley*, p. 507.

†Prof. F. H. King has examined the stomachs of 1608 Wisconsin birds, including five humming-birds, 34 families being represented. In these he found, among other things, 1779 *Hymenoptera*, 1262 *Coleoptera* and 52 spiders. The whole number of birds eating *Hymenoptera* was 189, the whole number eating *Coleoptera* 430 and the whole number eating spiders 35.

Prof. S. A. Forbes finds that spiders appear to the following extent in the food of Illinois birds: Robin, 1%; Catbird, 2%; Brown Thrush, 1%; other Thrushes, 1%;

The humming-birds feed largely on our small spiders. Mr. Gentry tells me that he has opened hundreds of stomachs of the Rubythroat (Troch. colubris), subjecting them to microscopical examination, and has always found an abundance of small spiders associated with Coleoptera and Aphidæ, the spiders being ten times more numerous than the other insects. This agrees with the statement of Mr. Belt that he has found the crops of humming-birds full of small, soft-bodied spiders.*

In Central and South America the destruction of spiders from this source must be enormous, since in those countries the humming-birds are exceedingly numerous. Mr. Belt estimates that they are so plentiful in some parts of Nicaragua as to equal, if not to greatly exceed, all the other birds together.†

In both temperate and tropical regions a dreaded foe of spiders is the solitary wasp. This strange creature stings and lays up as food for its larvæ great stores of spiders, or in some species, beetles, flies, or caterpillars.

Reports from many parts of the world show how universal is the enmity between spiders and wasps. Fabre, in speaking of some European species of Pompilidæ and of the spiders with which they do battle, says: "D'une part sont les Pompiles,

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Bluebird, 8%; House-wren, 6%; Chestnut-sided Warbler, 6%; Summer Yellow-bird, 6%; Yellow-winged sparrow, 30%.

Mr. Thomas Gentry has, with a kindness which I gratefully acknowledge, made out for me the percentage of spiders in the food of the land birds of Eastern Pennsylvania. It will be seen that his results agree with those of King and Forbes in showing that the *Arachnida* furnish but an insignificant part of the food of North American birds, always excepting the *Trochilidæ*.

The *Turdidæ*, consume a few spiders, but the ratio to the whole number of insects eaten is so small as to be of little value.

Saxicolidæ, about 2%; *Sylviidæ*, less than ½%; *Paridæ*, less than ½%; *Sittidæ* 1%; *Certhiidæ*, ½%; *Troglodytidæ*, 2%; *Sylvicolidæ*, 2%; *Tanagridæ*, ¾%; *Hirundinidæ*, 1%; *Ampelidæ*, none; *Vireonidæ*, 2%; *Laniidæ*, none; *Fringillidæ*, represented by 28 species, .01¾%; *C. passerinus* consumes about 32%; *P. gramineus*, often as much as 10%.

Icteridæ, represented by eight species, are occasional spider eaters, especially the sub-family *Icterinæ*. *Corvidæ*, none; *Tyrannidæ*, ¾%; *Caprimulgidæ*, occasional traces of spiders; *Cypselidæ*, very few; *Trochilidæ*, 80%; *Alcedinidæ*, none; *Cuculidæ*, a few traces; *Picidæ*, 1½%; *Strigidæ*, none; *Falconidæ*, none; *Cathartidæ*, none; *Columbidæ*, uone; *Tetraonidæ*, none.

* *The Naturalist in Nicaragua*, p. 315.

† *Loc. cit.*, p. 140.

champions toujours vainqueurs; d'autre part sont les Araignées, champions toujours vaincus."*

Wallace also has a reference to this family: "The Pompilidæ comprise an immense number of large and handsome insects, with rich blue-back bodies and wings, and exceedingly long legs. They may often be seen in the forests dragging along large spiders, beetles, or other insects they have captured. Some of the smaller species enter houses and build earthen cells, which they store with small, green spiders, rendered torpid by stinging, to feed the larvæ."†

In *The Naturalist in Nicaragua* we find the following remarks on the relations between spiders and wasps: "The tramway in some parts was on raised ground, in others excavated in the bank side. In the cuttings the nearly perpendicular clay slopes were frequented by many kinds of wasps that excavated round holes of the diameter of their own bodies, and stored them with sting-paralyzed spiders, grasshoppers, or horse-flies. Amongst these they lay their eggs, and the white grubs that issue therefrom feed on the poor prisoners. I one day saw a small, black and yellow-banded wasp (*Pompilus polistoides*) hunting for spiders; it approached a web where a spider was stationed in the center, made a dart towards it—apparently a feint to frighten the spider out of its web; at any rate, it had that effect, for it fell to the ground and was immediately seized by the wasp, who stung it, then ran quickly backwards, dragging the spider after it, up a branch reaching to the ground, until it got high enough, when it flew heavily off with it. It was so small, and the spider was so heavy, that it probably could not have raised it from the ground by flight. All over the world there are wasps that store their nests with the bodies of spiders for their young to feed on. In Australia, I often witnessed a wasp combating with a large, flat spider that is found on the bark of trees. It would fall to the ground, and lie on its back, so as to be able to grapple with its opponent;

* *Les Pompiles, Nouveaux Souvenirs Entomologiques*, p. 206.

† *Loc. cit.*, p. 90.

but the wasp was always the victor in the encounters I saw, although it was not always allowed to carry its prey off in peace. One day, sitting on the sandbanks on the coast of Hobson's Bay, I saw one dragging along a large spider. Three or four inches above it hovered two minute flies, keeping a little behind, and advancing with it. The wasp seemed much disturbed by the presence of the tiny flies, and thrice left its prey to fly up toward them, but they darted away immediately. As soon as the wasp returned to the spider, there they were hovering over and following it again. At last, unable to drive away its small tormentors, the wasp reached its burrow and took down the spider, and the two flies stationed themselves one on each side the entrance, and would, doubtless, when the wasp went away to seek another victim, descend and lay their own eggs in the nest." *

Mr. Bates, speaking of a wasp of the genus Pelopatus, says: "On opening closed nests of this species, which are common in the neighborhood of Mahicá, I always found them to be stocked with small spiders of the genus Gasteracantha, in the usual half-dead state to which the mother wasps reduce the insects which are to serve as food for their progeny." †

This is a particularly interesting fact since the Gasteracanthides belong to specially protected group, being so armed with spines that birds cannot eat them. Mr. Bates also mentions two species of Trypoxylon which provision their nests with spiders.

Monteiro, writing on the natural history of Angola, says:

"Whilst at Bembe, I fortunately witnessed a fight between a large specimen of these wasps (Pelopæus) and a powerful spider which had built its fine web on my office wall. The spider nearly had the wasp enveloped in its web several times, and by means of its long legs prevented the wasp from reaching its body with its sting, but at last, after a few minutes of hard fighting, the wasp managed to stab the spider right in the

* P. 133.

† *Naturalist on the River Amazon*, p. 186.

abdomen, when it instantly curled up its legs and dropped like dead to the ground. * * * I have counted as many as twenty spiders in a single cell, and there are seldom less than three cells together, and sometimes as many as eight or ten." *

On the wasps of South America, in their relation to spiders, I will also quote from a letter written by Mr. Herbert Smith † in answer to some questions about the enemies of spiders.

"In my opinion, the chief enemies of spiders in the tropics are Hymenoptera. The solitary wasps are far more numerous than here; some of the larger Pompilidæ provision their nests with Mygale, but commonly take great numbers of small Epeiridæ, Attidæ, etc. Some of my best specimens of spiders were obtained from wasps' nests, though the wasps have an unpleasant habit of cutting off all the spiders' legs."

To come nearer home, Hentz, in the United States, found about forty spiders in one tube of Sphex cyanea. ‡ He says that these wasps commonly enclose from twenty to forty spiders in their nests. §

Mrs. Treat has also noticed that wasps make war upon a large spider, T. tigrina, which lives in a hole which it excavates in the ground. She had at one time twenty-eight spiders of this species under observation. She writes: "In August the digger-wasp is making sad havoc among these spiders. She wants them to feed her young, and nothing but this particular species will do; and woe now to all spiders with unclosed doors, for she is sure to find them. * * * She runs over the ground swiftly, peering here and there, until she alights upon an open burrow, down which she speedily goes, and soon comes out dragging her victim, which she has paralyzed with her powerful sting. * * Toward the end of August out of the twenty-eight spiders only five are left."‖

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* *Angola and the River Congo*, p. 324.

† Author of *Brazil, the Amazons and the Coast.*

‡ *Spiders of the United States*, p. 122.

§ *Ibid*, p. 154.

‖ *Home Studies in Nature*, p. 82.

The wasps that were watched by Fabre, dared not enter the nests of the spiders they wished to capture, only attacking them when they came partly outside.

Lastly, we ourselves have opened a number of Sphex nests, which we always found to contain twenty-five or thirty spiders, nearly all of them being E. strix.

In regard to the other enemies of spiders, I will quote again from Mr. Smith's letter:

"The smaller monkeys, I know, prey upon spiders a good deal; they seem to delight in tearing them to pieces even when they do not eat them. I have observed this frequently with small Cibi and marmosets. To these mammalia I should add some kinds of armadilloes and all the ant-eaters; the latter devour 'white ants' by preference, but I have generally found their stomachs filled with all sorts of insects, wasps, beetles, etc., and (if I remember rightly) terrestrial spiders. Snakes eat spiders sometimes, as I can attest from actual observation; no doubt lizards do the same. Owls may sometimes eat the larger nocturnal species, and I feel pretty sure that I have seen other birds eating them. Foraging ants (*Eciton*) kill great numbers of terrestrial spiders and some arboreal ones, though the latter generally escape them by letting themselves down on lines. Scorpions do not eat spiders I think; at all events the latter do not seem at all afraid of them. Except the foraging ants, I never saw ants attack living spiders; the butchery is all on the other side. As you observe, the spiders eat each other; yet I should not think that the destruction from this cause was very great. Spiders as well as insects are sometimes killed by parasitic fungi."

My own observations have led me to think that hunting and running spiders prey to a considerable extent upon each other. We have had great difficulty in keeping numbers of Attidæ, even of one species, together in our boxes, since, although they were supplied with gnats and flies, they preferred to devour each other. *Phid. morsitans, Phid. rufus, Hasarius hoyi, Astia vittata and Phil. militaris* were especially troublesome in

this respect. A large Lycosa, which we kept under observation for some time, instantly seized and devoured any smaller spider that was put into the box with it. The Thomisidæ are very fierce and voracious, attacking and eating Attidæ larger than themselves when caught with them in a sweep-net—a time at which all other captured creatures think only of how to escape.

Walckenaer refers again and again to the warfare going on among spiders. In his introduction, after giving some account of the conflicts between males and females of the same species, he goes on to say:

"If individuals of the same species behave toward each other with such ferocity, one may well believe that different species and different genera are in a state of continual war." *

Spiders of one genus, Mimetus, have developed a habit of taking possession of the webs of other spiders, first devouring the owners and sometimes their eggs as well.†

We have other instances of spider eggs being eaten by spiders. For example, Vinson gives a graphic description of the great Epeiridæ of Madagascar, in the corners of whose mighty webs live many small Argyrodes, which thus secure immunity from the attacks of birds. These little spiders, unmolested by their big relatives, sometimes make a poor return for the hospitality shown them by devouring the eggs of their hosts. ‡

Many spiders are destroyed by parasites whose eggs may be deposited upon, or within the body of the spider, or may be laid within the cocoon, the parasitic larvæ devouring the eggs. It is a very common thing to find spider cocoons inhabited by

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* *Hist. des Insectes Aptères*, I, p. 143. See also pp. 172,, 408., 644, and vol. II, pp. 32, 71.

† In characterizing this genus Hentz says: "The parasitic habits of the spiders composing this sub-genus, remind the naturalist of the depredations committed by various Hymenoptera upon many species of insects. The Mimetus can make a web like that of Theridion, but prefers prowling in the dark, and taking possession of the industrious Epeiras' threads and home, or the patient Thendion's web, after murdering the unsuspecting proprietor." *Loc. cit.*, p. 137.

‡ *Aranéides des iles de La Reunion, Maurice et Madagascar*, p. 269.

young ichneumons; and it is probable that spiders have no more destructive enemies than these insects.

FERTILITY OF SPIDERS.

As we have for some years made a practice of keeping notes on all observations relating to spiders, whether they touched on work on hand at the time or not, it happened that we found ourselves, some time ago, in possession of a good many facts concerning the number of eggs laid by different species. These numbers varied so greatly, running from forty or fifty up to several hundred, as to excite considerable speculation, on our part, as to the meaning of the variation.

Why should one species lay eight hundred or a thousand eggs, while another, equally common, laid only fifty?

At about this time we had, in confinement, one male and half a dozen females of the little ant-like spider, Synageles picata, and before long each female made a cocoon containing three eggs. This number was so small as to still further arouse our interest and the idea suggested itself that a possible explanation might be found in the principles laid down by Herbert Spencer in regard to the inverse variation, in every species, of its birth rate to the powers of self-maintenance possessed by its individual members; and that if this could be established it would have a direct bearing on protective resemblances, since one test of the advantage of its own peculiar modification to a species might then be found in the number of eggs laid by that species.

To show how this doctrine bears upon the subject I will briefly state Spencer's introductory considerations, and will then quote at length from that part of his discussion which applies to the point in question.

The varying degrees of fertility among organisms result from their conditions of life. We may class the actions which affect each race of organisms as forming two conflicting sets. On the one hand, by what we call natural death, by enemies, by lack of food, by atmospheric changes, etc., the race is constantly being destroyed. "On the other hand, (a) partly by the

endurance, the strength, the swiftness, and (b) partly by their fertility, it is constantly being maintained. These conflicting sets of actions may be generalized as the forces destructive of race and the forces preservative of race."

There exists an equilibrium between the destructive and preservative forces of every species. Any excess of either of these sets of forces itself generates, by the deviation it produces, certain counter-forces that eventually out-balance it and initiate an opposite deviation.

"Is this the sole equilibration that must exist? Clearly not. The temporary compensating adjustments of multiplication to mortality in each species are but introductory to the permanent compensating adjustments of multiplication to mortality among species in general. The above reasoning would hold just as it now does, were all species equally prolific and all equally short-lived. It yields no answer to the inquiries—why do their fertilities differ so enormously, or why do their mortalities differ so enormously? And how is the general fertility adapted to the general mortality in each? The balancing process we have contemplated, can go on only within moderate limits—must fail entirely in the absence of a due proportion between the ordinary birth-rate and the ordinary death-rate; * * * the minor adjustment of varying multiplication to varying mortality in each species, implies some major adjustment of average multiplication to average mortality. What must this adjustment be?

"We have already seen that the forces preservative of race are two—ability in each member of the race to preserve itself, and ability to produce other members—power to maintain individual life, and power to generate the species. These must vary inversely. When, from lowness of organization, the ability to contend with external dangers is small, there must be great fertility to compensate for the consequent mortality; otherwise the race must die out. When, on the contrary, high endowments give much capacity of self-preservation, a correspondingly low degree of fertility is requisite. Given the

dangers to be met as a constant quantity; then, as the ability of any species to meet them must be a constant quantity too, and as this is made up of the two factors—power to maintain individual life and power to multiply—these cannot do other than vary inversely: one must decrease as the other increases."*

To make a fair application of this to spiders—to determine with any degree of certainty whether the spiders that lay a large number of eggs are poorly equipped for individual maintenance, while those that lay a small number are well equipped, we ought to have many more facts than are at present available about the conditions of life in the different species. It is interesting, however, to see how what facts we have accord with the theory, and, supposing the theory to be correct, to see which forms of protection are most successful.

To take two species from the same family, we have no other Epeirid which lays so many eggs (500–2,200) as *Argiope* cophinaria† and no other which lays so few (34) as *Tetragnatha* laboriosa. According to the theory, cophinaria should be ill equipped for the battle of life while laboriosa should be in much closer harmony with its relations.

Both depend upon their webs for their food supply and probably both secure as much as they need, so that their advantages in this respect may be considered equal.‡

In regard to their means of protection from enemies, a first view of the two spiders would seem to favor our theory. The slender, elongated form, the greenish-golden color, blending with that of the leaves, the habit of clinging, with legs extended in a line with the body, close to the branch upon which it rests, all combine to render laboriosa inconspicuous. On the other hand, we have in the great cophinaria, dressed

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* *Principles of Biology*, Vol. II, p. 396, *et seq.*

† *A. riparia Hentz.*

‡ The zig-zag band of white silk which runs up and down through the middle of the co*phinaria* web is used in the capture of prey by a relation of our spider in Madagascar. It serves as a reserve line with which to tie up any extraordinarily large insect, such as a grasshopper, when he becomes entangled in the web. *Cophinaria*, however, is not known to make this use of it, its only usefulness to her being the added strength which it gives to the web. Vinson, *loc. cit.*, p. xv.

in deep black and brilliant yellow, hanging out in the middle of her web, so striking an object that every passer-by must see her. An old-fasioned naturalist might be pardoned for calling her a wonderful instance of an all-regulating Providence, which has not only provided this lucious morsel to be the food of some bird, but has also made her so conspicuous that the bird cannot fail to see and recognize its natural prey. *

Cophinaria, however, is not unprotected. Of one means of defense common among conspicuous creatures, *i. e.*, the possession of a nauseous flavor, she seems to be destitute, as some chickens, to which she was offered, ate her with relish; but her size alone must protect her from a host of enemies that prey upon smaller species. For creatures large or fierce enough to attack her we must look to birds and wasps. From these foes she is protected by a number of irregular lines which she stretches beyond her web (fig. 1). These must be passed before the spider can be reached. Now cophinaria has a delicate sense of touch. Place your finger lightly upon one of the outlying lines—she falls like a shot to the ground, where, with her back down, and her legs drawn in she is difficult to find, unless you have followed the drop with your eye. Or approach the web without touching it; your shadow, the sound of your footstep, or perhaps the vibration of the

Fig. 1.—Web of Argiope cophinaria, showing outlying lines (from McCook).

* Darwin (*Descent of Man*, p. 343) says that M'Clelland, in describing certain Indian Cyprinidae, supposes that their remarkable brilliancy serves as a better mark for the birds which are destined to keep the numbers of these fishes in check.

ground warns her; still, the danger does not seem imminent; she has time to make use of another power—she will render herself invisible. The web begins to sway backward and forward; the rapidity of the motion increases; the outlines become indistinct, and within a few seconds of the first movement, spider, web and all have vanished from sight!

If a wasp, in attacking cophinaria, becomes in the least entangled in the web the position is quickly reversed. The spider darts to the spot, holds the would-be destroyer, who is now the victim, away from her body with her long legs, while she rapidly binds it up and reduces it to a condition of perfect helplessness.*

The young cophinaria is more open to attack than the adult, but is by no means so conspicuous. It is of a light, somewhat greenish tint, so intermingled with dark gray as to give the effect of transverse dark bands on a light ground. The legs are also light, banded with a darker shade. The web made by the young spider differs from that of the adult and is curiously adapted to conceal it, having a thickened place in the middle, which extends as far as the tips of the spider's legs This thickened portion is made up of concentric lines of web joined by short, transverse threads, so that it blends with the banded body and legs of the spider and protects it from observation.

Cophinaria, then, is so protected, at different periods of its life, that the disadvantage of its conspicuousness is, to some extent, counterbalanced. How, then, shall we account for its enormous number of eggs?

There is one stage of its existence which we have not yet examined. Serious dangers assail it while it is still in the egg, and here, probably, is the secret of its excessive fertility. The

* Once, when wishing to mark a number of social wasps (*Vespa maculata*), which we had caged, we liberated a few at a time in our wire-enclosed porch, and then catching them with gloved hands, cut their wings. At the time there were three or four individuals of *A. cophinaria* in the porch and many of the wasps were lost by becoming entangled in their webs. The spiders bound them up very quickly, showing no sign of fear. *V. maculata* is, of course, far from being so redoubtable an enemy as the solitary wasp.

cocoons of cophinaria, though a little smaller, closely resemble in shape and color the oak-apple, Quercus inanis, which abounds among red oaks; but if this is a case of protective resemblance, which seems improbable since cophinaria inhabits open, marshy places and is not found in the woods, the disguise is far from being a complete protection. Each cocoon contains many hundreds of eggs, but among them a wholesale destruction is carried on by cophinaria's most dangerous enemy, the ichneumon fly. The cocoons are hung among the long grass and are not difficult to find, but when opened they so frequently contain nothing but young ichneumons as to make it reasonable to believe that where the enemies of other species slay their hundreds this one enemy of cophinaria slays its thousands.*

Another, and perhaps the most serious of all the dangers to which this species is exposed, is the flooding of the marshy land upon which the cocoons are deposited. During the present spring we collected 62 cophinaria cocoons, some of which were in a fragmentary condition. Of the whole number 26 contained live spiders, 6 contained eggs just about to hatch, 24 had been destroyed by parasites and 6 by water. In the marsh where the full-grown spider is most abundant in August, every bush being covered with them, we found only three water-soaked cocoons. When they are destroyed by parasites the case remains, but when the water spoils them they are probably decayed, broken up and washed away, seldom leav-

* Of 406 cocoons of this species taken in one spring by Prof. Wilder, 134 were entire; 190 were pierced, but contained live spiders; 59 were torn, probably by birds, most of them still containing some of the spiders, and 23 contained the remains of parasites by which the young spiders, or the eggs, had been destroyed.—*American Association for Advancement of Science*, Vol. XXII, p. 261.

Prof. Wilder thinks that the young spiders devour each other to a considerable extent, as they are shut up for weeks or months after they are hatched with no food but one another. Young spiders, however, probably do not eat until after about the second or third moult, and although those that he observed did eat each other they were under unnatural conditions, and must have grown less rapidly and remained longer in the cocoon than they would had they been left out of doors, as even with our late Wisconsin spring we find the young of *cophinaria* running about, half grown, in June.

The eggs of this species are also open to the attacks of another spider Emerton has found the young of *P. morsitans* in cocoons of *cophinaria* (Note Hentz's *Spiders of North America*, p. 58.)

ing a trace behind. This recalls Prof. Wilder's suggestion that the immense fertility of Nephila plumipes is counter-balanced by the destruction of its cocoons, which are so placed, depending from leaves, that great numbers of them are washed away and destroyed by rain.

Let us look at the Attidæ. In this family the most fertile species on record is Phidippus morsitans, laying about 180 eggs; while the least fertile is the little, ant-like Synageles picata, laying three.

So far as defending itself from the attacks of enemies of its own class is concerned, morsitans has an unquestionable advantage. It has not only superior agility; it is also one of the largest and fiercest of the family, and it is improbable that any other spider preys upon it; while nothing more defenseless can be imagined than the little picata, with its tiny body, weak falces and slender legs. The fierceness of morsitans, however, would be useless against such foes as birds and wasps, while the strongly contrasted black and white of its coloration make it conspicuous.

Beyond the fact that it is small and dark-colored, picata has absolutely nothing to protect it excepting the resemblance which it bears to an ant. Can this alone gives the species so great an advantage that it is enabled to maintain itself with as low a birth-rate as three or four in a season?

We must accept one of two alternatives. The direct relation between mortality and multiplication is well established, and it is plain that no species could maintain itself with so low a birth-rate were not its mortality correspondingly low. It must, then, either have practically no enemies, or its means of protection from its enemies must be uncommonly efficacious. We cannot accept the first alternative. No creatures are exposed to the attacks of more enemies and none are more helpless under such attacks than small, soft-bodied spiders; and the conclusion seems unavoidable that picata enjoys immunity from attack because it appears to be not a spider but an ant.

A species, then, may depend for its preservation upon either active or passive means of protection, the passive means often outvaluing the active. But whatever the means may be —fierceness, inedibility, protective resemblance, or mimicry— I would suggest that one test of its efficiency may be found in the fertility of the species.

DIRECT PROTECTION.

Resemblances to Vegetable and Inorganic Things.

As a general rule the forms and colors of spiders are adapted to render them inconspicuous in their natural homes. Bright colored spiders, except where sexual selection has been at work, either keep hidden away or are found upon flowers whose tints harmonize with their own. This rule, while it has numerous exceptions, is borne out by the great majority of cases. A good illustration is found in the genus Uloborus, of which the members bear a deceptive resemblance to small pieces of bark or to such bits of rubbish as commonly become entangled in old, deserted webs. The only species in our neighborhood is Uloborus plumipes, which I have almost invariably found building in dead branches, where its disguise is more effective than it would be among fresh leaves. The spider is always found in the middle of the web, with its legs extended in a line with the body. There has been, in this species, a development along several lines, resulting in a disguise of considerable complexity. Its form and color make it like a scrap of bark, its body being truncated and diversified with small humps, while its first legs are very uneven, bearing heavy fringes of hair on the tibia and having the terminal joints slender. Its color is a soft wood-brown or gray, mottled with white. It has the habit of hanging motionless in the web for hours at a time, swaying in the wind like an inanimate object. The strands of its web are rough and inelastic, so that they are frequently broken; this gives it the appearance of one of those dilapidated and deserted webs in which bits of wind-blown rubbish are frequently entangled. The web represented in Plate IV was unusually perfect, and yet did not appear as it does in the drawing. The pattern was made out by

using a magnifying glass and turning the branch from side to side, only two or three of the radii being visible from any one point of view. The web, moreover, is built in such a place that the spider is easily confounded with the objects among which it is seen.* To these characteristics we must add its habit of making a number of roughened grayish or brownish cocoons, and of so disposing them in the web, either heaped one above another or strung along tip to tip, that they seem to be nothing more than a mass of rubbish.

Out of seven examples of the species taken during one summer, five were found in dead tamarack branches, one on a dead bush, and the seventh, an interesting variety, under the eaves of a porch. My eye was caught by what seemed to be a string of eleven cocoons (it is not common to see more than four in a web). On attempting to take them down I was surprised to see one of the supposed cocoons begin to shake the web violently. Ten were what they seemed to be, but the eleventh was the mother spider, whose color and general appearance was exactly like that of the little cases that she had made for her eggs.

The plumipes which is represented in Plate IV was brought from a tamarack swamp and placed on some dead branches in the corner of a porch. She proved a most patient little model, hanging in one position all day long. When the drawing began she had one cocoon; two more appeared at intervals of three days. She lived in the porch for several weeks. At one time, becoming dissatisfied with her position, she raised her cocoons seven inches, to a higher crotch in the branch, and there built a new web. She moved rather slowly.

From the descriptions of U. productus, U. borbonicus and U. Walckenærius, these species must be close to plumipes in shape and general coloring, in habits, in the character of their webs and in the form and color of their cocoons.

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* Simon says of this species: "Il s'établit soit sur les broussailles sèches, soit dans les trous des vieux murs; il se tient toujours les pattes étendues longitudinalement et se confond avec les objets sur lesquels il est placé." *Arachnides de France*, Vol. I, p. 169.

Near to Uloborns is Hyptioides, in which is found the same kind of protective resemblance. The little brown spider, H. cavatus, is so inconspicuous that no ordinary observer ever sees it, and even when his attention is called to it he takes it to be a bit of dirt. Looking closely, we find it to be of a light, yellowish gray, with several dark humps and lines; while the legs and cephalothorax are blackish. It usually crouches, with its legs drawn in, at the end of a branch, holding the elastic thread which runs to its web, and in this position it is all but indistinguishable. Emerton has noticed that it is colored like the ends of the dead pine branches among which it usually lives. *

In many ways similar to H. cavatus, is H. paradoxus. Of this species Thorell says: "The identity of color between the animal and the dry branches causes it not to be so easily perceived." †

Among the Epeiridæ there is no prettier instance of protective form and habit than Cyrtophora conica, the little spider which we once taught to recognize the sound of the tuning-fork. Its color is gray, broken with irregular lighter and darker lines, and its abdomen, behind, has a rounded projection. This neutral coloring and irregular outline give it the same advantage as that possessed by Uloborus and Hyptioides, and like the former genus it strings its cocoons across the web; but it is protected in a still higher degree by its habit of accumulating a quantity of light rubbish, remains of insects, etc., which it places in a band across the web, binding all together with some loose strands. The cocoons are partly hidden in this mass of débris, and they, as well as the spider itself, standing at the central point, appear to be a part of it. This resemblance is extremely close—so much so that although we visited the little spider before referred to at least once a day for several weeks we were frequently deluded into thinking she was gone,

* *New England Spiders of the Family Ciniflonidae*, Trans. Connecticut Acad., Vol. VIII, 1888, p. 456.

† *European Spiders*, Part I, p. 70.

a close inspection being necessary before she could be distinguished.*

The same kind of resemblance is found in the genus Argyrodes. These spiders are usually of parasitic habit, building in the corners of webs of larger species. Two of them are common in this country, fictilium and trigonum. They are small and slender, with elongated bodies. Of trigonum Mr. Emerton says: "These spiders live among the upper threads of the webs of Agelena, Linyphia and Theridium and are most common in woods of pine and spruce. They look, in the web, like straws, or still more like the scales from pine buds, which are often caught in the same webs." † We find it in Wisconsin, on the ground among the grass. Fictilium has not been found in the web. We have caught it always in a swampy piece of ground, where the long grass is partly green and partly dead and yellow. In this locality its slender, yellowish, elongated body affords it good protection.

A foreign species, A. epeiræ, is referred to by Cambridge as follows: "It appeared to have spun its own little irregular snares among the mazes of the Epeira's webs, in which it sat, looking like a little morsel of dead stuff, and perhaps deluding the other spiders into a belief that it was so, and thus escaping being devoured." ‡

In Ariamnes attenuata (fig. 2, see p. 80), the abdomen is still more elongated than in Argyrodes. This species is also yellowish in color and is probably protected by its resemblance to a straw or blade of dead grass. Many related forms have been described by Simon, Taczanowski and others.

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* While the *C. conica* of Menge seems to be identical with *C. caudata* Hentz, his description of the web as from seven to ten feet wide, and stretching from tree to tree, does not at all correspond to the web of the American species, which does not exceed twelve or fifteen inches in diameter. The measurements that he gives seem strangely out of proportion to the size of the spider, which is only 8 mm. long.

Menge says that Lister, who first observed the habits of this species, thought that the remains of insects which the spider had devoured were hung across the web as trophies of victory. *Preussische Spinnen*, p. 76.

† *New England Spiders of the Family Theridiidae*, Trans. Connecticut Academy, Vol. VI, 1882, p. 24.

‡ *Spiders of Palestine and Syria*, Proc. Zool. Soc. 1872, Part I, p. 279.

Similar in many respects to the Argyrodes group are the Tetragnathinæ. These spiders are all slender, and, whenever they are at rest, keep their legs extended in a line with the body. Their usual position is on a branch at one side of the web. Their coloring runs through the shades of brown, yellow and green, and they are frequently mottled or lined with black or white. Mr. Atkinson speaks of a Tetragnatha (probably grallator) which mimics elongated, dark blotches on grass stems; he says: "I have often seen them, when frightened, leave the web and, clinging to a grass-stem, place their bodies close to the stem, stretching the anterior legs above and the posterior ones below. The body being dark and the legs green, the spider was well protected." *

Fig. 2.—Ariamnes attenuata (from Cambridge).

In some species of Tetragnatha, as in Argyrodes, the tip of the abdomen is elongated and turned upwards.

We come now to a large and interesting class in genus Epeira. I refer to those species, mostly nocturnal, which are protected during the day, not by hiding in crevices nor in any way actually getting out of sight, but by the close resemblance which they bear to the bark of the trees to which they cling. This resemblance is brought about in two ways; through their color, which is like that of wood or lichens, and through their tuberculated and rugose forms, which resemble rough bark.

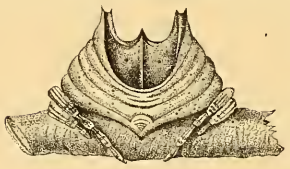

Fig. 3.—Cærostris mitralis (from Vinson).

One of the most remarkable of these forms is C. mitralis, a Madagascar species, which, looked at in profile, probably resembles a woody knot. The abdomen is divided into two divergent cones (fig. 3). The entire upper surface of the body is covered

*I quote from some manuscript notes which Mr. Atkinson has kindly allowed me to make use of.

with conical elevations, which render it rough and uneven; the sides of the abdomen are made up of several layers, which form stages, one above another, like the ridges of bark on a woody excrescence. The legs, formed of wide, flattened plates, make the base. The color of the spider is yellowish-gray, varied with white and dark reddish-brown. It has the habit of perching on a branch and clasping it like a bird,* so that the elaborate modification of form, which would be useless if the spider hung exposed in the web, is made as effective as possible.

Fig. 4.—Cærostris mitralis, in profile (from Vinson).

To take an example nearer home, E. infumata is a large, round-bodied spider, with two humps on the abdomen, which Emerton describes from New England as being brown, mottled with white and black; he adds that when it draws in its feet it looks like a lump of dirt. Infumata, in Wisconsin, has always a good deal of bluish green on the upper surface of the abdomen. This may be a variety which has been so developed as to resemble the lichens which cover the tree to which it clings. It is one of the spiders which bear a good deal of handling without uncurling its legs, or showing any sign of life. Its humpy form and its color give it a very inanimate appearance. It is rather common in our neighborhood and may be caught in the late twilight while building its web, but to search for it in the daytime, even among the trees that it most frequents, is an almost hopeless task. A more grotesque form is E. stellata, in which the abdomen has not two, but twelve or fifteen humps. These are so disposed that the edge of the abdomen, all around, is scalloped. The colors are light and dark brown, modified by gray and white hairs. This spider remains motionless during the daytime, keeping its legs drawn up to its body. It is common on grass and low bushes. It is not found in Wisconsin,

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Vinson, *loc. cit.*, p. LIII.

but the description of it suggests a resemblance to a piece of dead leaf.

There are many other spiders in this genus that have humps and are colored in brown, gray or dull yellow, as nordmanii, angulata, solitaria, etc. It is an almost universal habit among the Epeiridæ to drop to the ground when threatened, and when a humped gray or brown spider drops to the ground and draws in its legs it is nearly indistinguishable from the lumps of earth, sticks and stones that surround it.

Fig. 5. — Ulesanis americania (from Emerton).

One of the Theridiidæ which has the same protection is Ulesanis americana* (fig. 5). The abdomen, which covers the cephalothorax nearly to the eyes, has a prominent hump in the middle of the back and four or five others behind. Its color is in shades of brown and yellow.

Analogous to the humped Epeiridæ is Thomisus foka, of Madagascar, a spider which is regarded with great terror by the natives, as being so poisonous that even its breath is deadly. They say that cattle, when about to lie down, look carefully about to see if one of these spiders is in the neighborhood. This dread is, no doubt, inspired by the strange and uncanny aspect of a perfectly harmless creature. It has a rugose, tuberculated body of trapezoid form, the colors being brown and reddish, while the whole aspect is crab-like. The thick, short legs are reddish, covered with tubercules. The secret of its strange form is made clear when we learn that it resembles in color and general appearance the fruit of Hymenæa verrucosa, a tree common in the forests where this spider is found. ‡

Among the curious forms which must have been developed

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* This species, Emerton says, looks like a seed or a lump of earth.

‡ Vinson, *loc. cit.*, pp. 70-71.

through advantageous variation, but which we are unable to explain, is Eriauchenus workmanni (fig. 6).

Epeira prompta (a variety of parvula, Plate IV, fig. 2) is a common spider in Wisconsin. It is most frequently seen on cedar bushes, where its color harmonizes with that of the foliage and fruit. During the day it usually rests on a branch near its web. The back of the abdomen is of a peculiar bluish-green, exactly like that of the lichens growing on tree trunks. The bluish color is broken by waving black lines which imitate the curling edges of the lichens. The one represented in the plate was found on an old cedar which was covered with lichens. It was kept for two weeks in a glass-covered box, where it spent most of the time crouching in a corner. It built no web, but spun some irregular lines to run about on. It ate gnats, flies, and once a little jumping spider, S. pulex, which we were keeping in the same box, leaping upon its prey, as noted by Hentz,* like an Attus. This seems a curious habit to be acquired by an Epeirid, since these spiders, as we have noticed among our captives, are usually dependent for food upon what is caught in their webs. Prompta moves awkwardly, but very rapidly.

Fig. 6.—Eriauchenus workmanni (from Cambridge).

Drapetisca socialis, while quite a different looking spider, is protected in the same way—by its resemblance to the bark upon which it lives. Emerton speaks of finding it on the bark of spruce trees, which it "closely resembles in color."† Menge says that it is common in Prussia, where it is seen in great numbers on fir trees, whose spotted bark it resembles in color, so that it is not easily seen.‡ We have found them, most commonly, upon birch trees, and in this situation their color adaptation is perfect. Both the spider and the peeling bark of the tree are of a light silvery brown, covered with little blackish marks.

* "This very distinct species is very active after sunset, running with great speed, and leaping like an *Attus*. It is motionless during the day." *Loc. cit.*, p. 112.

† *New England Theridiidæ*, p. 67.

‡ *Preussische Spinnen*, p. 142.

On the bark these marks are, of course, irregular, while on the spider they form a pattern made up of straight and curved lines and dots, the legs being silvery, barred with blackish.

Another little Theridion that is found on birch bark has the same colors arranged a little differently. The abdomen above has a large and peculiarly irregular black patch, which shades off into mottled brown and black on the sides and below. The cephalothorax has stripes of brown and black, and the legs are barred with light and dark brown.

Spiders that live upon walls, fences, tree trunks, or on the ground harmonize in color with the surfaces upon which they are found, being usually gray, brown or yellow, mottled with black and white. This proposition is so well established* as to need but few illustrations. The Theridiidæ furnish many examples, as T. murarium, a gray spider varied with black and white, said by Emerton to live usually "under stones and fences, where it is well concealed by its color"; and Lophocarenum rostratum, a yellowish brown spider, found among leaves on the ground. Among the Attidæ bright sexual coloring often gains the ascendancy over the protective tints, yet this family gives us good examples in such species as M. familiaris and S. pulex.

To these may be added an as yet undescribed species which we discovered last season in a neighborhood that we had searched thoroughly for eight summers. We found the new spider in great numbers, but could only detect it by a close scrutiny of the rail fences on which it lived, its color being dark gray.

Among the Lycosidæ we have scores of dull-colored species that live on the ground. Vinson refers to L. vulcani, which is of a smoky black color and which lives in the crater of a volcano, saying: "Its sinister color seems to conform to its

* Dr. McCook says: "Spiders that nest in stables, houses, on fences, etc., ordinarily have dusky colors harmonious with the environment."—*Notes on Relations of Structure and Function to Color Changes in Spiders*, Proc. Acad. of Natural Sciences of Philadelphia, 1888, p. 174. See also *Cenni sulle colorazioni e forme mimetiche utili nei ragni*, by Prof. P. Pavesi, in *Atti d. Società Ital. d. Scienze Naturali*, Vol. XVIII, 1875.

habitat." * A more peculiar example is *D. sex-punctatus*, which is said by Dr. McCook to have a tint like that of the water upon which it is constantly found.†

In the Thomisidæ we find the rule holding good through whole genera with scarcely an exception, as with Xysticus and Synema, whose members, colored yellowish brown or gray, haunt fences and tree-trunks. These spiders, moreover, often have the body very much flattened, so that they the more easily escape notice and can readily conceal themselves by slipping into cracks and crevices.

In the Drassidæ we have the same resemblance, as in H. ecclesiasticus, a gray spider found running on walls, and in H. bilineatus, whose distinct black and white would seem to render it conspicuous, but really have the opposite effect on the stony beaches where it is found.

A spider of another family, Hersilidia lucasii, is spoken of by Cambridge as follows: "Their position is usually with the legs extended flat upon the under side of the stone, with the sandy-yellow, mottled color of which the color of the spider so admirably agrees that it requires a practiced eye to detect it." ‡

Another general rule is that spiders living in dark places are dull-colored, usually having more or less livid white, mingled with gray, as Pholcus phalangoides, which is pale with dark bands, and is common in cellars; or Meta menardi, which is dull brown and yellow with light stripes, and lives in damp, shady places or in caves. Many species of Clubiona come under this head. They have commonly pale or livid coloring and are found under bark or stones, in caves, etc.

Turning from these to the brightly colored spiders the most obvious instances of protective coloring are the green species which live on leaves. Such are Lyssomanes viridis and many other Lyssomanæ, which are of a faded yellow color in

* *Loc. cit.*, p. 16.

† *Loc. cit.*, p. 174.

‡ *Catalogue of a Collection of Egyptian Spiders*, Proc. Zool. Soc., 1876, p. 563.

alcoholic specimens, but which, I am told by Mr. Herbert Smith, are of a bright green in their tropical homes. Olios viridis and Linyphia viridis* come under this class. The former is entirely "of a tender yellowish green" and is found on the leaves of orange trees. The latter has both male and female of a tender green color and is found on the leaves of rose bushes.

Pavesi enumerates the following green species which live on leaves: *Micromata virescens* (*Cl.*), *Epeira cucurbitina* (*Cl.*), *Theridium viride Nic.*, *Dictyna viridissima* (*Wlk.*), *Clastes viridis Wlk.*, *Peucetia viridis* (*Blkw.*), *Attus pistacius.*†

The spiders which imitate the colors of flowers are found, to a great extent, among the Thomisidæ; and here a point of interest must be noted. The resemblance of Epeiridæ and Theridiidæ to the surfaces upon which they are found are simply protective. It is useful in preserving the spider from enemies, but does not assist it in capturing prey. In the Thomisidæ, on the other hand, the protective disguise serves a double purpose, and it seems probable that it is fully as great an advantage to them to deceive their prey as their enemies.

No family can show more brilliant and beautiful colors than the Attidæ. Wallace speaks of them in the tropics as being so exquisitely colored as to resemble jewels rather than spiders.‡ Yet no cases have been cited in which spiders of this family imitate the colors of flowers; and from what we know of the mating habits of our own bright colored Attidæ there can be little doubt that these jewel-like spiders also owe their beauty to sexual, and not to natural selection.

It is probably to Thomisidæ that Bates refers when, in speaking of spiders with showy colors, he says: "Some double themselves up at the base of leaf-stalks, so as to resemble flower buds, and thus deceive insects on which they prey;" § and again: "Some hunting spiders mimic flower buds and sta-

* Vinson, *Loc. cit.* pp. 103 and 277.

† *Loc. cit.*, p. 2.

‡ *Tropical Nature*, p. 97.

§ *Loc. cit.* p. 54.

tion themselves motionless in the axils of leaves and other parts of plants to wait for their victims." *

Mr. Herbert Smith also refers to this habit. He says: "Some of the spiders, we find, are excellent imitators. The cylindrical species lie extended in their webs, with the legs stretched out, to look like a stick; round-bodied kinds draw their legs close and look like a leaf-bud, or a ball of their own silk entangled in the web. * * How shall we notice this one that sits on a leaf, all in a heap; the pink three-lobed body appears just like a withered flower that might have fallen from the tree above; to the flies, no doubt, the deception is increased by the strong, sweet odor of the spider, like jasmine."†

Trimen gives several instances in which Thomisids mimic flowers. He says: "Many species of *Thomisus* are well adapted to succeed by being colored in resemblance to the flowers in or on which they await the arrival of their victims. One that inhabits Cape Town is of the exact rose-red of the flowers of the oleander; and to more effectually conceal it, the palpi, top of cephalothorax, and four lateral stripes on the abdomen, are white, according remarkably with the irregular white markings so frequent on the petals of *Nerium*.

"I was led to notice a yellow spider of the same group, in consequence of seeing that two of a number of butterflies on the flowers of *Senecio pubigera* did not on my approach fly off with their companions. Each of these unfortunates turned out to be in the clutches of a spider, and when I released them I observed their captors very narrowly, and I found that the latters' close resemblance to the *Senecio* flowers was not one of color alone, but due also to attitude. This spider, holding on to the flower-stalk by the two hinder pairs of legs, extended the two long front pairs upward and laterally. In this position it was scarcely possible to believe that it was not a flower seen in profile, the rounded abdomen representing the central mass of florets, and the extended legs the ray florets; while, to complete the illusion,

* *Lepidoptera of the Amazon Valley*, *Trans. Linn. Soc.*, Vol. XXXIII, p. 509.

† *Loc. cit.*, p. 221.

the femora of the front pair of legs, adpressed to the thorax, have each a longitudinal red stripe which represents the ferruginous stripe on the sepals of the flower.

"On another occasion I witnessed the actual capture of a small blue butterfly (*Lycœnesthes*) by a white spider of the same genus. The butterfly was engaged in honey-sucking on a white flower-head of *Lantana*, and explored each individual flower with its proboscis. While I was watching it, the butterfly touched and partly walked over what looked like a slightly folded or crumpled flower about the middle of the cluster. This turned out to be a spider, which instantly seized the butterfly, throwing forward its front legs somewhat after the fashion of a Mantis. In this spider the effect of the little depressions on the limb of the corolla was given by some depressed lines on the back of its smooth white abdomen." *

Among our own Thomisidæ we have a pretty example of flower copying in Misumena vatia, a very variable little spider, which is usually golden yellow, living upon the yellow flowers of our fields. Sometimes it is light green, when it is found upon low trees and bushes, and sometimes light pink, living upon wild roses. Each variety is a perfect match, in color, for the leaves upon which it is found. Pavesi says that this species when living on flowers is white, or white or yellow with red stripes on the abdomen; but that when found among the grass it is grass-green, with dark, obscure stripes on the cephalothorax and palpi.†

Bright spiders seem to feel the necessity of keeping out of sight more than dull-colored ones. Thus such bright Epeiridæ as insularis keep hidden, during the day, in tents by the side of the web, only coming down into the center at night. Bright Theridiidæ, as frondeum, usually live under leaves. This seems to hold even with Attidæ. I have noticed among those kept in captivity that while the dull-colored ones ran about in the box,

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* Roland Trimen, *Protective Resemblances and "Mimicry" in Animals*, p. 4.

† *Loc. cit.*, p. 5.

the brilliant male splendens passed his entire time curled up in a corner under a sheet of web, seeming very morose and sulky.

Cambridge notices a peculiar case of protective resemblance among the Thomisidæ. This is T. setiger, whose abdomen, covered with spines and bristles, is whitish mingled with yellow. He says: "The peculiar clothing of long, pale spines and bristles affords an evident protection to this and the preceding species (T. buffoni), making them look exactly like bits of coarse, fleecy wool, or the rough seeds of some plant or other; had I not observed them moving, they would probably have escaped notice." *

The last instance that I shall cite is a predaceous spider which is disguised from both its enemies and its prey by an elaborate combination of form, color, position and character of web. I refer to Ornithoscatoïdes decipiens (fig. 7), first described by Forbes and afterwards by Cambridge, the latter author giving in the same paper descriptions of three other species of the same genus, whose habits have not been noted, but whose protection is evidently of the same order as that of decipiens. I give Forbes' interesting account of his capture of decipiens, quoting also the remarks by which Cambridge prefaces his description, since his explanation of the gradual development, through Natural Selection, of the spider's deceptive appearance applies as well to all the cases of protective disguise which have been here enumerated.

Fig. 7. — Ornithoscatoïdes decipiens (from Cambridge).

The capture is described as follows:

"On June 25th, 1881, in the forest near the village of Lampar, on the banks of the Moesi river in Sumatra, while my 'boys' were procuring for me some botanical specimens from a high tree, I was rather dreamily looking on the shrubs before me,

* *Spiders of Palestine and Syria*, Proc. Zool. Soc., 1872, Part I, p. 308.

when I became conscious of my eyes resting on a bird-excreta-marked leaf. How strange, I thought, it is that I have never got another specimen of that curious spider I found in Java which simulated a patch just like this! I plucked the leaf by the petiole while so cogitating, and looked at it half listlessly for some moments, mentally remarking how closely that other spider had copied nature, when, to my delighted surprise, I discovered that I had actually secured a second specimen, but the imitation was so exquisite that I really did not perceive how matters stood for some moments. The spider never moved while I was plucking or twirling the leaf, and it was only when I placed the tip of my little finger on it, that I observed that it was a spider, when it, without any displacement of itself, flashed its falces into my flesh.

"The first specimen I got was in W. Java, while hunting one day for Lepidoptera. I observed a specimen of one of the Hesperidæ sitting, as is often a custom of theirs, on the excreta of a bird on a leaf; I crept near it, intending to examine what they find in what one is inclined to consider incongruous food for a butterfly. I approached nearer and nearer, and at last caught it between my fingers, when I found that it had as I thought become glued by its feet to the mass; but on pulling gently the spider, to my amazement, disclosed itself by letting go its hold; only then did I discover that I was not looking on a veritable bird's excreta. * * The spider is in general color white, spotted here and there with black; on the underside its rather irregularly shaped and prominent abdomen is almost all white, of a pure chalk white; the angles of the legs are, however, shining jet-black. The spider does not make an ordinary web, but only the thinnest film on the surface of the leaf. The appearance of the excreta rather recently left by a bird on a leaf is well known. There is a pure white deposit in the centre, thinning out round the margin, while in the central mass are dark portions variously disposed; as the leaf is rarely horizontal, the more liquid portions run for some distance. Now, this spider one might almost imagine to have in its rambles 'marked and

inwardly discerned' what it had observed, and to have set about practicing the 'wrinkles' gained; for it first weaves a small, irregular patch of white web on some prominent leaf, then a narrow streak laid down towards its sloping margin ending in a small knob; it then takes its place on the center of the irregular spot on its back, crosses its black-angled legs over its thorax, and waits. Its pure white abdomen represents the central mass of the bird's excreta, the black legs the dark portions of the slime, while the web above described which it has spun represents the more watery marginal part (become dry), even to the run-off portion with the thickened knob (which was not accidental, as it occurred in both cases), like the residue which semi-fluid substances ending in a drop leave on evaporation. It keeps itself in position on its back by thrusting under the web below it the spines with which the anterior upper surfaces of the legs are furnished."*

In answer to the idea that the supplementing of the color and form of the spider by its peculiar web almost implies consciousness,† Cambridge says:

"It seems to me, on the contrary, that the whole is easily explained by the action of Natural Selection, without supposing consciousness in the Spider in any part of the process. The web on the surface of the leaf is evidently, so far as the Spider has any design or consciousness in the matter, spun simply to secure itself in the proper position to await and seize its prey. The silk, which by its fineness, whiteness, and close adhesion to the leaf causes it to resemble the more fluid parts of the excreta, would gradually attain those qualities by Natural Selection, just as the Spider itself would gradually, and probably *pari passu*, become, under the influence of the same law, more and more like the solid portion." ‡

We may repeat, in regard to this species, what Wallace has

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* On the habits of *Thomisus decipiens*, by H. O. Forbes, Proc. Zool. Soc., 1883, p. 586.

† Mr. Forbes has especially disclaimed any idea of consciousness on the part of the spider.

‡ *On two new Genera of Spiders*, Proc. Zool. Soc., 1884, p. 197.

said about a butterfly which imitates a shrivelled leaf: "We thus have size, color, form, markings, and habits, all combining together to produce a disguise which may be said to be absolutely perfect." *

PROTECTIVE HABITS.

Going along with these forms of protective resemblance, we find certain habits which sometimes serve independently to protect the spider, but oftener are supplemental to color and form. Many species hide in crevices or in leaves which they roll up and bind together at the edges. In the Epeiridæ some are like thaddeus, which makes a little tent of silk under a leaf near its web. The young thaddeus also makes a tent, but spins its little geometrical web on the under side of the leaf, the edges being bent downward. E. insularis has the more common habit of forming its tent by drawing the edges of two or three leaves together with strands of web; in this it sits all day, but at night descends and occupies the center of the web during the hours of darkness. I have often found it in this position when hunting nocturnal species by lantern light. It is probable that in tropical countries the monkeys, and perhaps the birds, which devour these large Epeiridæ have learned to recognize their webs, which are very large and conspicuous, and to trace them to their hiding places close by; and thus may have arisen the curious habit noticed by Vinson as possessed by E. nocturna and E. isabella of destroying the web each morning and rebuilding it at night;† the spider in this way gaining greater security from diurnal enemies.

Atypus abbotii builds a purse-shaped tube which is found attached to the bark of trees, and which has the external surface dark and covered with sand.‡ The trap-doors which close the nest of some of the Territelariæ are wonderful examples of

* *Natural Selection*, p. 61.

† *Loc. cit.*, p. CXIII.

‡ For a complete account of this species see *Nesting Habits of the American Purseweb Spider*, by Rev. Henry C. McCook, Proc. Acad. Nat. Science of Philadelphia, 1888, p. 203.

protective industry. They fit with such absolute accuracy into the openings of the nests and are so covered on the upper side with moss, earth, lichens, etc., as to be indistinguishable from the surrounding surface.

The rectilinear lines which are stretched in front of the webs of many Epeirids are useful in taking and sending on to the spider the shock which tells of an approaching enemy. Some spiders, when danger threatens, shake the web so violently as to grow indistinct to the eye, and others, as Pholcus atlanticus, hang by the legs and whirl the body rapidly with the same bewildering result.

Mr. Herbert Smith gives me the excellent suggestion that the sideways movement of the Thomisidæ, or Laterigradæ, has a direct protective value, since the enemies of spiders are accustomed to allow for a forward, but not for a lateral movement of their prey.

A habit common to many spiders, especially among the Epeiridæ, is that of dropping to the ground at the approach of danger and resting motionless among the dirt, sticks, leaves, etc., which they resemble in color. The holding of the body in some peculiar position, as in Uloborus, Hyptioides, and the flower-like Thomisidæ, is a necessary accompaniment to the color modification.

The cocoons of spiders are seldom left exposed and unprotected. We find them in corners and crevices, concealed in rolled up leaves or under bark. Very often the cocoon itself is covered over with a sheet of web. In some families the mother carries it about with her attached to the underside of the abdomen. In others she carries it in her falces until the young are hatched. The cocoons of others, as Uloborus, Argyrodes, etc., while hung out in the web are still concealed by deceptive form and color, or by being covered with rubbish.

Cambridge speaks of A. brunnea, whose cocoons "are covered over very soon after they are made and the eggs deposited in them, with a coating of clay, which effectually destroys all their form and beauty. This coating of clay answers probably two ends: first, the concealment of the cocoon and its protection from

insect enemies; and, secondly, the protection of the eggs from the too powerful rays of the sun, dry clay being (as is well known) one of the best non-conductors of heat." *

The peculiar cocoon of C. bisaccata is described by Emerton† as follows: "Only one specimen of this (*bisaccata*) was found on a beech tree at New Haven with two cocoons. These were dark brown, as dark as the bark of the tree and as hard. Around the middle of each was a circle of irregular points. One of the cocoons was attached by a strong stem to the bark, and the other was attached in a similar way to the first cocoon. The spider held on to one of the cocoons." In this instance the egg has evidently the same protection as that possessed by the gray, bark-haunting spiders, with the added advantage of hardness.

The habit of distributing the eggs through a number of cocoons made at intervals of several days, is protective. In this way, although one or two of the cocoons may be pierced by the ichneumon, there is a chance that part of the brood may survive. ‡

INDIRECT PROTECTION.

The indirectly protected group includes those spiders which are rendered inedible by the possession of sharp spines and chitinous plates, and also those that mimic other specially protected creatures.

The females of the specially protected group are characterized by the following attributes:

Their inedibility, which they owe to a more or less coriaceous epidermis and an armature of strong sharp spines (fig. 8, see p. 95).

Their brilliant colors—glistening black and white, yellow, fiery gold, metallic silver, rose-color, blue, orange and blood-red.

* *Ann. and Mag. of Nat. Hist.*, Feb., 1887, p. 113.

† *New England Epeiridæ*, p. 325.

‡ *E. sancta benedicti* Vinson makes as many as thirteen cocoons. Vinson, *loc. cit.*, p. 204. *Cyrtophora bifurca* McCook sometimes makes fourteen, which, like the mother-spider, are light-green in color. *Proc. Acad. of Nat. Sci. of Philadelphia*, 1887, p. 342.

Their habit of hanging always exposed in the center of the web.

In an interesting discussion of the protective value of color and marking in insects, Poulton says that "the smaller convergent groups of nauseous insects often present us with ideally perfect types of warning patterns and colors — simple, crude, strongly contrasted—everything subordinated to the paramount necessity of becoming conspicuous," the memory of enemies being thus strongly appealed to.

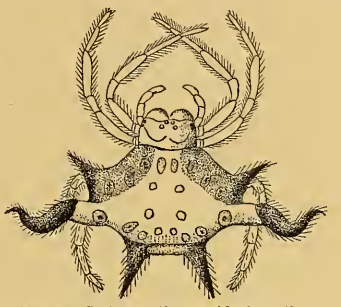

Fig. 8. — Gasteracantha crepidophora (from Cambridge).

This proposition is well illustrated by the Gasteracanthidæ. Among larvæ the warning colors are almost invariably black and white, or black (or some very dark color), in contrast with yellow, orange and red.* These are the colors that also constantly recur among the Gasteracanthidæ.

I will cite a few species as illustrative of the general coloring in the group.

G. lepida Camb., Proc. Zool. Soc., 1870, p. 821. "The upperside is of a bright, rich, orange yellow, with two broad parallel transverse bands of blood-red tinged with carmine. * * * The abdomen might almost be described as alternately barred on the upper side, with transverse bars of red and yellow."

Phoroncidia aurata Camb., (Plate III, fig. 4). Referred to by Butler, Proc. Zool. Soc., 1882, p. 766, as follows: "Four examples of this rare and extremely beautiful species were obtained. * * Two of these are typical, their abdomen being

* *Experimental Proof of Protective Value of Color and Markings in Insects*, by E. B. Poulton, Trans. Ent. Soc., 1887, p. 230.

*Poulton, *loc. cit.*, p. 231.

of a fiery golden color, with black spines upon red bases; the two others are considerably larger, and the abdomen is of a metallic silver color, the spines black with red-brown bases and the ocellations black."

Paraplectana thorntoni Blk., referred to by Cambridge, Proc. Zool. Soc., 1879, p. 293.

"The jet-black ground-color of the abdomen, with its somewhat raised, large and conspicuous bright-yellow markings, and yellow cephalothorax, render it one of the most striking and handsome known spiders of this family."

G. alba Vinson, *loc. cit.*, p. 240. Milk-white, with the glisten and polish of porcelain. A dorsal stripe of a beautiful black in the middle, dividing the shell into two equal parts.

G. helva Blk., described by Cambridge. Proc. Zool. Soc., 1879, p. 287. Yellow or yellow-brown, with the spines of a deep, rich, shining steel-blue color.

The Gasteracanthidæ are not all brilliantly colored; many are of a light écru tint, with black spots and spines, but even in these the smooth, glistening character of the shell gives them a certain degree of brightness.*

Cases that may be more justly considered exceptions to the rule that these hard, uneatable spiders are conspicuous are such species as Acrosoma rugosa (fig. 9, see p. 97). One of this species was sent me by Mrs. Treat last summer. It lived for several weeks in my window, making no regular web, but hanging among a few irregular strands. It ate nothing, although provided with insects, but drank greedily of water. It might seem that its black and white coloring would make it conspic-

*Alcoholic specimens of this group usually lose their bright colors. Thus we have a number of species described by Cambridge (Proc. Zool. Soc., 1879) as "dull yellowish-brown," "blackish-brown," etc., but the author warns his readers that in his opinion alcoholic and more especially dried specimens of Gasteracanthidæ lose their original brightness. He says: "We are probably therefore, in nine cases out of ten, totally ignorant of the true colors and markings of the Gasteracanthides." P. 280.

He then goes on to note, in proof of this proposition, the case of an African species which had been described as of a uniform, dull, muddy, brown hue, which, in life, has a shade of "the loveliest and most delicate yellow, scalloped at the edges, where occurs a dainty moulding of blue."

uous, but in connection with its irregular shape and its way of hanging motionless in the web it had the opposite effect.

We have no reason to suppose that the class represented in rugosa is like that touched upon by Poulton, in which very protectively colored larvæ suddenly assume a terrifying aspect on the near approach of an enemy; still they do enjoy a kind of double protection. They are inconspicuous, and thus likely to escape attack, but in case they are attacked they have still the advantage of being quickly rejected. This experience cannot be as fatal to them as to the soft and thin-skinned larvæ. Their hard covering and projecting spines would protect them to such an extent as to give them a fair chance of surviving.

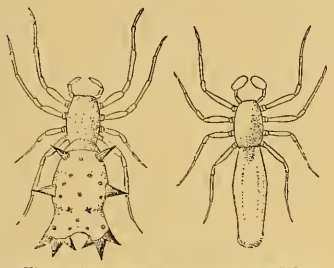

Fig. 9.—Acrosoma rugosa. Left-hand figure female, right-hand figure male (from Emerton).

In one respect the inconspicuous Gasteracanthidæ have a decided advantage over their bright colored relatives. The birds, indeed, avoid the conspicuous ones, but their brilliancy serves to attract another enemy against which spines are no protection—the hunter wasp, which, as we have seen in the work of Bates, sometimes provisions its nest wholly with spiders of this family. Mr. Smith gives like testimony, saying:

"Spines on the abdomen of certain spiders would serve as a protection against vertebrate enemies, though they do not protect against the hunter wasps, which frequently provision their nests with these species." He adds, however, that most of the spiny spiders are common, and that their colors make them conspicuous; just as butterflies that are protected by an odor are common and bright-colored.*

*Letter on Enemies of Spiders.

Taczanowski says that A. horrida (Pl. III, fig. 5,) is very like rugosa, and adds that he considers this species as transitory between Epeira and Acrosoma.

Cambridge remarks upon the great variability in the length and direction of the spines in individuals of the same species of Gasteracantha.* Vinson notices the same character in regard to the color of at least one species.† That variability in the spines is found also in Acrosoma, is illustrated in Plate III, where figures 1 and 3 represent extreme forms of the female of A. spinea, the former being found in the northern and the latter in the southern part of the United States. A. oblonga (fig. 6) is given to show the sharpness of the spines in some of these species.

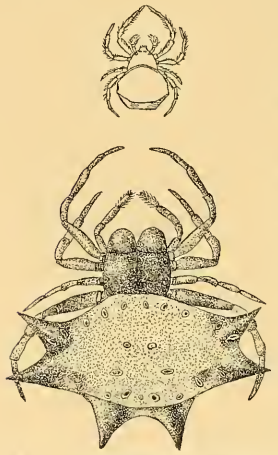

Fig. 10.—Gasteracantha rufispinosa. Upper figure male, lower figure female (from Marx).

The sexes in Gasteracantha and Acrosoma are entirely different. The males are small, sometimes very minute, and lack both the spines and the brilliant color of the females (fig. 10, and Plate III, figs. 1, 2 and 3). Indeed, they resemble the females so little that for many years the relations between the two were undiscovered. In the genus Gasteracantha, up to so late a date as 1879, only two males had been described, against one hundred and seventy females.‡

This disparity has come about through the different habits and functions of the female. Wallace has shown that among insects the females often acquire protective colors which are

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*Proc. Zool. Soc., 1879, p. 279.

† *Loc. cit.*, p. 241.

‡ Cambridge, *Proc. Zool. Soc.*, 1879, pp. 279 and 281.

lacking to the males, because long life in the females is of greater importance to the species than long life in the males.*

This applies also to the Gasteracanthidæ where the females are much larger, much more inedible, and much more conspicuous than the males. Wallace, however, limits his proposition to cases where the modification is for concealment, and illustrates it by instances among butterflies where the female alone mimics some nauseous species. The Gasteracanthidæ are an exception to his rule, that in groups which have a protection of any kind independent of concealment, sexual differences of color are either quite wanting or slightly developed.† That I do not misinterpret his meaning is shown by the fact that after stating this rule he goes on to enumerate several cases in which specially protected species have the sexes almost or quite alike.

In Gasteracantha and Acrosoma the habits of the female as well as her functional importance call for some special protection. She is much exposed, remaining in her web all the time, while the male passes most of his life in concealment. Thus the female of A. spinea, though not so gaudily colored as many others, is easily recognized, and is constantly seen on low bushes during the summer. At about the first of August the males appear, quite suddenly and in large numbers, and may be seen running about the leaves and branches near the webs of the females. Toward the end of the month they disappear. Acrosoma and Gasteracantha are so near together that this tends to prove the correctness of Cambridge's surmise that the males of the latter genus are short-lived.‡

* "The comparative importance of the sexes varies much in different classes of animals. In the higher vertebrates, where the number of young produced at a birth is small and the same individuals breed many years in succession, the preservation of both sexes is almost equally important. * * * In insects the case is very different; They pair but once in their lives, and the prolonged existence of the males is in most cases quite unnecessary for the continuance of the race. The female, however, must continue to exist long enough to deposit her eggs in a place adapted for the development and growth of her progeny. Hence there is a wide difference in the need for protection in the two sexes; and we should therefore expect to find that in some cases the special protection given to the female was in the male less in amount or altogether wanting." A. R. Wallace, *Natural Selection*, p. 112.

† *Loc. cit.*, p. 113.

‡ This shortness of life is common in the males of the Attidæ. In several species it is almost impossible to find the male, which is very common earlier in the season, after the first of August, although the females are still numerous.

In at least two genera of the Gasteracanthidæ, then, there is a difference between the sexes, which is the result of the inheritance of special protective modifications by the female alone.

In replying to Wallace's theory that color differences between the sexes are due to the keeping down for protective purposes of the color of the female, Darwin says: "I do not wish to deny that the female alone of some species may have been specially modified for protection."* In most cases when the female is dull and the male bright colored it is difficult or impossible to show that the difference has resulted from the greater need of protection in the female. The difference in the Gasteracanthidæ, however, is just such a case as was referred to by Darwin, since it is unquestionably due to natural and not to sexual selection.

The young of Gasteracantha and Acrosoma present certain pecularities. Darwin's propositions in regard to differences between the two sexes in birds are as follows:

"Whenever and in whatever manner the adult male differs from the adult female, he differs in the same manner from the young of both sexes. * * *

"When, on the other hand, the adult male closely resembles the young of both sexes (these, with rare exceptions, being alike), he generally resembles the adult female."†

Acrosoma and Gasteracantha are not included in these rules, since although the young are alike at the very first, both resembling the adult male, the young females very early begin to vary toward the form and color of the adult female; so that we have the young males and females resembling the adults of the same sex, while the adult male and female differ greatly from each other.

Darwin notes the occasional occurrence of such cases as this in the following words:

"As variations occurring late in life, and transmitted to

*Descent of Man, p. 321.

†Loc. cit., pp. 232, 233.

one sex alone, have incessantly been taken advantage of and accumulated through sexual selection in relation to the reproduction of the species; therefore, it appears at first sight an unaccountable fact that similar variations have not frequently been accumulated through natural selection, in relation to the ordinary habits of life. If this had occurred the two sexes would often have been differently modified, for the sake, for instance, of capturing prey, or escaping from danger. Differences of this kind between the two sexes do occasionally occur, especially in the lower classes. But this implies that the two sexes follow different habits in their struggles for existence, which is a rare circumstance with the higher animals."*

In the Gasteracanthidæ we have the necessary conditions for the production, by natural selection, of a difference between the sexes early in life, *i. e.*, the habits of the sexes are distinctly different, the males living in some place of concealment, while the females soon begin to sit exposed in the web. It is naturally of the greatest importance that the young females, while adopting the habits of the adults, should acquire also her special protection of form and color.

The variation in the female, although entirely due to natural selection, probably first occurred in the adult, since variations occurring early in life tend to be inherited by both sexes.

MIMICRY.

Mimicry, or the imitation of animal forms, while it is a form of indirect protection, differs in no essential respect from the imitation of vegetable and inorganic things. As Bates has said, the object of mimetic tendencies is disguise, and they will work in any direction that answers this purpose.†

In nearly all respects spiders come under the three laws given by Wallace, as governing the development of mimetic resemblances in several large classes. These laws are as follows:

1. In an overwhelming majority of cases of mimicry, the

Loc. cit., p. 241.

†*Lepidoptera of the Amazon Valley*, Trans. Linn. Soc., Vol. XXIII, p. 514.

animals (or the groups) which resemble each other inhabit the same country, the same district, and in most cases are to be found together on the very same spot.

2. These resemblances are not indiscriminate, but are limited to certain groups, which, in every case, are abundant in species and individuals, and can often be ascertained to have some special protection.

3. The species which resemble or "mimic" these dominant groups, are comparatively less abundant in individuals, and are often very rare.*

The second and third of these laws are confirmed by what we know of mimetic resemblances among spiders. They mimic ants much oftener than other creatures, and ants are very abundant, are specially protected, and are much more numerous than the mimetic spiders. To the first law, also, they conform to a great extent, since everything tends to show that in tropical America and in Africa the ant and the spider, the one mimicked and the other mimicking, are always found together. So far as I can discover, however, the ant-like spiders of North America, are not found in company with any species of ant which they resemble. This may be because they do not mimic any particular species, but only the general ant-like form; or, considering that the genera which contain their nearest relatives are much more abundant in Central and South America, it may be that these forms were originally tropical, mimicking some tropical species of ants, and that after the Glacial Epoch they migrated northward, leaving the ants behind them. However this may be, their peculiar form has served them well, since they have maintained themselves as fairly abundant species with a lower fecundity than is found in any other group of spiders.

The cases in which one species mimics another may be divided, according to the kind of benefit derived, into four classes: Class 1. As a rule, where we find one species mimicking another, the mimicked species possesses some special means

Natural Selection, p. 76.

of defense against the enemies of both. This defense may consist of a disagreeable taste or odor, as in the Heliconidæ, which are mimicked by other butterflies; of some special weapon of offense, as where wasps and bees are mimicked by flies and moths, or posionous vipers by harmless caterpillars; or of a hard shell, as where the coriaceous beetles are mimicked by those that are soft-bodied.

Instances of this rule are exceedingly numerous; indeed, Wallace says that specially protected forms are always mimicked; still we have nothing mimicking our Gasteracanthidæ.

Class 2. The mimetic may prey upon the mimicked species, its disguise enabling it to gain a near approach to its victims; as the mantis, mentioned by Bates as exactly resembling the white ants upon which it feeds; and the flies which mimic bees, upon which they are parasitic, and are thus able to enter the nests of the bees and lay eggs on the larvæ.

Class 3. The mimetic species may, by its imitation, be protected from the attacks of the creature it mimics, as is the case with the crickets and grasshoppers which mimic their deadly foe, the hunter wasp.

Class 4. The mimetic species may prey upon some creature which is found commonly with and is not eaten by the mimicked species.

No two of these classes are mutually destructive so that in any case of mimicry a double advantage may be gained.

Let us see which of these advantages has directed the development of mimetic tendencies among spiders.

While among beetles and butterflies we most commonly find mimicry of one species by another within the same order, we have no instance of a spider mimicking another spider.* This may be accounted for by the fact that the specially protected spiders depend for their safety upon the possession of hard plates and spinous processes, and although the hardened epidermis might be imitated (we know that hard-shelled beetles

* The spiders instanced by Pavesi (*loc. cit.*, p. 7) which resemble other genera rather than their own, such as *Nephila tetragnathoides*, *Tetragnatha epeirides*, etc., cannot, it seems to me, be classed properly under mimicry.

are mimicked by others that are soft), spines could scarcely be imitated by a soft-bodied creature with sufficient accuracy to insure disguise.

While spiders most commonly mimic ants, we hear also of their imitating beetles, snail-shells, ichneumons and horse-flies. There is also a curious Madagascar species which looks exactly like a little scorpion, the resemblance being heightened by its habit of curving its flexible tail up over its back when irritated.

Those that resemble beetles comprise nearly all the species of the genera Coccorchestes and Homalattus. These are small spiders with short, convex bodies. The abdomen fits closely over the cephalothorax and the epidermis, which has usually a metallic lustre, is sometimes coriaceous. Striking examples are found in H. coccinelloides, which bears a strong resemblance to beetles of the family Coccinelloidæ and in C. cupreus, in which certain marks on the abdomen imitate the elytra of beetles.

The following account of a spider which mimics a snail-shell is given by Mr. G. F. Atkinson:

"An undescribed species of *Cyrtarachne** mimics a snail-shell, the inhabitant of which, during the summer and fall, is very abundant on the leaves of plants in this place. In the species of *Cyrtarachne* the abdomen partly covers the cephalothorax, is very broad at the base, in this species broader than the length of the spider, and rounds off at the apex. When it rests upon the under side of a leaf with its legs retracted it strongly resembles one of these snail-shells by the color and shape of its abdomen. The two specimens which I collected deceived me at first, but a few threads of silk led me to make the examination. The spider seemed so confident of its protection that it would not move when I jarred the plant, striking it several hard blows. I pulled the spider forcibly from the leaf, and it did not exhibit any signs of movement until transferred to the cyanide bottle." †

*C. multilineata.

†*New Instances of Protective Resemblances in Spiders*, American Naturalist, June, 1888, p. 545.

Cambridge, in the *Enc. Brit.*, says that a species of Cyrtarachne, found in Ceylon, resembles a small mollusc and that some of the genus Erysoma are very like a minute crab, giving E. cabindæ as an example. But he does not seem to imply that the crabs are actually mimicked, and he gives no details. Stoliczka describes a small Xysticus which both in form and color strongly resembles a minute crab, but the habits of the spider, which was always found inside of flowers, preclude any idea of mimicry.

Trimen gives an account of the imitation, by spiders, of horseflies, a case falling into class 2, as follows:

"Hunting spiders are in some cases very like their prey, as may everywhere be noticed in the case of the species of *Salticus* which catch horseflies on sunny walls and fences. The likeness is not in itself more than a general one of size, form and coloring; but its effect is greatly aided by the actions of the spider, which walks hurriedly for short distances, stopping abruptly, and rapidly moving its falces, in evident mimicry of the well-known movements so characteristic of flies."

Instances of spiders mimicking ants are very numerous, and in many cases the resemblance is so close as to, at first sight, deceive a trained naturalist. This resemblance is brought about by the spider's body being elongated and strongly constricted, so that it appears to be composed of three segments instead of two, by the color, by the way in which the spider moves about, zig-zagging from side to side like an ant, and by its habit of holding up one pair of its legs and moving them in such a way that they look exactly like the antennæ of an ant.

Ants may be regarded as specially protected, by their sharp, acid flavor, and in some species by the possession of stings or of horny processes.

On the ground that there are birds which do eat ants, and eat them greedily, it has been thought by some naturalists that they cannot be considered specially protected creatures, and that, as spiders can therefore derive no protection from mim-

icking them, all cases of such mimicry depend upon the spider's increased ability to capture the ants as prey, but I am convinced that this is too hasty a conclusion. It is unquestionably true that some birds feed almost exclusively upon ants, but these are the exceptions. It is a common thing to find that specially protected groups, which are safe from the attacks of most creatures, have their special enemies. Thus, even the nauseous Heliconidæ are preyed upon by certain spiders and wasps; and bees, in spite of their stings, are preferred to other insects by the bee-eaters. Moreover, the ant-devouring birds are found largely among the wood-peckers, which eat the ants that run on the trunks of trees, and are therefore not a source of danger to the ant-like spiders, the American species of which, so far as I can learn, live entirely upon the ground.

In the United States comparatively small numbers of either ants or spiders are eaten by birds, but in tropical America there are enormous numbers of humming-birds feeding almost exclusively upon spiders, and there the protective advantage of looking like ants must be of great importance to the smaller species.

Belt considers that the advantages gained by ant-mimicking Central American spiders lies entirely on the side of protection. In relation to this subject he says: "Ant-like spiders have been noticed throughout tropical America and also in Africa. The use that the deceptive resemblance is to them has been explained to be the facility it affords them for approaching ants on which they prey. I am convinced that this explanation is incorrect, so far as the Central American species are concerned. Ants, and especially the stinging species are, so far as my experience goes, not preyed upon by any other insects. No disguise need be adopted to approach them, as they are so bold that they are more likely to attack a spider than a spider them. Neither have they wings to escape by flying, and generally go in large bodies easily found and approached. The use is, I doubt not, the protection the disguise affords against small insectivorous birds. I have found the

crops of some humming-birds full of small, soft-bodied spiders, and many other birds feed on them. Stinging-ants, like bees and wasps, are closely resembled by a host of other insects; indeed, whenever I found any insect provided with special means of defense I looked for imitative forms, and was never disappointed in finding them."*

The ant-like species are probably protected by their appearance from the attacks of many of the larger spiders. We have kept great numbers of Attidæ in captivity, and, although they devoured flies, gnats, larvæ, and other spiders, they would never touch ants. Among spiders, however, as among birds, we find that certain groups subsist almost entirely upon ants.†

The class of spiders whose mimicry protects them from their enemies, whether they are birds or other spiders, probably includes at least two of our own ant-like species, Synageles picata and Synemosyna formica, which, in confinement, are always hungry for gnats, but will not touch ants, even of small size.

The existence of a class of spiders which mimic the particular species of ants upon which they prey is not to be questioned, but it is doubtful whether the benefit to the spider is increased facility in capturing the ant, or whether it is merely protective. It may be that the spider, by virtue of its resemblance to the ant, not only gets an abundant supply of food, but also escapes being eaten itself, and thus enjoys a double advantage. Both Bates and Wallace‡ take the ground that the advantage derived by

Loc. cit., p. 314.

†Dr. McCook tells me that *L. formidabilis* pitches her tent over or near the formicary of the powerful agricultural or stinging-ant of Texas, *P. barbartus*, and captures the insects as they climb the stalks of ant-rice. He also says that *T. tepidariorum* devours large numbers of ants, and he has seen them eaten by *A. fasciata*. Simon also gives an interesting account of the depredations committed upon ants by spiders of the genus Enyo, *Arachn. de France*, Vol. I, p. 243.

‡Bates says: "There are endless instances of predaceous insects being disguised by having similar shapes and colors to those of their prey; many spiders are thus endowed." *Lepidoptera of the Amazon Valley*, p. 509; and Wallace: "There is a genus of spiders in the tropics which feed on ants, and they are exactly like the ants themselves, which, no doubt, gives them more opportunity of seizing their prey." *Natural Selection*, p. 98.

the spider consists in greater ease in the capture of prey, but both of these writers refer to spiders only incidentally to illustrate a general proposition, without special consideration of their peculiar conditions.

Mr. Herbert Smith, who has paid a good deal of attention to this subject, is inclined to believe that the mimicry in question is entirely protective. He writes as follows:

"In the United States there are a few rare spiders that mimic ants. Here at Taperinha we find a good score of species of these spiders aping the various kinds of ants very closely; even the odd, spiny wood-ant, *cryptocerus*, furnishes a pattern, and there are spiders that mimic the wingless ichneumons. We find, after awhile, that the spiders prey upon ants just as our spiders catch flies; indeed, this fact has already been noted by other observers. But we go a step beyond the books when we discover not only that the spiders eat the ants, but that they eat the particular ants which they mimic. At all events, we verify this fact in a great number of cases, and we never find the spiders eating any but the mimicked species. * * * I do not like to hazard a theory on this case of mimicry. It is difficult to suppose that the quick-witted ants would be deceived even by so close a resemblance; and, in any case, it would seem that the spiders do not require such a disguise in order to capture slow-moving ants. Most birds will not eat ants; it seems likely, therefore, that this is simply another example of protection; the spider deceives its enemies, not its prey; it mimics the particular species that it feeds on, because it is seen in that company when it is hunting, and among a host of similar forms is likely to pass unnoticed." *

At first sight, and especially in view of the fact that such cases are not uncommon among insects, it would be naturally supposed that the object of the mimicry was to enable the spider to approach its victim without exciting suspicion; and it is difficult to account, on any other supposition, for the very close resemblance between certain species of spiders and the

* *Loc. cit.*, p. 223.

particular species of ants which they prey upon. It seems as though the highest point of *protective* benefit would have been reached long before the resemblance of the spider to the ant had become so close as it really is. On the other hand, it is difficult to believe that ants are deceived, even by those spiders which mimic them most closely, when we remember that their perceptions are so keen that they discriminate not only between ants of their own and different species, but even between ants of their own species living in two different communities.*

The mimicry of ichneumon flies by spiders was noted some years ago by Mr. Herbert Smith. This case comes under Class 3, in which one species mimics another which preys upon it. Great destruction is caused by ichneumons which lay their eggs on the bodies of the live spiders, and the disguise probably protects the spider by leading the fly to mistake it for one of its own species.

We have no proof that spiders ever mimic ants as a method of escaping from them, but it is possible that this sometimes happens. We know that some ants prey upon them. The foraging ants of South America destroy spiders as well as many kinds of insects, and Wallace mentions a small, wood-boring ant which fills its nest with small spiders.†

If the spiders that feed upon ants deceive them by their mimicry those which are preyed upon by ants would gain an advantage by a similar disguise. I once placed a little ant-like spider of the genus Herpyllus in a bottle with three ants no larger than itself, which I had caught with it in the sweep-net. In a very few minutes the ants had killed and began to devour the spider. It may be that the resemblance was sufficiently close to deceive them in the open, but failed when spider and ants were confined together in close quarters.

I will now give some account of an ant-like spider which we have studied closely.

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* Sir John Lubbock.

† *Tropical Nature*, p. 83.

Synageles picata (fig. 11), while not a rare spider with us, is not often caught in the sweep-net, as it usually keeps close to the ground. One hot afternoon in July, however, while sweeping on a sunny, stony hillside, sparsely covered with grass, I captured five females and one male of this species along with eight or ten ant-like beetles and a dozen or fifteen small ants of two or three different species. Being anxious to discover what relations existed between these creatures, which, though belonging to different orders, bore so strong a resemblance to each other, I put them all together in a glass-covered box. The results of this experiment were negative. The spiders, while greatly interested in each other, paid but little attention to the beetles and none at all to the ants. The ants ran wildly about and seemed to be entirely absorbed in trying to get out. The beetles took matters more philosophically and kept quiet.

Fig. 11.—Synageles picata (from nature, by Mr. L. Kumlien).

After several hours I put some gnats into the box. These were caught and devoured by the spiders. A little later I liberated the ants and beetles. The spiders lived in the box in good health and spirits for the remainder of the summer. They were very fond of heat, running about very actively as long as their box stood in the sunshine, but retiring into their little, tubular nests as soon as it became cool or cloudy.

While picata is ant-like in form and color, by far the most deceptive thing about it is the way in which it moves. It does not jump like the other Attidæ, nor does it walk in a straight line, but zig-zags continually from side to side, exactly like an ant which is out in search of booty. This is another illustration of what Wallace has shown in relation to butterflies—that that which is an important functional structure in the mimicked group may be imitated by the mimetic species, even when the habits of the latter render it perfectly

useless.* The ant only moves in this way when it is hunting; at other times it goes in a straight line; but its little imitator zig-zags always.

In addition to its ant-like walk, picata holds up its second pair of legs in such a way that they appear like antennæ. The first legs are short and support the anterior part of the body. The second pair, although it is sometimes used, seems not to be needed for locomotion. All the threatening and similar movements made by other spiders with the first pair, are, with picata, made with the second.

Spiders commonly remain nearly motionless while they are eating; picata, on the other hand, acts like an ant which is engaged in pulling some treasure-trove into pieces convenient for carrying. I have noticed a female picata which, after getting possession of a gnat, kept beating it with her front legs as she ate, pulling it about in different directions, and all the time twitching her ant-like abdomen. Pavesi says that the ant-like Drassidæ and Attidæ continually move their abdomens exactly as ants do.† I have not noticed this habit in any of our spiders excepting this species.

Picata is found in company with several small species of ants, but does not seem to resemble one more than another. It does not molest, and neither is it molested by the ants, so that the cause of its mimicry must be looked for in either Class 1 or Class 4. I should not have formed this latter class, in which it is supposed that one species mimics another because it preys upon a third species found with the mimicked form, but not eaten by it, had it not been suggested to me by the fact that when, as before related, I captured the spiders, ants and beetles together, one of the spiders (picata) was engaged in eating a tiny beetle. It may be that picata preys upon some small beetle which is not eaten by ants—possibly one of those which, undisturbed by the proprietors, inhabits their nests. In

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* *Natural Selection*, p. 91.

†*Loc. cit.*, p. 12.

this case the disguise of the spider would enable it to approach the beetle without arousing suspicion. While I give this as a possible explanation, it is improbable that any such disguise is necessary in order to capture beetles, and I think it most likely that the object of the mimicry is to preserve the spider from some enemy that would rather eat spiders than ants.

To sum up the peculiarities of picata—it is ant-like in form and color; it moves like an ant and holds up its second pair of legs to represent antennæ; it is found among ants, but neither eats them nor is eaten by them.

Fig. 12. — Synemosyna formica (from nature, by Mr. L. Kumlien).

Synemosyna formica (fig. 12) agrees in all respects with picata, unless it is in the zig-zag walk; upon that point I am unable to speak with certainty. Of formica, which is more ant-like in form and color than picata, Hentz says: "I had seen individuals of this species running on the blades of grass and stems of weeds long before I distinguished them from ants. They move with agility and can leap, but their habitus is totally different from Attus. They move by a regular progression or regular walk, very different from the halting gait of that subgenus."*

Both formica and picata hold the second pair of legs like antennæ. Many of the ant-like Epeiridæ from South America, seen in collections, have palpi that look extremely like antennæ, while their long legs can only be useful in locomotion. Belt speaks of a spider in Nicaragua which holds up its first legs like antennæ and moves them about like an ant. He also says that in one spider the palpi are lengthened and thickened so as to resemble an ant's head. The following quotation from J. P. M. Weale, shows that some African ant-like species also hold up their first legs: "The most perfect cases of mim-

*Loc. cit., p. 73.

icry I know of are two spiders (specific name unknown to me) which bear the closest resemblance to ants. They belong to the Salticidæ and are apparently related to S. formicarius. The one is smooth, black and shining and runs rapidly on the ground and bark of trees, and resembles the ant which builds its nests in Acacia horrida and is used by the Kafirs for the purpose of torture. The other is larger and has its cephalothorax dull black and its abdomen covered with short yellowish hairs. It is generally found running on the stems of herbaceous plants and small bushes and closely resembles an ant found in similar situations. The fore legs in both species are larger than the second pair and are frequently held up, when they closely resemble the antennæ of ants. So exceedingly close is the resemblance that at first sight I have nearly always taken them for the imitated ants."*

Among spiders, then, as among other arthropods, we find that some groups have reached a condition of close harmony with their environment; this harmony being brought about through the same modifications of color, form and habit as those seen among insects, the common ends of capture of prey and protection from enemies being thus attained.

*Nature, 1871, Vol. III, p. 508.

PLATE I.

Habrocestum splendens: Male and female, to show the difference between the sexes; first three moults, to show the greater resemblance of the young to the female; variety of the female.

Habrocestum peregrinum and Habrocestum auratum males, to show the departure in that sex from the general coloring of the genus; note that the female of splendens resembles these males more than she does the male of her own species.

H. splendens. ♂

H. splendens. ♀

H. splendens.
1st moult.

H. splendens.
2nd moult

H. splendens.
3rd moult.

H. splendens. var. ♀

H. peregrinum ♂.

H. auratum. ♂

From nature by Ludwig Kumlien.

PLATE II.

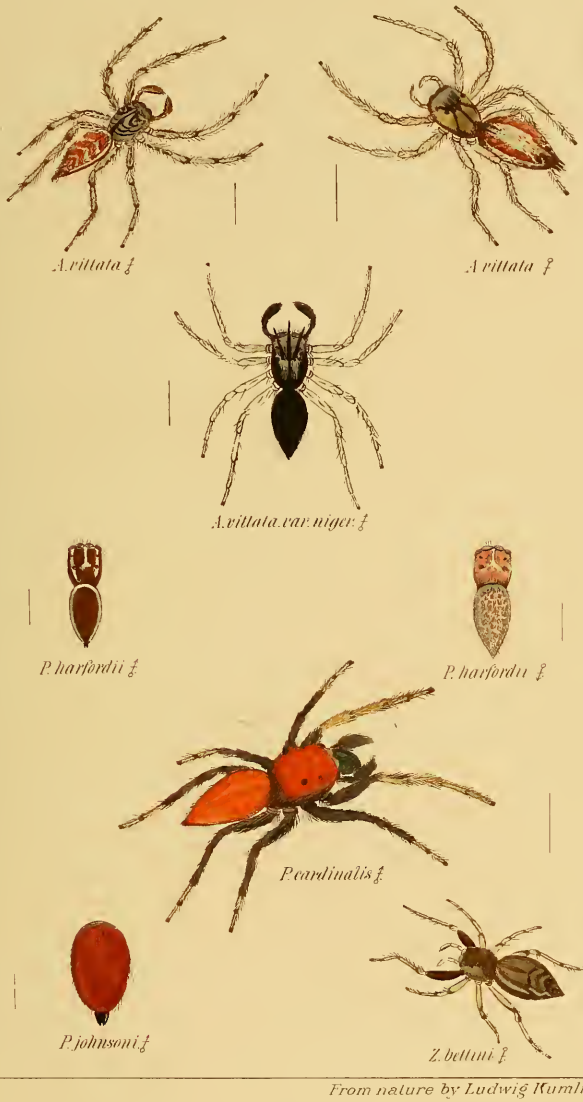
Astia vittata: Female and two male forms, to show the two varieties and the sexual differences.

Pseudicius harfordii: Male and female, to show the sexual differences.

Phidippus cardinalis: To show the coloring in the male.

Phidippus johnsonii: To show the coloring in the male.

Zygoballus bettini: To show the coloring in the female, the male being still more brilliant.



From nature by Ludwig Kumlien.

PLATE III.

Figures 1 and 3. Acrosoma spinea, two forms of female.

Figure 2. Acrosoma spinea, male.

Figure 4. Phoroncidia aurata, female.

Figure 5. Acrosoma horrida, female (from Taczanowski).

Figure 6. Acrosoma oblonga, female (from Taczanowski).

Note: By mistake, figures 5 and 6 were included as being drawn from nature by Mr. Kumlien. They were, in reality, copied from Dr. Taczanowski's work, *Araniédes de la Guyane Française.*

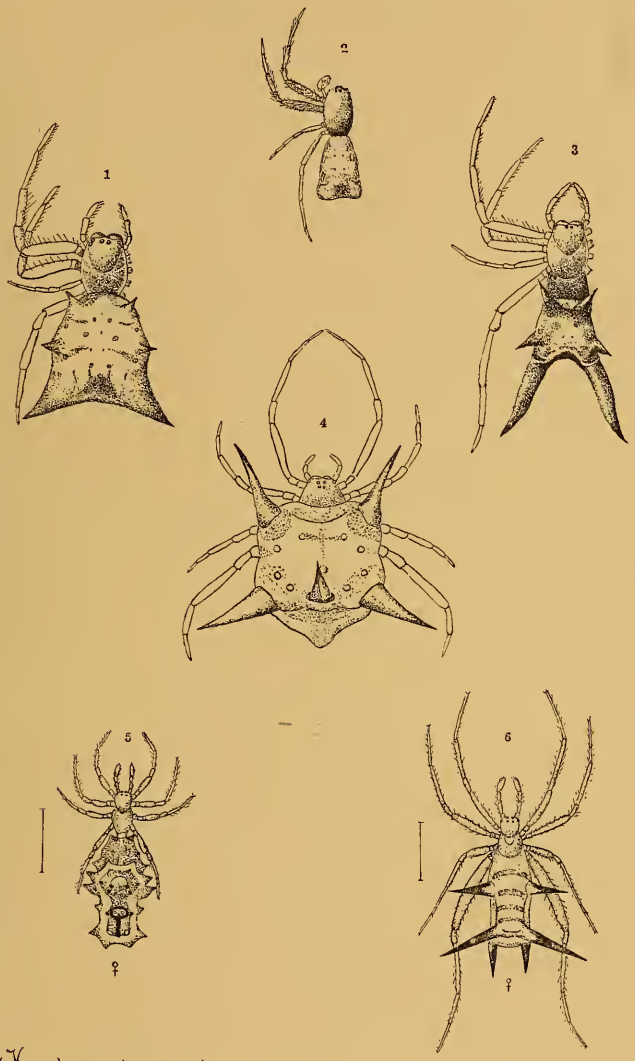


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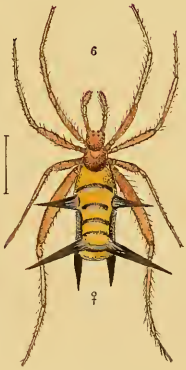
PLATE IV.

Upper figure: Uloborus plumipes in web, with one cocoon, to show protective resemblance.

Lower figure: Epeira prompta, resting on lichen-covered tree-trunk, to show protective coloring.

PLATE IV.



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