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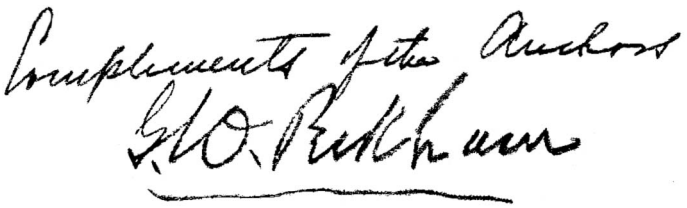
All text or characters not in the original are in red. Spelling errors or other errors in usage are highlighted in blue. All scientific names are italicized in this version.



SOME OBSERVATIONS ON THE MENTAL POWERS OF SPIDERS.

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INTRODUCTION.

The differences of structure between a man and a spider are so numerous and profound that he who infers the mental state of a spider from a given action should not be in haste to make positive statements and broad generalizations. A critical study of many of the current anecdotes concerning animal intelligence would prevent their use as data for comparative psychology, at least until after their confirmation by competent observers. Up to that time they have, as Romanes says, only the value of suggestions. How far, for example, are "personal preconceptions" responsible for both facts and inferences in Dr. Brookes' assertion that *Epiblemum scenicum* "has been sometimes seen in the act of instructing its young ones how to hunt"? and also that "whenever an old one missed its leap, it would run from the place and hide itself in some crevice, as if ashamed of its mismanagement"? [1] After having observed spider after spider building a new web on the eve of a storm, how shall we explain the statement, that "when a storm threatens, the spider, which is very economical with its valuable spinning material, spins no web, for it knows that the storm will tear it in pieces, and waste its pains, and it also does not mend a web which has been torn; if it is seen spinning or mending, on the other hand, fine weather may be generally reckoned on"? [2] This would be, no doubt, the wisest way for spiders to act under the circumstances, and Dr. Büchner is in very illustrious company when he — unconsciously, of course — orders the actions of such simple creatures in full accord with the higher reason.

Lange has well said that the core of all the numerous cau-

[1] Bingley's *Animal Biography*, Vol. III., p. 455.
[2] Romanes' *Animal Intelligence*, p. 211.

tionary measures of the scientific method lies just in the neutralizing of the influence of the observer's subjectivity. The subjective element cannot, of course, be eliminated; but the observer should keep facts and inferences separate, and should, in addition, state the particular action, among the many, which is the external sign of the mental state which he believes to be proved by the experiment. Lange's words on the subject are worthy of immortal memory: —

"Where external observation shows us primarily only movements, gestures, and actions, the interpretation of which is liable to error, we may, nevertheless, carry out a comparatively very exact procedure, since we can easily subject the animal to experiments, and put it into positions which admit of the most accurate observation of each fresh emotion, and the repetition or suspension, as we will, of each stimulus to a psychical activity. Thus is secured that fundamental condition of all exactness; not, indeed, that error is absolutely avoided, but certainly that it can be rendered harmless by method. An exactly described procedure with an exactly described animal can always be repeated, by which means our interpretation, if it is due to variable bye-conditions, is at once corrected, and at all events thoroughly cleared from the influence of personal preconceptions, which have so great a share in so-called self-observation." [1]

We have felt that it might properly be demanded of us that we give the generic and specific names of every spider experimented upon, and also that we so describe our methods that the experiments can be repeated by any one who desires to test the validity of our conclusions.

Our rule has been not only to repeat an experiment many times, but to repeat it under as many different conditions as possible. The histologist often finds it necessary to adopt complicated and tiresome methods in order to demonstrate a single fact. So, also, we have found that to learn anything of the mental processes of spiders the way is long and beset with difficulties. To use the words of Ribot: "Many of these investigations, we shall see, pertain to very modest questions, and it is probable that the partisans of the old psychology will find the work too great for results so small. But those who give allegiance to the methods of the positive sciences will not com-

[1] *History of Materialism*, Vol. III., p. 178.

plain of this. They know how much effort the smallest questions require; how the solution of small questions leads on to the solution of great ones, and how barren of results it is to discuss great problems before the small ones have been solved." [1]

SENSE OF SMELL.

Our experiments on the sense of smell in spiders extended over two summers. Many of them were performed by each of us separately, that one might detect the mistakes of the other. Our usual plan was to hold a slender grass [2] rod, eight inches in length, in such a position that one end closely approached the spider, noting what effect, if any, was produced, and then to dip it into whatever scent we were using, hold it in the same position, and again note the effect. We tested them in this way while at rest in the web, while stalking their prey, while feigning death, and under various other conditions.

The scents used were some essential oils, cologne, and several kinds of perfumes. Acetic acid, vinegar, and like materials were avoided on account of their irritating action upon the integument.

Our first experiments were upon some tame Attidae that had taken up their abode with us. They were fearless little creatures, always ready to jump upon a finger, to catch the gnats that we offered them, or to drink from a spoon. They were quick to respond to any test of their sense of smell.

For example, an *Astia vittata* ♂ (var. *niger*) was placed upon a table and the end of a clean rod was held just in front of him. He promptly leaped upon it as he had been in the habit of doing with our fingers, and after a moment's pause leaped again to some other object, whence he was returned to the table. This trial was repeated with the same result. The end of the rod was then dipped into oil of peppermint and placed as before. The spider instantly raised his first legs and palpi and waved them in the air, this being the usual position for threatening or defence. After standing in this way for two minutes he turned slowly and walked to a little distance. Soon, however, he returned and took up his former position in front of the rod, remaining again for two minutes, but not repeating the

[1] *German Psychology of To-day*, p. 14.
[2] Most likely a *glass* rod.

movements of the legs and palpi. A second time he walked away and came back, but this time he came so close as to touch the oil with one leg, whereupon he hurried away, evidently in distress. Half an hour later we found him with his legs drawn in, looking very miserable, but when the oil of peppermint was held three inches away he immediately came to it and stood near it for about a minute, when it was removed.

We next tested a *Philaeus militaris* ♂, placing him on a table and using oil of peppermint, but holding the rod, at first clean and then wet with the oil, behind him and just over the extremity of the abdomen. When the clean rod was used he remained perfectly quiet; but when it approached him wet with the peppermint, he raised his first legs and palpi very high, and moved them up and down, turning from side to side, and trying to reach the rod, which was kept behind him.

Another male of the same species was experimented upon in the same way, excepting that cologne was substituted for oil of peppermint. This one also made no response to the clean rod; but when the cologne was held behind him he stood with his head and first legs erect for several minutes, and then turned and tried to reach it.

A female of *Astia vittata* gave the following results: When the clean rod approached her from in front she paid no attention to it; when the oils of lavender and cedar were used she raised her head and backed away; when oil of cloves was used she raised her first legs and palpi and struck at it, but when peppermint was used she became greatly excited, dancing about with her legs and palpi raised, and finally leaped upon the rod.

A little colony of *Drapetisca socialis*, which we found on the wall of a smoke-house, was now made the subject of a series of experiments. An empty bottle was held near ten individuals in succession. They remained quiet. An open bottle of oil of peppermint was then used in the same way. All indicated that they noticed it, at first by moving their legs, and afterward by walking away. A dry cork was held near six individuals. They paid no attention to it. A cork wet with oil of wintergreen was substituted, when they acted as they had with the peppermint. The corks and bottles were held sometimes behind and sometimes in front of them. Both males and

females were represented among the spiders experimented upon. At another time ten individuals were tested, at first with a clean match, and then with a match dipped into oil of lavender. The results were in all respects like those given above.

We next turned our attention to the orb-weavers. To procure good material we made a trip to a neighboring swamp, and captured half-a-dozen large and handsome specimens of *Argiope riparia*. These we set free in a wire-enclosed porch, which, by the following morning, was ornamented by several of the interesting webs peculiar to this species.

Our first trial was made with a female, while she hung in the usual position in her web. The end of a clean rod was held for some moments just in front of her. There was no response. The rod was then dipped into oil of lavender and held as before. The end of the abdomen was immediately jerked upward, and the first legs were moved from side to side. After an interval of ten minutes the lavender was held just above the end of the abdomen; it was again lifted, and a moment later the tips of the third and then of the first pair of legs were rubbed, one at a time, between the falces and the palpi.

Turning to another female of this species, we held a clean rod near the hind legs. There was no response. The rod was then dipped into essence of heliotrope, and held as before. One of the legs of the third pair was immediately moved, the tip being rubbed between the palpi and falces, as in the preceding instance; and similar movements of some of the other legs followed. The same movements took place when the heliotrope was held in front of the spider.

Finding a female of *Epeira strix* with her head and most of her body hidden under the silken covering within which spiders of this species commonly remain during the day, we brought a rod, at first clean, and then wet with oil of lavender, near the tip of the abdomen. There was no response in the first instance, but in the second the spider quickly retreated within the covering, so as to be entirely out of sight.

A female of *Epeira labyrinthea*, while hanging in her web, was gently touched with a rod which had shortly before been dipped into essence of heliotrope, but which was quite dry. She instantly seized the rod, and went vigorously to work to bind it

up, as though it had been a fly. After she had worked at it for two minutes, and had wrapped it up very thoroughly, it was taken away as gently as possible, whereupon she began to put the tips of her legs between the palpi and falces. We have seen a male of this species go through the same motions, after catching an ant in his web, and then losing it. So decided a response to the dry heliotrope seeming to show an unusual sensitiveness, the rod was again dipped into heliotrope, and held, as soon as it was dry, first, near a male, and then near three females of *labyrinthea*. All jumped at it and grasped it, seeming puzzled, but returned to the web without binding it up.

We now took a clean, unscented rod, and with it gently touched, in turn, the five spiders already experimented upon. Each of them clasped it, examined it for a moment, and then returned to the web, their action being not very unlike that of the second, third, fourth, and fifth spiders experimented upon with the dried heliotrope, but showing less excitement of manner.

The dried heliotrope was then again offered to the first spider. She began to bind it up as before; then stopped and rubbed her palpi violently up and down upon it for some time; then rubbed it hard with all her legs, excepting the fourth pair; then again with her palpi. She seemed to be trying to get something off. After five minutes, while she was still at work in this way, the rod was removed.

It may be noted, in connection with this experiment, that we have repeatedly noticed, among spiders of the same species, great differences of degree in their sensitiveness to odors.

The position of the organ of smell in spiders is unknown. It has been generally supposed that it existed in the palpi, although Robineau-Desvoidy located it in the mandibles. [1]

[1] "As to spiders, it is not certainly known whether, and to what extent, they share in the sense of smell. Robineau-Desvoidy (1842) said that their sense of smell is very well developed and localized in the mandibles, but Perris placed them in the lowest rank of arthropods; though he remarks on the sensibility of their palpi to smells." — A. S. Packard's abstract of Kraepilin's criticisms on the works of writers on the olfactory organs of arthropods. *Am. Nat*., Vol. XXI., p. 182.

"Perris accorde aux palpes une faible olfaction à courte distance. Il fait remarquer que les araneides, les seuls articulés qui n'ont pas d'antennes, paraissent avoir l'olfaction tout à fait rudimentaire. . . . Enfin Perris et Comparetté croient que les palpes servent à l'olfaction à côté des antennes." — Auguste Forel. *Sensations des Insectes*, II. *Recueil Zoölogique Suisse*, Tome IV., No. 2, pp. 190, 192.

Hoping to throw some light on the matter, we made a few experiments to determine whether spiders deprived of their palpi would respond to a test of their sense of smell.

Taking two females of *Argiope riparia* that had shown themselves sensitive to cologne, heliotrope, oil of lavender, and a perfume called Chinese bouquet, we carefully removed their palpi and replaced them in their webs. They spent some hours in rubbing the tips of their legs over the wounded parts, but by the following morning appeared quite comfortable, and breakfasted, with appetite, upon some grasshoppers with which we provided them.

We tested the first one, after the usual check with a clean rod, by holding a rod wet with cologne at first in front of her, and then at the posterior end of the abdomen. In the course of twenty-five minutes there was no more decided response than an occasional slight jerk of the abdomen or a faint movement of the legs. Oil of lavender was then held in front of her. Instantly the legs contracted and their tips were rubbed, one at a time, upon the falces.

Passing to the second and offering the clean rod without response, we tested her with heliotrope and Chinese bouquet. To each she responded quickly by jerking the abdomen and rubbing the tips of the legs over the falces.

To sum up our work on the sense of smell, we made, in all, two hundred and twenty experiments. We found three species (*Argyroepeira hortorum*, *Dolomedes tenebrosus*, and *Herpyllus ecclesiasticus*) that did not respond to the tests. In all other cases it was evident that the scent was perceived by the spiders. This they showed in different ways, — by various movements of the legs, palpi, and abdomen, by shaking their webs, by running away, by seizing the rod and binding it up with web as they would an insect, and in the case of the Attidae, by approaching the rod with the first legs and palpi held erect; but whether in the way of attacking it, or, as it sometimes seemed, because the smell was pleasant to them, it is impossible to say.

We add a list of the species experimented upon: —

Epeira infumata Hentz, *Epeira insularis* Hentz, *Epeira strix* Hentz, *Epeira labyrinthea* Hentz, *Epeira bombycinaria* Hentz, *Cyllopodia cavata* Hentz, *Cyclosa conica* Menge, *Argiope riparia* Hentz, *Argyroepeira hortorum* Hentz, *Tetragnatha*

laboriosa Hentz, *Theridion blandum* Hentz, *Theridion* unknown, *Drapetisca socialis* Menge, *Linyphia communis* Hentz, *Linyphia mandibulata* Emerton, *Astia vittata* Hentz, *Philaeus militaris* Hentz, *Hasarius hoyi* Peckham, *Phidippus rufus* Hentz, *Philodromus duttoni* Hentz, *Xysticus gulosus* Keyserling, *Thomisus piger* Hentz, *Misumena* unknown, *Herpyllus ecclesiasticus* Hentz, *Micromata carolinensis* Hentz, *Agelena naevia* Bosc.

HEARING.

Our first experiments in this direction consisted in shouting, clapping our hands, and whistling close to spiders which were at rest in their webs. They gave no sign of hearing anything. We felt, however, that this was not enough to warrant us in concluding that they were deaf, since there is nothing in the habits of these spiders that would lead them to make any active response to loud noises, even supposing they did hear them. *A. vittata*, when standing on a finger, jumped to one side when “bang" was shouted in a loud voice, with the head turned away; and when we whistled, it stood on the tip of its abdomen with its head held high. With this exception we failed to discover, by these means, anything about the hearing of spiders.

Fortunately a better method was suggested to us by the experiment of Mr. C. V. Boys with a tuning-fork on the garden-spider.[1]

We began a new series of experiments by sounding three tuning-forks near a large female of *E. strix* as she stood in the centre of her web. Two of the forks, A and C, were small, while B was large. The spider did not notice the two small forks, but when the large one was sounded she raised her first legs almost vertically, holding them as though ready to ward off an attack, and looking much like a boxer in an attitude of defence. The B fork was again sounded, and again the legs were raised. As a control experiment the fork, when not in vibration, was brought into the same relation to the spider. No notice was taken of it. The fork was again sounded, and held behind and above her cephalothorax. She extended her legs as before. The experiment was repeated with the fork still. She paid no attention to it. The fork was sounded and

[1] *Nature*, XXIII., pp. 149-150.

brought to one side of her, when she not only moved the first legs, but also the leg of the second pair on the side toward the fork. It would tire the reader unnecessarily were we to describe the check experiments that were made after each observation, but we felt their importance, and never failed to make them; in fact, our check experiments were more numerous than our direct ones.

Later on tests similar to those given above were made on a smaller spider, a female of *E. labyrinthea*, as she stood in her web. In this instance she responded to all the forks, A, B, and C.

Second and third large individuals of *E. strix* acted as the first had done, responding to the large fork, but not to the small ones. On the other hand, five small individuals of *strix* were much excited by the small forks. Subsequent observation left no room for doubt that the large spiders, with few exceptions, only attended to the sound produced by the large forks.

To show the results of our experiments and also the way in which we worked we quote from our notes.

July 14. —	Held the big fork, in vibration, over a large male of *E. insularis*, an inch and a half away. He threw up his first legs, making frantic efforts to reach it. When the fork was removed he settled down quietly in his web. This was repeated ten times, always with the same result. A female of this species acted as the male had done, but seemed less excited by the vibrations. Unless the fork was sounding neither spider paid any attention to it.
July 18. —	Held the large fork, in vibration, near a female of *E. infumata* standing quietly on a wire screen. She did not move. Repeated the test with the fork, at first vibrating and then still, ten times without result. She was then placed in the web of another spider, and the B fork was brought near her as she stood there. She appeared frightened, and at once threw up the first and second pairs of legs. The fork was next held behind and to one side, so that she could not see it; but she seemed to hear it, since she turned toward the fork and almost fell backward in her efforts to reach it. The fork was now held in front of her again, when she moved her legs as before. This experiment was repeated many times with like results. To hear the fork when she could not see it evidently excited her

	more than to both hear and see it. The presence of the fork, when not in vibration, brought no response, nor did rapidly moving it to and fro in front of her attract her attention.
August 13. —	The large fork, in vibration, was held near a female of *A. riparia*. She at once gave the usual sign that she heard it. It was next held behind her, and entirely out of her sight, when she quickly turned in the direction of the sound.
August 14. —	Tried a new species, a young *Phillyra mammeata* Hentz. When the vibrating C fork approached she lifted first one, and then the other, of the anterior legs.

Were it necessary, we could cite a great many similar experiments which had like results, to show that certain spiders indicate that they hear a vibrating tuning-fork by characteristic movements of the legs. Another set of spiders, however, manifested their perception of the sound in a different way. With these the approach of a vibrating fork seemed to cause greater alarm, making them drop from the web and keep out of sight for a longer or shorter time. However, after one of these spiders had been subjected to the experiment several times, it would, instead of dropping, raise its legs in the manner described above.

For example, when the vibrating C fork approached a female of *E. labyrinthea* as she stood in her web, she fell. This was repeated eleven times, the spider falling each time, but at the twelfth she merely raised her first legs.

A few days after this experiment we found a more excitable spider of the same species. Not until she had fallen out of the web twenty-two times, at the approach of the fork, could she restrain the impulse to drop. It was apparent, however, after the seventh or eighth time, that she was less startled by the sound than at first, since the distance that she fell and the period of time that elapsed before she returned to the web grew shorter and shorter in the later experiments. At first she fell fifteen or eighteen inches, and remained at the end of her line for several minutes, while toward the last she fell only an inch or two, and immediately ran back to the web. After the twenty-second trial she only held up her legs as the fork approached. Finally, completely worn out and disgusted, she retreated to a neighboring branch, drew in her legs, and remained sullenly unresponsive to all further attempts.

We shall now give a series of notes which describe an attempt to teach a very interesting and docile little female spider of the species *Cyclosa conica* Menge to listen composedly to the vibration of the tuning-fork. We first saw her on July 18, when we marked her with a spot of scarlet paint, that there might be no question of mistaken identity; and by the time that we lost her, a month later, we had come to have a very friendly interest in all that concerned her. Her web was about five feet from the ground, in the branches of a cedar-tree. Across it was stretched a line of bits of rubbish, dead insects, and cocoons, and in the middle of this stood the little spider, bearing so close a resemblance, in color and shape, to the other parts of the line that she was almost indistinguishable. So perfect was the mimicry, that even after we had visited her day after day for weeks, we frequently thought, at the first glance, that our spider was gone.

Her record stands as follows : —

July 18. —	*C. conica* fell from the web three times when the vibrating C fork was held one inch away. Further efforts failed to move her.
July 19. —	Used the B fork. She fell five times in succession, — only short distances the fourth and fifth times, — after which she would not leave the web.
July 20. —	She fell nine times before becoming accustomed to the C fork ; the last three times she dropped only two or three inches, and hung at the end of the line.
July 21. —	After falling six times she paid no attention to the sound.
July 22. —	After falling six times became accustomed to the sound, and would not leave the web.
July 24. —	A day having elapsed without a lesson she fell eleven times before becoming accustomed to the sound.
July 25. —	Dropped from her web six times as the fork was held near; after that, paid no attention to it.
July 26. —	Dropped only five times before becoming accustomed to the vibration.
July 29. —	Dropped seven times, and then became indifferent.
July 31. —	Dropped eleven times before refusing to move.
August 1. —	Dropped seven times, and then remained undisturbed by the sound.
August 2. —	She dropped fifteen times, and then refused to

	move. We left her for fifteen minutes, and, then returning, sounded the fork near her five times without making her move. She probably remembered her former experience and profited by it.
August 3. —	Her memory proved short. She dropped eleven times before remaining quiet, as the fork approached. Moreover, she was very slow about returning after each fall, so that it took a much longer time than usual to teach her to pay no heed to the sound.
August 4. —	She seems to be in better mood to-day. After the seventh trial she gave no sign of hearing the fork.
August 5. —	Education begins to affect her character. When the fork was sounded she seemed startled, and ran up a little way on the band of rubbish, but quickly returned to the centre. This she did a second time, but to nine subsequent trials, the fork being held both behind and in front of her, she gave no response.
August 6. —	We could not make her move, though we sounded the fork nine times.
August 7, 4 P.M.—	Eight attempts failed to move her in the least. 6:30 P.M.— Made eleven trials, with the same result.
August 8. —	Sounded the fork near her fifteen times, but she did not move.
August 9. —	Seven trials ; the spider remained perfectly quiet.
August 10. —	She has spun herself a new web inside the circumferential lines of the old one, preserving the debris in its original position. (This is the fourth web she has spun since we found her on July 18.) The fork was sounded ten times, but she paid no attention to it.
August 11. —	She seemed more nervous. At the first trial she dropped two inches; at the second and third, she fell about a quarter of an inch, and immediately ran back. Five subsequent efforts failed to move her.
August 12. —	In the morning we made nine, and in the afternoon eight, trials with the fork. The spider gave no sign that she heard anything.
August 14.—	A day and a half having passed without a lesson, the spider was somewhat startled at the approach of the fork, falling a very short distance the first time it was sounded, but after that remaining imperturbable.

August 15, 10 A.M. —	Sounded the fork near the spider ten times. She would not move. 5 P.M. — Made nineteen trials, with the same result.
August 16.—	The fork was sounded twenty times in the morning and twenty in the afternoon without disturbing her.
August 17. —	While the fork was sounded close to her eleven times she stood immovable in the centre of the web.
August 18. —	The web was tenantless. Our little *conica* has probably fallen a prey to some bird or wasp.

As the habit of falling from the web is almost the only safeguard of these spiders in times of danger, the instinct must be of immense importance to them. Taking this into consideration, it seems remarkable that one of them should so soon have learned the sound of the vibrating fork, and should have modified her action accordingly.

In all essentials our results agree with those of Mr. Boys, who says: "If, when a spider has been enticed to the edge of the web, the fork is withdrawn, and then gradually brought near, the spider is aware of its presence and of its direction, and reaches out as far as possible in the direction of the fork; but if a sounding-fork is gradually brought near a spider that has not been disturbed, but which is waiting as usual in the middle of the web, then, instead of reaching out toward the fork, the spider instantly drops — at the end of a thread, of course." [1]

A few experiments were made to determine where the organ of hearing is located, but we can offer nothing positive on this question. It seems probable that the auditory apparatus is but little specialized. Possibly it is spread over a considerable portion of the epidermis.

Finding that *E. strix* and *E. labyrinthea* were very sensitive to the tuning-fork, we removed both palpi from an individual of each of these species. They seemed a good deal disturbed by the operation, and retreated to the tents near their webs. On the next day, when the fork was sounded near them, there was no definite indication that it was heard. On the second day they each responded once; and on the third, they seemed to have entirely recovered, and responded eight or ten times in succession. We afterward removed the palpi from several

[1] *Loc. cit.*, p. 149.

specimens of *strix*, *labyrinthea*, and *insularis*. All seemed able to hear perfectly well without these organs. We also found that the palpi play no essential part in the building of the web, since all these spiders constructed normal webs after their palpi were removed. This confirms, to some extent, the conclusions of Plateau, [1] though his further statement that "these appendages are to be placed in the category of useless organs" seems to be scarcely warranted.

We made an effort to determine how far the first and second pairs of legs subserve the sense of hearing, by removing them, and noting the results. We first removed, at the coxae, the two anterior legs of a female of *E. insularis*. She soon built a good web, and when, two days later, the B fork was sounded near her, she promptly threw up her second pair of legs in the characteristic way.

Some days later we caught a large female of *A. riparia* that had lost her first pair of legs and also the left leg of the second pair. She was placed in the enclosed porch, and by the next day had built a good web, which lacked, however, the zigzag line down the centre, which is characteristic of the web of this species. (Two other specimens of *A. riparia* that had lost their palpi, also omitted the zigzag.) The remaining leg of the second pair was then removed, leaving the spider with only the posterior two pairs. She was now offered a fly, which she quickly seized and devoured. After her repast the B fork was sounded near her, when she attempted to lift the third pair of legs, but only partly succeeded. Several trials gave similar results. The fork was next held well behind her, when she slowly turned toward the sound.

So far we had experimented only upon orb-weavers. We now used the tuning-fork with half-a-dozen species of different groups, making ten or twelve trials with each spider. None of them gave the least indication of hearing anything. These unresponsive species were: *Herpyllus bilineatus* and *ecclesiasticus* Hentz, *Pardosa pallida* Emerton, *Pirata minutus* Emerton, *Lycosa nigroventris* Emerton, and *Dolomedes tenebrosus* Hentz. It struck us as remarkable that, while all the Epeirids responded promptly, being evidently alarmed by the sound of the tuning-fork, the spiders that make no web, on the contrary, gave not

[1] American Naturalist, April, 1887, p. 384.

the slightest heed to the sound. This may, perhaps, be partially explained by the difference in the feeding habits of the two groups.

MATERNAL EMOTIONS.

The only tender feeling that can be attributed to spiders is the affection for her offspring manifested by the female; except, perhaps, in the case of a few species where the male and female live together in the same web, in conjugal happiness.

Our observations on this subject necessarily included other mental states beside the emotions, and for the sake of convenience we shall consider, under this head, the various sensations, perceptions, and manifestations of memory met with in this set of experiments.

We endeavored to estimate the strength of the maternal feeling in our spiders by removing their cocoons and then noting with what degree of eagerness they sought to regain them; and also by determining for how long a time they would remember the cocoons if they were separated from them.

We selected for study the Lycosidae, spiders that keep the egg-sack attached to the spinnerets, and carry the young about on their backs for a certain length of time after they leave the cocoon. We thought that the lengthening of the period of infancy, during which the female cares for her young, might — as in the case of monkeys and man — produce a greater development of the maternal instinct than in other species of spiders where the eggs receive little or no attention from the parent after she has deposited them.

On July 15, 1886, we found a female *Pirata piraticus* Clk. carrying her cocoon. While we were taking the egg-sack away from her she seized it with her falces several times and tried to escape. After we had finally accomplished its removal she seemed very much affected by its loss, and searched about in all directions to find it. In an hour and a half we returned it to her, when she immediately took it between her falces, and after a slight delay passed it back to the under side of her abdomen, where she fastened it. It was again removed and not returned to the spider for three hours. She did not seem so ready to receive it as in the first instance, but after a little hesitation took it up and carried it off.

On the following day we kept the cocoons away from three spiders of the same species for thirteen, fourteen and a half, and sixteen hours, respectively. All remembered them and took charge of them when they were returned. From the same spiders we again removed the cocoons, keeping them, this time, for twenty-four hours. The spiders again picked them up. There seem to be individual differences in the depth of feeling experienced by these spiders, since one female of this species utterly refused to take back her cocoon, after an interval of twenty-four hours.

We repeated the experiment with the three Lycosids mentioned above. Their cocoons were kept away from them for twenty-four hours, and then restored. Two of them refused to resume their maternal duties, seeming not to recognize their cocoons; the third, after hers had been placed in front of her seven times, slowly resumed charge of it, but with none of the eagerness before displayed.

In the following summer, on July 14, we took the cocoon from a female of *Lycosa* (sp. ?) She recollected it and promptly took it up after having been separated from it for one day. We kept the eggs away from a second individual of this species for forty-three hours. When it was restored she had apparently forgotten all about it, since, although she touched it five times with her legs, and we four times placed it directly under her, not until the fifth time did its presence recall her to a sense of duty. She then very slowly and languidly took it up and attached it to the usual place. From another individual of the same species we kept the cocoon forty-eight hours; but the little spider could not remember so long, and, although we worked long and patiently to make her recollect, she would have nothing more to do with it.

Pardosa pallida Emerton was also separated from her cocoon for forty-eight hours. We tried for thirty minutes to make her take it back, but failed. She held it under her legs and palpi five times, several seconds at a time, seemingly feeling of it, and then left it.

Notwithstanding many efforts we never found a spider among the Lycosidae that was constant in her affection for so long a period as forty-eight hours. A female of *Clubiona pallens* Hentz, however, remembered her eggs for this length of time,

and, when they were returned to her, spun a web over them in the corner of the box in which they were placed. Of all the spiders that we experimented upon, the little *Theridium globosum* Hentz had the best memory for her cocoon. We took her from her web and returned her to it after fifty-one hours. She at once went to the eggs and touched them with her legs. She then left them to improve her house, every now and then running back to see if they were safe. After she had arranged her household to her satisfaction she settled down near them.

Several species of Attidae and Thomisidae did not remember their cocoons for twenty-four hours; yet these spiders, although they do not carry the egg-sack about with them, remain near it for from fifteen to twenty days.

SENSE OF SIGHT.

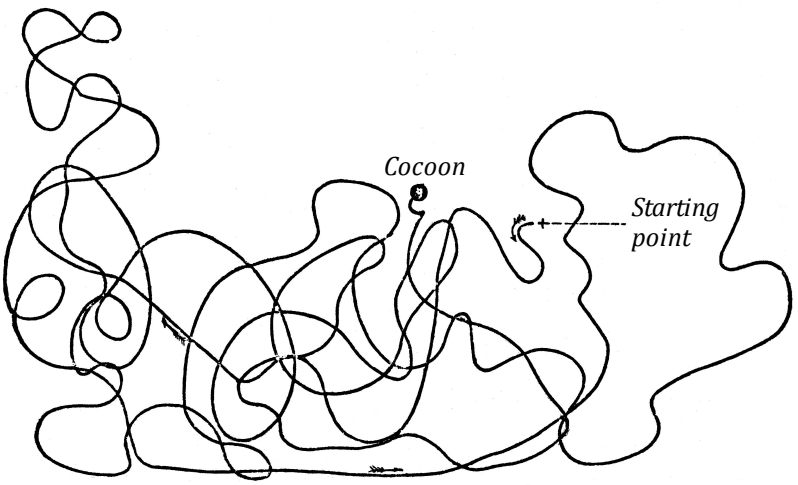
We were much surprised in the earlier experiments to find how entirely the Lycosidae depended upon touch in finding their cocoons. We had almost concluded that their sense of sight was but little developed. To quote from our notes : —

> *July* 9. — Took the cocoon from *P. montanus* Emerton. She seemed much disturbed, and hunted around very eagerly; several times she passed close to it, and her eyesight must have been dull, or she would have seen it. At last she chanced to touch it with one leg, when she at once perceived it and laid hold of it with her falces. After a little we repeated the experiment, but now the cocoon was suspended just high enough to allow her to pass beneath, without touching it. She ran about seemingly very anxious to find it, but although she several times passed directly under the cocoon she did not discover it.

During the past summer we took away the eggs from a number of these spiders, and, placing them upon paper from one to two inches away from their cocoons and looking toward them, traced along the course they ran in looking for them. The tracing on the next page illustrates the persistency of the spider in hunting for her egg-sack, and how little she was aided by the sense of sight in recovering it.

The spider, *Pardosa pallida*, was some ten minutes in making the various turns before she reached the cocoon. Three times she came very close, and when, at last, she found it, she had

already turned away, but accidentally touching it with her leg, returned and seized it.



ROUTE FOLLOWED IN FINDING COCOON, BY *PARDOSA PALLIDA*.

To further test how far they depended upon sight for finding the cocoon we removed the egg-sacks from two specimens of *P. montanus*, and, after coloring them scarlet and letting them get thoroughly dry, placed them on a board near the mothers. Both approached them several times, but, until they came into actual contact with them, did not take them up. The instant, however, that they were touched, they were seized by the mothers, and treated as affectionately as they had been before they were colored. We repeated this experiment five times, with the same results.

Professor Auguste Forel, in discussing the sight of arthropods, says that insects furnished with only simple eyes see but a short distance, more distinctly when an object is in motion, very imperfectly when it is at rest. Regarding spiders, he remarks that if you take up one of the ground-spiders (probably one of the Lycosidae) carrying its eggs, and remove the cocoon to a distance of two or three inches, she will hunt about for it, and have the greatest difficulty in finding it. He also observes that jump-

ing-spiders (Attidae) only perceive their prey when two or three inches distant.[1]

When our spiders came within a fifth of an inch of their cocoons, and yet gave no sign of seeing them, we were almost ready to agree with Professor Forel; but a little further consideration convinced us that we were judging them too hastily.

Let us go over the history of the egg-sack. In forming it, the spider first makes the upper part, and then, holding the openings of the oviduct against it, forces out the eggs. After the eggs are laid she uses the spinnerets, and possibly the posterior legs, to complete the cocoon. When it is finished she bends down the end of the abdomen, and attaches it there by lines of web. All this time she has probably not seen it once; and she never will see it, since it remains on the under side of the body until the young spiders come out, when they attach themselves to her back.

Now, bearing in mind that a perception is the interpretation of a sensation in terms of past experience, what is there in the experience of this spider to enable it to make a mental synthesis of the sensation of sight, with those other qualities of the cocoon which are learned by touch? The spider doubtless saw the cocoon, but could only recognize it as such through the medium of the sense of touch.

That this explanation is the correct one is made more probable by the fact that those spiders that not only touch their cocoons, but also see them, evidently depend on sight in recognizing them, if they are removed.

We took the cocoon from *Theridion blandum* Hentz, and placed the spider in a bottle three inches high. After she had settled herself in the upper end, we dropped the cocoon into the bottom of the bottle. She immediately descended, picked it up, and returned to her former position. We repeated this experiment several times.

Theridion frondeum Hentz was placed under an inverted tumbler, four inches high. While she was standing on the upper surface of the glass the edge was lifted and the cocoon pushed under. She at once lowered herself, seized it, and took it up to

[1] *Sensations des Insectes*, I. *Recueil Zoölogique Suisse*, Tome IV., No. I, pp. 18, 19.

the top of the glass. This experiment was repeated at least ten times.

It is evident that these spiders recognized their cocoons by means of the sense of sight. It was not that the Lycosidae could not see their eggs at a distance of a fifth of an inch, but rather that they could not perceive them unless they came into contact with them.

While experimenting on the color-sense of spiders, we have frequently, while feeding our captives, seen them stalk their prey at a distance of five inches; and we have repeatedly held the active jumping-spider, *Astia vittata*, on one finger, and allowed it to jump on to a finger of the other hand, gradually increasing the distance up to eight inches. As the distance increased the spider paused longer before springing, gathering its legs together to make a good ready.

We have twice seen a male of this species chasing a female upon a table covered with jars, books, and boxes. The female would leap rapidly from one object to another, or would dart over the edge of a book or a box so as to be out of sight. In this position she would remain quiet for a few moments, and then, creeping to the edge, would peer over to see if the male were still pursuing her. If he happened not to be hidden she would seem to see him, even when ten or twelve inches away, and would quickly draw back; but in case he was hidden behind some object she would hurry off, seeming to think she had a good chance to escape.

The male, in the meantime, frequently lost sight of the female. He would then mount to the top of the box or jar upon which he found himself, and, raising his head, would take a comprehensive view of the surrounding objects. Here he would remain until he caught sight of the female, — which he often did at a distance of at least ten inches, — when he would at once leap rapidly after her.

The ocelli of some spiders, then, enable them to see objects at a distance of at least ten inches. [1]

[1] We quote, in this connection, some observations of Hentz, in which he speaks of the sight of spiders as being acute: "This very common spider (*Marptusa familiaris* Hentz), almost domesticated in our houses, by its habits, deserves a longer notice than others. It dwells in cracks around sashes, doors, between clapboards, etc., and may be seen on the sunny side of the house, and in the hottest places, wandering in search of prey. It moves with agility and ease, but usually with a cer-

COLOR-SENSE.

Spiders are often so brilliantly colored that their being endowed with a well-developed color-sense seems *à priori* probable. Hoping to decide this question, which, as yet, had not been attempted, we began a series of experiments in the summer of 1886. The details of our method we omit, since the results were entirely unsatisfactory. In the following summer, however, we hit upon a plan of procedure which gave us the desired data.[1]

We had worked, during the first year, on species that are found in exposed places, or even in direct sunlight; but in our

tain leaping gait. The moment, however, it has discovered a fly, all its motions are altered; its cephalothorax, if the fly moves, turns to it, with the firm glance of an animal which can turn its head; it follows all the motions of its prey with the watchfulness of the falcon, hurrying its steps or slackening its pace, as the case may require. Gradually, as it draws near to the unsuspecting victim, its motions become more composed, until, when very near, its movements are entirely imperceptible to the closest observation, and, indeed, it would appear perfectly motionless, were it not for the fact that it gradually draws nearer to the insect. When sufficiently near, it very suddenly takes a leap, very seldom missing its aim. I saw one, however, make a mistake, for the object which it watched was only a portion of the wing of an hemipterous insect entangled in a loose web. It took its leap and grasped the wing, but relinquished it immediately, apparently very much ashamed of having made such a blunder. This proves that the sight of spiders, though acute, is not unerring." — *Spiders of the United States*, p. 56.

Also, Bingley says of the jumping-spider: "If it sees a fly at the distance of three or four yards, it does not run directly to it, but endeavors, as much as possible, to conceal itself till it can arrive near; and then creeping slowly up, and but seldom missing its aim, it springs upon the insect's back, and it is then almost impossible for the fly to effect an escape. But if, before the spider gets to it, the fly takes wing, and fixes upon another place, it whirls nimbly about, and still keeps its eyes upon it, in order to commence a fresh attack." — *Animal Biography*, Vol. III., p. 455.

While it is probably an exaggeration to speak of a spider seeing an object at a distance of three or four yards, it would scarcely have been possible for the writer to make such a statement if the spider he had been watching had been able to see only at a distance of three or four inches.

[1] Mr. Wallace, in *Tropical Nature*, p. 238, remarks that "the fact that the higher vertebrates, and even some insects, distinguish what are to us diversities of color by no means proves that their sensations of color bear any resemblance whatever to ours. An insect's capacity to distinguish red from blue may be (and probably is) due to perceptions of a totally distinct nature."

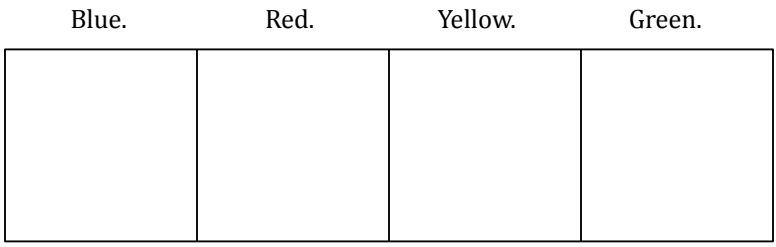
It is true enough that the mental states of men and insects must differ greatly, but if we are to comprehend the sensations of insects at all, we must do so by thinking of them in terms of the only conscious states that we know anything about, namely, our own. For this reason we shall assume that when a spider distinguishes red from blue, the best conception of its feelings will be attained by reference to our own sensations under similar circumstances.

second attempt we turned to the spiders that are found during the day, running among dead leaves or hiding under stones or wood.

In July last we constructed two cages in the following manner: On a base of wood we placed a row of four pieces of differently colored glass, each four inches square, held upright by slender nails on the inner and outer sides of each piece; and parallel to this, four inches away, a similar row. The ends and roof were formed by squares of glass which matched in color the parts of the sides which they touched. Thus we had a cage sixteen inches long by four inches wide, and four inches high, formed of four differently colored compartments all opening freely into each other. The cages were placed on a table in a covered porch with the wall of the house to the east, while the south, west, and north sides were exposed to the light.

On July 18 we placed a spider (*Lycosa nigroventris* Emerton) in a cage with the order of colors as in the following diagram : —

Figure 1.



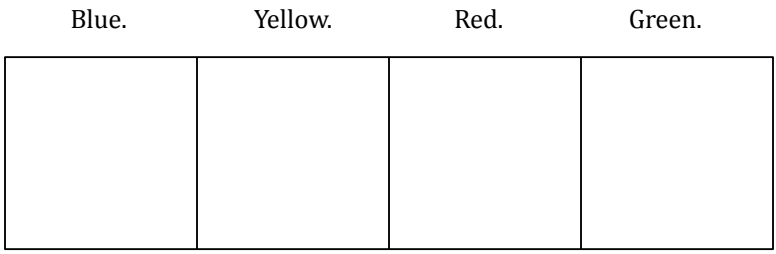
After walking about for a time, remaining in no spot more than a few moments, it at last settled down in the green compartment at one end of the cage, where it remained without change of position for several hours. Being satisfied that it had given up all efforts to escape, we now began our experiments by lifting off the green roof-plate, and gently driving the spider into the blue compartment at the other end. (Hereafter, to avoid circumlocution, we shall designate the compartments by their colors, — red, blue, green, and yellow.)

After an interval of thirty minutes it was found in the red. It was driven into the yellow, but after fifty minutes was again found in the red. It was then driven into the green, where it remained for half an hour, when it was driven into the blue. It

again moved to the red. We proceeded in this way, driving it into the various compartments, and crediting it, each time, with the color it had settled in, until its account stood as follows: Red 16, yellow 5, blue 2, green 2.

The order of the colors was then changed as follows : —

Figure 2.



After every three or four experiments the cage was brushed out to remove any web-lines that the spider might have formed.[1]

We now allowed the spider more time in which to choose its color, and had better results. The record for July 21 and 22 stood as follows: Red 21, yellow 4, blue 1, green 2.

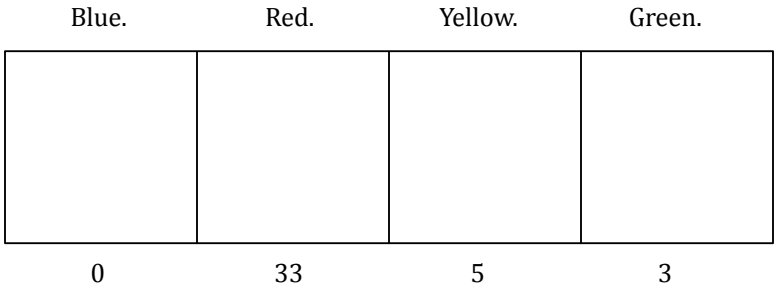
On July 18 we had placed another species of *Lycosa* (unfortunately this spider and a second specimen of the same species escaped before we identified them) in the second cage. After it had become accustomed to its new conditions we kept a record of its performances as before, with the following result: Red 16, yellow 2, blue 2, green 0. This spider escaped on July 21. The second specimen did not seem to have as marked color sensibilities as the first, but the record of this one, also, shows a preference for the red: Red 16, yellow 6, blue 3, green 2.

On July 31 second specimen of *L. nigroventris* ♂ was placed in the cage, and, though very restless, soon settled down in the red. The cage was carried into the direct sunlight, and the spider driven into the blue, at the end; but after a moment it turned around and went back to the red. After ten minutes it was driven to the opposite end into the green compartment. Again it came back to the red. The record for the day was: Red 10, yellow 0, blue 0, green 1. The cage was overturned that evening, and the spider escaped.

[1] All the species used in the color experiments make no web, but stalk their prey.

On August 2 a third specimen of *L. nigroventris* was placed in the cage. Three days' experimenting showed that this spider had stronger preferences than any of the others. The cage was arranged as follows : —

Figure 3.



The record for each color is given just below the line.

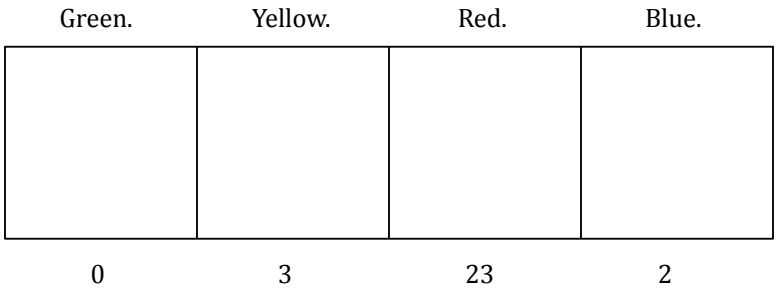
It seemed quite apparent that this animal preferred red, since it returned to this color thirty-three times out of forty-one. Still the experiment was open to the objection that it was temperature rather than color that determined the spider's movements. To test this we carefully covered the eyes of this specimen with paraffine. After having satisfied ourselves that it could not see, we put it back into the same cage. The color now produced no effect. It remained quiet in whatever compartment it was placed until it was driven out. It was once placed in the blue, with its eyes as close as possible to the red square, but it showed no inclination to enter, although this color had before proved so attractive. When taken out the spider was still blind. The record of this experiment was as follows: Red 6, yellow 6, blue 6, green 5.

A fourth specimen of *L. nigroventris* ♀ gave similar results: Red 11, yellow 2, blue 0, green 0.

The record of a fifth specimen of the same species (a male) was: Red 12, yellow 3, blue 0, green 1.

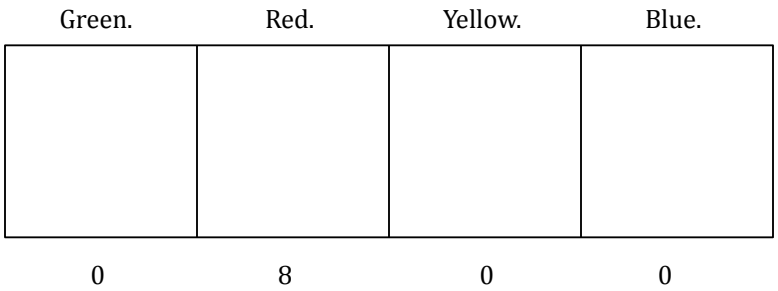
Our last experiment was with a large *Lycosa* (*L. nidicola* ♀, Emerton) which we found under a stone on August 18. The arrangement of the colors and the preferences were as follows: —

Figure 4.



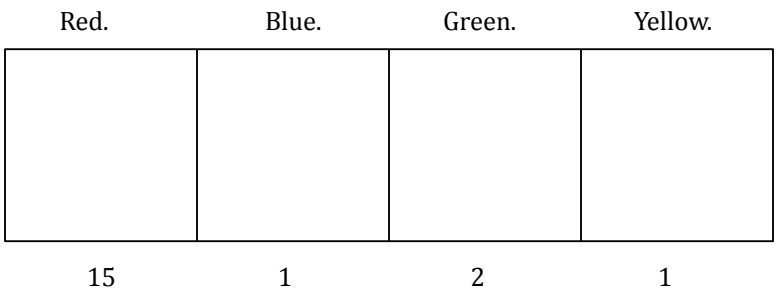
We then changed the colors, transposing the red and yellow, with this result: -

Figure 5.



All the colors were then changed, and the following record obtained : —

Figure 6.



The following table gives the facts for all the experiments with all the spiders : —

Red	181.
Yellow	32.
Blue	11.
Green	13.

The preference of our spiders for red seemed to be much more marked than that of Sir John Lubbock's ants; and the spiders had not so positive a dislike for blue. In Lubbock's experiments, on one occasion there congregated under a piece of red glass 890 ants, under yellow 495, under green 544, and under blue 5.

These experiments seem to be conclusive as to the existence of a color-sense in certain spiders.

FEIGNING DEATH.

Wishing to discover what spiders would do in the way of feigning death, we subjected them to various alarming conditions, in the hope of getting an exhibition of this interesting habit. We began with a female of *Astia vittata* that had been caught in a sweep-net. She was prevented from escaping by lightly striking the cloth of the net underneath the spot upon which she was standing. In this way, as often as she attempted to run or jump out of the net, she was knocked over and baffled. At first she immediately jumped up and made another attempt to escape; but at the eleventh repetition of the blow she fell upon her back and remained motionless, with legs outstretched, for half a minute. The next time she was knocked over she fell in the same position, and did not move for ten minutes. After that she kept quiet for only half a minute at a time. Several other species of this family behaved in the same way when subjected to like annoyances, but we never again saw an *Attus* lie quiet for so long a time as ten minutes.

A very active female of *H. ecclesiasticus* was placed upon a table and lightly knocked and brushed about. She jumped up as soon as she fell, excepting in one instance, when she lay on her back with legs outstretched for half a minute.

A female of *Micromata carolinensis*, a species which runs with great rapidity, was treated in the same way. She appeared much alarmed, but when she fell always struggled to her feet without an instant's pause, and again endeavored to escape.

A great many more tests were made with running and jumping spiders; but in no case did they show that the spider would feign death, nor, indeed, that it had even acquired a habit of keeping still when alarmed. They were only reduced to quiet

after much buffeting about, when they probably lay still from sheer confusion.

Thinking that less active spiders would be more likely to develop a habit of keeping quiet as a means of escaping danger, we next tried some experiments with the Epeiridae. A pretty little female of *E. bombycinaria* was softly touched as she hung in the web; she dropped two feet and then swung to a neighboring branch, where she crouched motionless for three minutes. Being again gently touched, she fell to the ground, with her legs outstretched, and then quickly drawing them in, remained clinging in a very inconspicuous heap to a blade of grass. Here she stayed motionless for one hour, when she was placed in a bottle, carried into the house, and, still keeping perfectly quiet, was shaken out upon a table. After two minutes she was pushed about with the end of a glass rod, and then her legs were lifted one by one with a needle. She seemed so lifeless that we began to wonder if we had been watching a dead spider, after all. We finally touched her with the point of a needle; but at the first suggestion of a prick she ran rapidly away. She was knocked over as she ran, and remained motionless just as she fell, resting on the cephalothorax, with all the legs drawn closely in, excepting one, which was slightly extended. She did not look like a live spider, nor yet like a dead one, nor like anything else, excepting, perhaps, a bit of bark or a small lump of dirt. She lay thus, without a perceptible quiver, for more than two hours and a half, and then suddenly ran away. She was reduced to quiet several times after this, but was less patient, and endured no more handling. She did not usually lie still just as she fell, but deliberately gathered up her legs in such a way that they were undistinguishable from each other and from her body.

Shortly after this, while walking in the woods at dusk, we caught a large female of *E. infumata*. She was put into a tumbler, and left until the following morning, when one of us, upon going to look at her, exclaimed that she was dead. Her legs were drawn up and bent, and she looked stiff and dry. She was handed from one to another of those present. Her demise was duly regretted, and her wonderful protective coloring was remarked upon. She was then put back into the tumbler. An hour later, much to our astonishment, we found

her moving about alive and well. As we were, at this time, experimenting upon the color-sense, she was placed in one of the boxes of colored glass described above, and at intervals of one hour, during the day, was moved from the section in which she had settled to another. Every time that this removal was made she fell stiffly on to her side, drawing her legs in, and remained thus for about three minutes. In experimenting with her afterward we found that when knocked about on a table she would stay in the position in which she fell, although this was often a very uncomfortable one. She showed no sign of life when rolled about, but jumped up at the least prick of a needle. She never remained quiet for more than twenty-seven minutes, and never absolutely motionless for so long a time as this, there being slight quivering movements of the legs and palpi at intervals of three or four minutes.

We had thus far found no spider that would endure bad treatment without showing signs of life; but in our next experiment we were more successful. A female of *E. insularis*, when rolled about on the table, acted a good deal as *infumata* had done, but had no such rigid, lifeless appearance. When she was knocked or touched with the point of a needle there was a convulsive twitch of the legs, though she seemed to be trying to keep quiet. The first time that she was pricked so as to puncture the skin she remained motionless, but at the second puncture she ran. On experimenting afterward with both males and females of this species we met with similar results, once finding an individual that did not run until the skin had been punctured five times. When the needle entered the skin there was usually a twitch of the legs, which seemed to show that sensation was present. Outside of this species we found no spider that would endure a puncture of the skin without running away, and we rarely found one that would keep quiet while being handled.

We now made a series of experiments with Epeiridae under more natural conditions, alarming them as they hung in their webs, and noting whether they feel, how long they kept quiet, and whether they were absolutely or only comparatively still. Some selections from our notes will best show what the experiments were, and how they resulted.

July 25. —	Experiments were performed with four females of *E. strix* as they hung in their webs.
	Number one shook her web with sharp jerks when a branch to which it was attached was moved; and did the same when she was lightly struck, eight times in succession, with a glass rod.
	Number two, when touched, dropped to the ground and lay on her back, with her legs drawn in, for ten minutes. She then moved, but upon being touched again became quiet. Tried to pick her up, when she ran a few steps and then drew in her legs and kept still. Repeated this several times.
	Number three, when touched, ran to the circumference of her web and hid under a branch. On being touched again she dropped to the ground and remained quiet for ten minutes, then began to run back and forth on the grass, and after fifteen minutes settled under a branch which touched the ground. Had she lost her way?
	Number four, when touched, did not run nor drop, but huddled her legs together and hung, apparently lifeless, for three minutes, then ran to a neighboring branch.
July 26. —	Finding a female of *strix* in her web we held a vibrating tuning-fork near her, when she dropped to the ground. The tuning-fork was then applied to her web, when she ran quickly up, probably under the impression that a fly was struggling there. [1] Repeated this with six individuals of *E. strix* and *E. labyrinthea* with the same result. Then tried holding the vibrating tuning-fork just over the spiders as they lay motionless after dropping from the web. They did not move.
	When a male of *Tetragnatha grallator* was touched, as he stood in the web, he ran to a branch and there stretched himself out. In this position he was almost indistinguishable, as his color was exactly like that of the branch to which he clung. When the branch was gently shaken, instead of keeping quiet, he ran a little way and then stretched out again; and this he repeated, stupidly betraying his presence as often as the branch was touched.

[1] Mr. Boys, in the experiment before referred to, found that after a spider has been made to drop, by bringing a tuning-fork near it, "if the fork is made to touch any part of the web, the spider is aware of the fact, and climbs the thread and reaches the fork with marvellous rapidity."

July 27. —	Four experiments were made with females of *E. bombycinaria* as they hung in their webs.
	Number one, when touched, shook her web violently; when touched again she dropped to the ground and remained still ten minutes. She then ran among the grass and was lost sight of. At the end of thirty-five minutes she had not returned to her web. Had she lost her way?
	Number two, when lightly touched, dropped two feet, resting motionless on a twig. After twenty-five minutes she ran straight up to the web.
	Number three, when touched, ran to a twig and crouched there with the first and second legs of one side extended on the web. After forty minutes she ran back to the centre.
	Number four, when touched, ran to a twig and crouched there, but kept one leg of the fourth pair extended on the web. After fifteen minutes she was touched with the end of a pencil, when she started on a rapid run. As often as she paused she was again touched. She ran and swung from place to place, stopping every moment to crouch on twigs; when swinging she gathered up her legs. Her idea seemed to be to keep quiet and inconspicuous. There was no suggestion that she thought of feigning death.
July 29. —	A female of *C. conica*, at the approach of a vibrating tuning-fork, dropped nearly to the ground and waited some minutes before returning to her web; but after this had been repeated several times the fork ceased to be alarming, and she paid no attention to it.
	A male of *T. laboriosa*, when caught in the hand and then dropped, fell on his side and remained quiet half a minute. He was dropped again, and while he lay motionless first one leg was pinched and then a second and a third. He remained quiet. His abdomen was then pinched, when he ran away.
August 1. —	A female of *Cyllopodia cavata* stood on a line leading to her little triangular web. When touched she ran to the nearest branch, and, dropping an eighth of an inch, gathered her legs together and remained hanging, without perceptible motion, for four hours. As she hung there, swinging in the wind, she looked much more like a bit of dry leaf than like a spider.
	A male of the same species was caught in a sweep-net. On

being shaken he suspended himself from a fold of the cloth, remaining quiet at first two minutes, and after a second shake, three hours and a quarter. When touched he ran away. Here we have an instance of one of our best feigners keeping quiet for hours while holding on to a line by a muscular effort.

In two of these experiments it seemed probable that the spider was unable to retrace its way to the web. This suggested the idea that the habit of keeping still after dropping must not only help a spider to avoid detection, but must also make it more certain of finding its way home after the danger is over. There would thus be a double advantage in absolute quiet.

It must be remembered that as a spider drops, it spins a line of web which forms a straight path backward to the starting-point; but as soon as the spider moves, the line adheres first to one twig or blade of grass and then to another, and its way home is thus rendered indirect.

Bearing this point in mind in our subsequent observations we were soon convinced that if a spider kept quiet after dropping, it could easily return to the web by means of its line; whereas, if it moved only a very little, it became confused and either lost its web entirely or only regained it after a lengthy search.

For example, we found, one evening, a female *labyrinthea* spinning her web in a cedar-tree, and made her drop by bringing a vibrating fork near her. She paused on a branch two feet below the web, and remained quiet for four minutes; she then changed her position, moving about half an inch. After this she was perfectly still for twenty minutes. At the end of that time she began to climb up and down over the branches, with her first legs extended, apparently hunting for the line leading to her web. She occasionally swung off from a branch for a little way, and then returned to it. After forty-five minutes she seemed to become discouraged, and crouched down on a twig, where she remained for over an hour, when she was replaced in the web, and immediately went to work to complete it.

We made another female of this species drop from her partly completed web. She stopped on a branch, and, after keeping perfectly quiet for one minute, changed her position (probably to one of greater comfort), moving about a quarter of an inch. After keeping still for five minutes more, she started to go back to her web; but it soon became evident that she had lost her

line. She began to search for it, stretching out her first legs, and running about over the branches. After hunting for twenty-five minutes she touched a strand leading to the web, and ran to it, taking up her work just where it had been interrupted.

Both of these spiders were spinning their webs at the usual time, — toward nightfall, — and, had they not regained them, would probably have gone without their suppers, and perhaps their breakfasts and dinners the next day. Any interruption in the food-supply must be in a high degree detrimental, and we therefore incline to the opinion that we have here an important factor in the development, at least among orb-weavers, of the habit of lying motionless after dropping out of the web.

It seems probable that the habit of keeping quiet in time of danger is better developed in adult than in young spiders. In the few experiments that we have made on this point the young spiders neither remained motionless so long, nor endured so much handling while keeping still, as the old ones. Thus, the adult *E. bombycinaria* will frequently lie motionless for hours; but in working with three young spiders of this species, we never saw them keep still for more than half a minute at a time.

Our experiments on this subject numbered two hundred and ten. They were made upon spiders from nineteen different genera.

The consideration of the meaning of the so-called habit of feigning death may be appropriately prefaced by the following quotations from Darwin and Romanes: —

"Animals feigning, as it is said, Death — an unknown state to each living creature — seemed to us a remarkable instinct. I agree with those authors who think that there has been much exaggeration on this subject: I do not doubt that fainting (I have had a robin faint in my hands) and the paralyzing effects of excessive fear have sometimes been mistaken for the simulation of death. Insects are most notorious in this respect. We have amongst them a most perfect series, even within the same genus (as I have observed in Curculio and Chrysomela), from species which feign only for a second and sometimes imperfectly, still moving their antennae (as with some Histers), and which will not feign a second time however much irritated, to other species which, according to De Geer, may be cruelly

roasted at a slow fire without the slightest movement — to others, again, which will remain motionless as much as twenty-three minutes, as I find with *Chrysomela spartii*. Some individuals of the same species of Ptinus assumed a different position from that of others. Now it will not be disputed that the manner and duration of the feint is useful to each species, according to the kind of danger which it has to escape; therefore there is no more real difficulty in its acquirement, through natural selection, of this hereditary attitude than of any other. Nevertheless, it struck me as a strange coincidence that the insects should thus have come to exactly simulate the state which they took when dead. Hence I carefully noted the simulated positions of seventeen different kinds of insects (including an Iulus, Spider, and Oniscus), belonging to the most distinct genera, both poor and first-rate shammers; afterwards I procured naturally dead specimens of some of these insects, others I killed with camphor by an easy slow death; the result was that in no one instance was the attitude exactly the same, and in several instances the attitude of the feigners and of the really dead were as unlike as they possibly could be." [1]

Romanes, after some discussion of the habit of feigning death in higher animals, goes on to say that Professor Preyer "ascribes the shamming dead of insects to the exclusive influence of kataplexy. . . . Now, I think it is not at all improbable that ' kataplexy' may have been of much assistance in originating, and possibly also in developing, this instinct. . . . But I desire it to be particularly noted that I only adduce this speculation, as it were, parenthetically. I think with Preyer that the shamming dead of insects is a phenomenon in which the principles of hypnotism are probably concerned. But if so, I regard these principles only as furnishing the materials out of which natural selection has constructed this particular instinct." [2]

There seem to be no reasonable grounds for thinking that spiders have any idea of simulating death, since only about once in fifty times is their attitude when motionless from alarm like that which they take when dead. The point at issue, then, is

[1] Darwin's *Essay on Instinct; Appendix to Mental Evolution of Animals*, by G. J. Romanes, p. 363.

[2] *Mental Evolution in Animals*, pp. 308-309.

whether alarm may cause them to fall into a kataplectic state in which they will endure bad treatment without showing any sign of pain.

Duncan, "On Instinct," says that spiders while feigning death "will suffer themselves to be pierced with pins and torn to pieces without discovering the smallest signs of terror," and Darwin refers to De Geer as saying that some insects may be cruelly roasted at a slow fire without the slightest movement. Out of the species with which we experimented we found one which would endure a moderate amount of pricking with a needle, and a second which did not move when its legs were pinched. Beyond this there was no stoicism under anything that approached bad treatment, although a few species allowed themselves to be handled without showing signs of life. We do not believe that any spider which came under our observation ever fell into a kataplectic condition. Our reasons for this disbelief may be formulated as follows : —

As a usual thing the spiders did not become motionless as soon as they were alarmed, but only after a preliminary arrangement of their legs, which tended to make them inconspicuous.

During the time that they were quiet they frequently were not absolutely motionless, there being not only slight quiverings of the terminal joints of the legs, but also slight changes of position.

When a vibrating tuning-fork was brought into contact with the web of a spider which, upon being alarmed, had dropped to the ground, and was lying motionless, it quickly ran up the line, apparently not being able to resist the inclination to secure its supposed victim.

While lying motionless in time of danger they were not insensitive to pain, and would seldom endure even a gentle touch without running.

The gist of the matter is, that certain Epeiridae, when alarmed, drop from the web and remain quiet for a longer or shorter time, their concealment being greatly assisted by the protective coloring which is present to some extent in nearly all of them. This amounts to nothing more than that when another spider runs to a place of safety, an Epeirid drops a greater or less distance (in the case of *C. cavata* only an eighth of an

inch) to a place of safety; both then remain quiet, unless disturbed, in which case the first spider trusts to its powers of running, while the Epeirid often (but not invariably) finds its best chance of safety in keeping quiet unless it is actually abused; the habit of keeping quiet also insuring the spider's safe return to its web when the danger is over. There is no need to call in "kataplexy" to explain the origin or development of a habit which can be so easily accounted for by natural selection alone.

We hold, then, that without question Darwin's explanation of the habit of lying motionless is the true one. It is the result of natural selection, and has been acquired by different species in different degrees, according to its usefulness in their various modes of life. Thus we find it in its greatest development among the comparatively sluggish Epeiridae, whereas it is badly developed or lacking in the running and jumping spiders, which are able, as any one who has pursued them will testify, to move with astonishing rapidity.

MISTAKES OF SPIDERS.

We found spiders much less clever than we had supposed them to be in regard to the recognition of their cocoons. We several times endeavored to deceive them by offering a bit of cotton rolled into a ball instead of their eggs, but without success, so that our spiders proved a degree more intelligent than the one deceived in this way by Dugès; [1] but, although they were too discriminating to take the cotton, a little pith-ball led them entirely astray.

When we took the cocoon from a specimen of *P. pallida*, and offered her in its place a pith-ball, she at first refused it, although it was several times so placed that it touched her. On comparing the pith-ball with the cocoon, however, we found that it was three times as large. When we reduced its size, and again offered it to the spider, she took it between her falces, and in a few minutes attached it to her abdomen. As far as we could see, the bit of pith gave her as much satisfaction as her eggs.

We found that when the cocoons were nearly of a size one

[1] Romanes' *Mental Evolution in Animals*, p. 382.

mother would take the cocoon of another — although of a different genus — just as quickly as she would her own. On one occasion we gave the cocoon of *Pardosa pallida* to *Lycosa* (sp?), and in a few minutes removed it from this spider to give it to *Pirata piraticus*, and the foster-mothers seemed fully as devoted to the eggs as the real mother.

To test still further their general intelligence, we took the outer coat from a cocoon of *pallida* and slipped it over a lead shot of the same size, but at least three or four times as heavy. There was so little of the cover left after the operation that we could scarcely perceive any difference between it and an uncovered shot. We offered it to the spider, and, much to our surprise, she at once seized it, and, after a good deal of trouble, succeeded in fastening it to the under side of the abdomen. Our impression that we had entirely demolished the cover in getting it over the shot must have been an error, since otherwise she could scarcely have attached it by means of the lines of web. The load was so heavy that the spider could only with great difficulty, and moving very slowly, walk up the side of a board. While transferring her to another box the shot, from its weight, fell from her abdomen, and she spent over thirty minutes, working with all her might, in fastening it on again. She had taken only five or six steps when it again fell off, and she then carried it about between the falces and the third pair of legs. We next endeavored to induce a second specimen of this species to take a plain shot, but all our efforts failed. We then took away the web-covered shot from the first specimen, and offered her in its stead the plain shot, but this she stubbornly refused, so that after a little we returned to her the web-covered shot, which she took back with every evidence of tender emotion.

Having satisfied ourselves that a Lycosid had not sufficient intelligence to distinguish between a pith-ball or even a heavy shot and its own cocoon, we made some experiments to determine whether it had intelligence enough to choose its cocoon if we offered the cocoon and the pith-ball together. To test this we placed the two side by side. The spider, approaching from one side, first touched the pith-ball and at once seized it with her falces; but as she moved away one of her anterior legs came into contact with the cocoon. In this position she remained quiet for a minute or two, and then dropping the pith-ball she took up her

cocoon and moved away with it. On the next day, when we placed the two in front of her, she again happened to meet the pith-ball first, and, as before, took it up at once. This time she ran off with it, and it was some time before we could manage to place the cocoon just in front of her; but as soon as we succeeded, and her legs touched it, she stood still, and within a few minutes dropped the pith-ball and took up her eggs.

It is evident, from these observations, that this spider, when allowed a choice, will select the cocoon rather than the pith-ball; but in the absence of the cocoon will content herself either with a pith-ball or a web-covered shot. The fact that a spider will carry about so comparatively heavy an object as a lead shot instead of its cocoon certainly argues a poorly developed muscular sense.

Milwaukee, Wisconsin, Nov., 1887.