Sense of sight, courtship and mating in Dugesiella hentzi (Girard), a Theraphosid spider from Texas.

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With Plates 10—11 and 4 figures in the text.

There seems to be sufficient evidence that the courtship in those spiders of the suborder Araneae verae, which make no snares and hunt their prey, depends mainly upon their sense of sight. Although Montgomery sought to ascribe the leading role to the sense of touch, this view finds no confirmation in experiments on blinded spiders, which were described years ago by Mr. and Mrs. Peckham. It is easy to observe that male jumping spiders (*Attidae*), admirable as an object for experiments on account of their love dances, do not approach the females and do not notice them at all so long as their eyes remain covered with paint. Direct observations of the courtship in spiders with good sense of sight, such as *Lycosidae, Pisauridae, Oxyopidae, Salticidae* and *Dysderidae*, show that the male watches the behaviour of the female attentively, now approaching her, now receding if she shows signs of anger and assumes a threatening attitude. The old story that the female attacks and devours the male after the coitus is finished, is still to be found in a good many textbooks, but it is very far from the truth. It may occasionally happen that a female kills a male, but such cases are rather rare exceptions to the general rule. On the other hand, we find males and females living peaceably together during the mating period. This is especially true in the case of orbweavers and Theridiids. I have seen as many as eight males of *Latrodectus mactans* in a single web together with one female, in San Geronimo on the Isthmus of Tehuantepec where this species is very abundant and is found chiefly upon the cactus. Yet courtship in spiders is naturally hazardous, since it is always doubtful whether the female will meet the male in a friendly way. In the case of the hunting spiders the male therefore as a rule, begins his courtship from a safe distance, dances, beats rapidly on the ground with his anterior legs, rises on the hind legs or walks head downward — a different mode of courtship characterizing each species — but he never stops watching the female and takes to his heels at the first sign of danger. Cannibalism is only too common among spiders. A robust, hungry female does not recognize her mate in the male unless she is sexually excited, looking on him only as prey; but when she has had sufficient food and is sexually excited, the latter condition depending largely upon the maturity of the eggs and the temperature of the atmosphere, then the male is allowed to approach. Now begins the second act of the courtship, in which the sense of sight plays no further rôle and both sexes are guided by the sense of touch alone. With the decreasing resistence of the female, the male becomes bolder and more aggressive until the reticence of the former is overcome and the palpus is introduced into the genital opening. In rare instances, as for example in the north American *Dendryphantes marginatus* (Walck.) (= *Philaeus militaris* Peckham) the male builds a bridal tent over the immature female, and keeps her there for several days, until she will emerge mature from her last moulting when the mating will be possible. But whatever the mode of the courtship may be, whether the spider is a sedentary or a hunting one, there takes place always a remarkable and sudden change in the instincts of the male when he attains maturity. This is true for all genera and for all families. Ontogenetically older and more general instincts are inhibited or superceded by new, temporary instincts and the male performs actions which be has never before performed and which, with the exception of some species, he will never repeat. The change in the structure of the body necessitates the change of all previous habits.

The Theraphosid spiders in many respects present a distinct and interesting group and for this reason I have for several years sought an opportunity to study their structure and habits. Their anatomy differs in many respects from that of the true spiders and they may be regarded as a phylogenetically older group connected with the palaeozoic spiders through the family *Liphistiidae*, representatives of which are known from Pinang and Sumatra. We find among the Theraphosids wonderful cases of adaptation and a great diversity of forms and instincts, but their study requires a thorough knowledge of the whole group as well as of the different species and their characters, since there are few animals which are more difficult of identification. Very few species can be identified offhand and then, only when the locality is well known. The majority require minute examination under the microscope, combined with careful measurements, a procedure of course possible only on dead specimens. Extreme caution is advisable in procuring material, in order to make sure that all individuals belong really to the same species. The actual handling of even the largest, so-called „Tarantulas" (name given in America to Aviculariids), is very simple and safe since they are peaceful and rather sluggish creatures.

There exists a remarkable parallelism between the Theraphosids and the true spiders, both in regard to their structure and habits. The „tarantulae" dig holes in the ground or live under rocks or logs, just as we find among the *Lycosidae*. The wonderful trapdoor nest of the *Ctenizidae* has its parallel in the turrets of some American and European *Lycosidae*, quite especially the *Lycosa singoriensis* and *Lycosa opifex*, the latter of which, according to Professor WAGNER who has given a detailed description of the species and its habits, makes a genuine trapdoor. The *Ischnothelidae* make webs similar to those of the common *Agelena* and are grey in color with long spinnerets and rapid in their motions. During my trip to Mexico I saw a great many webs of *Evagrus mexicanus* and *Ischnothele digitata* among the aloe and other plants in the vicinity of Vera Cruz and did not at first pay any attention to them, thinking that they were webs of *Agelena naevia*. Not until my attention was attracted by the unusual size of one of these webs, did I discover that every one of them contained a Theraphosid and not a true spider. These spiders, also, sit in the depths of the tubes of their webs, hurling themselves with lightning-like rapidity upon any insect that falls into the snare and hurrying back with it into the tube. They are, moreover, daylight creatures and not afraid even of the tropical sun at noon. It is interesting also to mention that I frequently found in the tropical jungles of Central America one or two males of

Evagrus mexicanus in the same web with a mature female and a whole family of young spiderlings.

The life and habits of the Aviculariids are but little known, partly because the majority of them are natives of tropical countries and more apt to fall into the hands of a collector than of an investigator and partly because they are preeminently night creatures and only rarely to be seen by daylight. In the species which came under my own observation, the mother guards the cocoon for a long time. Whether or not the young moult before leaving the mother, I do not know. At first they appear to lead a gregarious life and several individuals make a web in common. Later they separate and are to be found under the bark of fallen trees where some of them construct little webs of their own, somewhat similar to the webs in which certain true spiders hibernate, while other individuals of the same age and species seem to be content with the protection afforded them by the bark. This instinct for spinning a web is gradually lost and in the next stage we find the older but still immature individuals in the holes in the ground. These holes vary considerably according to the species to which the "tarantula" belongs. Some choose open places such as roads or fields and meadows; others prefer the jungle, while still others utilize natural depressions or holes among the rocks. But in each species all the holes are always alike. Indeed, one who is acquainted with all the species of a given locality, is able to identify the species from the looks of the hole and the little web which protects its entrance, for the majority of species spin a thin, opalescent sheet of web clear across the entrance upon retiring for their daytime rest. The beautiful *Eurypelma vagans*, a species very common on the Isthmus of Tehuantepec, has the entrance to its hole on a level with the surrounding ground and the opalescent sheet of web across the entrance is a sure sign that the spider is "at home". The grey-brown *Eurypelma rustica* makes a funnelshaped superstructure of earth and web and the *Hapalopus pentaloris* with its pink cephalothorax and red bars on the abdomen is also easily to be recognized by the structure of the entrance to its hole. The diameter and depth of the hole which is usually perpendicular, naturally vary in size and length according to the age of the individual and the composition of the ground. Once only I found a hole of an *Eurypelma*, having a little excavation in the side of the tube, halfway between the entrance and the bottom, where the spider would take refuge whenever water was poured into the hole. It was only by adding creosole to the water that she was finally forced to get out. A few holes were a whole meter deep. The "tarantula" spends the entire day at the bottom of the hole, and comes up at night, when it destroys the sheet of web over the entrance. It never goes away from the entrance but sits quietly close beside it. I have often seen them in this position when I was studying the night life of the tropical forest with the aid of an acetylene lantern. The slightest flash from the lantern would cause them invariably to disappear into the hole, but when a night insect comes in the way of one and is unfortunate enough to touch it, it is at once overpowered and carried down into the hole. Thus is the life of the tarantula divided between its daytime rest in the depth of its hole and the watch at its entrance during the night. Only when the forests are flooded and the water has driven the "tarantulas" out of their holes, may one see them occasionally in the daytime, climbing on bushes with an agility remarkable in such heavy and sluggish creatures. They seem to have little fear but prefer always to get out of the way of the aggressor and attack only when cornered. Even then they first assume a threatening attitude, warning the intruder and giving him ample time to reconsider the situation. At this stage it is wise to keep one's hand away. In case the tarantula is irritated still further, it throws itself suddenly, with indescribable rapidity and rage upon the enemy, grabs it with all eight legs and inflicts a deep wound with its powerful fangs. A housemouse which I placed in the same box with a mature female of *Dugesiella hentzi*, died 14 seconds after being bitten. Whether death was due to the poison alone or was accelerated by possible lesion of the heart, I am not able to say.

The life of the immature male resembles in all particulars that of the female, but as soon as he reaches maturity his habits undergo sudden change. Stimulated by the awakened instinct of propagation he leaves the hole in which he spent his youth and becomes a tramp. He fills his palpi with sperm and exposing himself to great dangers, seeks the female in order to accomplish the act which Nature has assigned to him and upon which the existence of the species depends. I do not know whether in nature the males live as many years as the females undoubtedly do or whether they die when the season of mating is over, but all the males which I kept in captivity died toward the end of November.

Which are the senses that enable the male to find the female?

Upon which senses is the preservation of the species dependent? What instincts are made use of by Nature to the accomplishment of this end? How do they originate in the individual? What is the rôle and the behaviour of the female? Is the entire act wholly unconscious or does the behaviour change under the influence of experience? These are the questions to which I endeavored to find answers in the course of my observations and experiments.

I owe the choice of *Dugesiella hentzi* as an object of investigation to a happy chance. During my stay in Texas on the return trip from Mexico, to which country I was sent by the American Museum of Natural History to collect arachnida, I had the pleasure of meeting Professor CARL HARTMANN. As I was unable at that time to find tarantulas in Texas on account of the extreme dryness of the season, I asked Prof. HARTMANN to send me later some living specimens. Through his kindness I received during May and June, 1910, over a score of individuals of *Dugesiella hentzi* from Huntsville, Texas. Of these some died during transport, others arrived in a condition of exhaustion that made experiments impossible. However, 3 females and 7 males reached me in perfect condition and these were used exclusively during the whole course of the observations. The males were all mature; so was one of the females and I am unable to state definitely whether they had mated before they were captured. As for the two immature females, they had certainly not been mated.

It may be of interest to others to know the best method of transport for the tarantulas. My experience showed that they suffer greatly for lack of water as well as from impact against the sides of the box due to careless handling in the mail. The safest way to express them is therefore to put each one in a wooden box of small size, the walls, bottom and lid of which have been lined with bath towelling, not glued but firmly tacked to the wood. The cloth should be moistened before the tarantula is placed in the box. The openings in the lid should be small and few. If they are big enough for the tarantula to get its legs through, it will do so and will break the tarsus or the whole leg. No moss or leaves should be put with the tarantula since even light friction will destroy the hairs on the dorsal surface of the abdomen, thus disfiguring the specimen. The towelling affords sufficient hold for the tarantula and protects it against sudden bumps. Immediately upon arrival water should be given in a little dish deep enough for the tarantula to immerse its cephalothorax. It will never fail to avail itself of the water and will spend some ten minutes drinking.

The best way to keep them in captivity is in a square glass box with a lid of wire-netting, about two inches of earth and a dish containing water. This dish should always be kept clean and filled and the earth should be kept moist. For food I use grasshoppers, crickets, black cockroaches and large ground spiders (*Lycosidae*). They eat comparatively little, not more than one grasshopper in two or three days in summer and scarcely anything at all in winter. For the experiments in mating I used a rectangular box of clear glass, having the bottom covered with white cardboard and the top entirely open to enable me to handle them with perfect freedom. Great difficulties were encountered in photographing them. In order to obtain clear pictures it was necessary to place the tarantulas against a white background which, to avoid reflections, had to be at a distance of at least a foot behind the glass box. The experiments cannot be made out of doors since the slightest breeze disturbs the animals. Direct sunlight has the same effect, so that I was forced to photograph them in a room near a north window. White screens were used to throw as much diffused light as possible on the box and to cut out reflections in the glass. The reflection of the camera in the front wall of the box was entirely obliterated by means of a deadblack cardboard placed immediately in front of the lens and having a hole of the same diameter as the lens. The Lumière Sigma plate was the only plate sufficiently rapid to give good results. Even then I had to use a stop F. 8, which did not permit of a sufficient depth of focus. To help the matter the box was made about 40 cm long and only 18 cm wide and the lens was focused on the center of the box. To change the focus during the experiment is quite impossible even if one has an assistant. The results could be better if one used a large lens with the camera placed at a greater distance, but I did not have such a lens as the size of the laboratory would have precluded its use, anyway. Since an exposure could not be made longer than $^1/_{25}$ of a second, the negatives were of course all under exposed and had to be intensified. Not including some 6 dozen of spoiled plates, 8 successful series were made which amounted in all to about seventy negatives. The reproductions shown on the accompanying plates are enlargements from the original negatives.

It seems to me advisable to give a detailed description of the specific characters of *Dugesiella hentzi* since the identification is not a simple matter and a correct description is lacking. Some of the figures given by McCook in his book on American spiders certainly represent some other species or else they are badly drawn. He shows a specimen with long and rather thin legs, whereas all my specimens are with rather short and heavy legs. The sexual dimorphism is also so great that one could not recognize the same species in the male and female by the appearance alone.

Description of the species.

Dugesiella is a genus belonging to the subfamily *Eurypelmateae*. Eugène Simon gives the following definition of this genus in his great work, "Histoire Naturelle des Araignées":

"*Coxa pedum primi paris antice, et spura et infra suturam, setis brevibus rigidis et spiniformibus echinata*" (p. 935).

On another page he writes: "Dans le genre *Dugesiella* la hanche de la première patte est garnie d'épines ou de crins spiniformes et la face correspondante de la patte-mâchoire offre aussi quelques petites épines isolées, disposition rappelant beaucoup celle que j'ai décrite dans le genre *Adranochelia* et pouvent être considérée comme le rudiment d'un organe stridulatoire" (p. 933).

The genus contains only two species, *D. crinita* Pocock from Mexico and *D. hentzi* from the United States.

Dugesiella hentzi (Girard)

= *Mygale hentzi* Girard, in: Marcy's Report Red River, Louisiana, 1854, p. 262, tab. 16, fig. 1—3.

= *Eurypelma mordax* Ausserer, in: Verh. zool.-bot. Ges. Wien, 1871, Vol. 21, p. 211, tab. 1, fig. 14.

? = *Eurypelma hentzi* McCook, American Spiders, 1889, Vol. 1, p. 327, fig. 313.

? = *E. hentzi* McCook, ibid., 1890, Vol. 2, tab. 5, fig. 1.

? = *E. hentzi* McCook, ibid., p. 321, fig. 303, 304.

= *E. hentzi* Banks, in: Entomol. News, Philadelphia 1892, Vol. 3, p. 147.

= *E. hentzi* D. H. Simon, in: Hist. Nat. Ar., 1903, Vol. 2, p. 937.

Hab. U. S. A., Louisiana, Texas (? Arizona, ? Kansas).

Color in life; sexual dimorphism.

The first impression one gains on seeing a live female and male together is of the difference in color. The male looks almost black, while the female is of a light brownish-grey color. When examined more carefully the male shows a number of long bristles of fire red color on the back of his abdomen. The female has no such bristles and the hair covering her abdomen is of the same color as that on her legs. Her cephalothorax is considerably lighter than her abdomen and faint stripes of a similar color appear on the patellas, tibias, metatarsi and tarsi, especially of the four front legs. The color of the ventral surface of body and legs is in both sexes a uniform black with the exception of the mandibles, maxillae and lips which are of a fire-red color. The relative length of the legs is in the male considerably greater than in the female and the legs are thinner. The behaviour of the mature male in captivity also differs from that of the female. He is much more nervous and agile, but apparently less inclined to fight, scarcely ever assuming the threatening attitude of the female. The rôle of the so-called secondary sexual characters of the male, represented in this species by two hooks at the end of the first tibiae, will be explained farther on.

Measurements. Female. The size of the female varies greatly according to age and nourishment. The following are the measurements (in millimeters) obtained from a rather small but already mature specimen.

Total length 38,0; Cephalothorax, length 15, width 14,6. Distance from dorsal groove to the edge of the clypeus 10,3. The grove is deep, semi-circular, procurve.

Legs	Femur	Pat. + Tibia	Metatarsus	Tarsus	Total
I	11,3	14,1	7,4	5,7	38,5
II	10,6	12,6	6,9	6,1	36,2
III	9,7	11,4	8,2	5,7	35,0
IV	11,9	14,9	10,5	8,0	45,3

Palpus	Femur	Pat. + Tibia	Tarso-metatarsus	Total
—	8,6	10,3	6,1	25,0

The arrangement of the spines on the legs is apparently irregular. They are present only on the tibiae and metatarsi and are more numerous on the hind legs but always very difficult of ascertaining even on dead specimens. The scopulae have the same structure as in the male. The modified, spinelike hairs on the inner surface of the coxa of the first pair of legs, are well defined. The mandibles in both sexes have a row of 8 teeth on the promargin (Textfig. A).

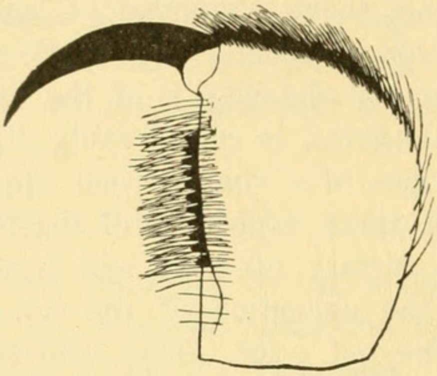

Fig. A. Mandible.

The position of the eyes on the cephalothorax is the same in both sexes (Textfig. B). (See the chapter dealing with their senses.)

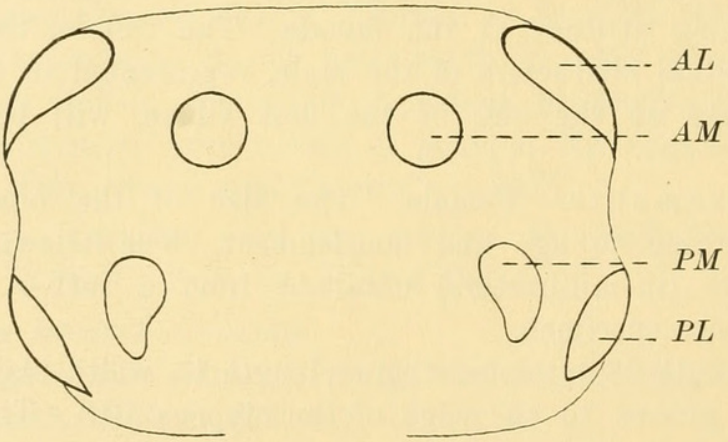

Fig. B. Eyegroup.

Measurements taken from a large, mature male. Total length 40,0. Cephalothorax, length 17,5, width 16,0.

Legs	Femur	Pat. + Tibia	Metatarsus	Tarsus	Total
I	14,5	18,3	11,7	7,5	52,0
II	13,5	17,0	10,7	7,5	48,7
III	12,0	15,5	11,5	7,5	46,5
IV	14,5	18,3	15,0	8,5	56,3

Palpus	Femur	Pat. + Tibia	Tarso-metatarsus	Total
—	10,5	14,0	0,4	24,9

The scapulae, which are not divided longitudinally by spines or setae, cover the entire tarsus and metatarsus of the first and second leg, tarsus and distal half of metatarsus in the third leg, tarsus and distal $^2/_5$ of metatarsus in the fourth leg. The spines are variable. The tibiae of the front legs with two hooks directed downward and a little inward. The claws are in both sexes small and smooth and entirely concealed by the well developed fasciculi unguiculares. The spinelike hairs on the anterior coxae are still better developed than in the female. The structure of the palpal bulb is apparent from the drawings (Textfig. C and D).

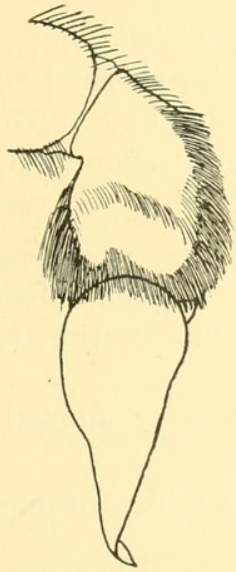
Fig. C. Palpus.

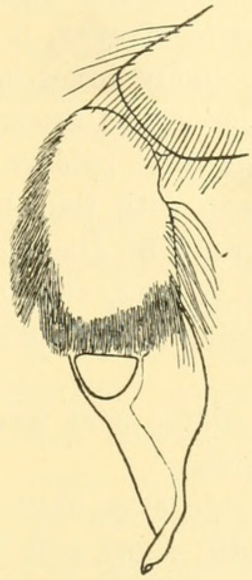
Fig. D. Palpus.

The senses.

It seems to be quite certain that neither sex is able to perceive either low or high sounds. At least they never react. If a male cricket is placed in the same box with a *Dugesiella* which has been kept hungry for several days, it will sing for hours sitting quite close to the tarantula without attracting the latter's attention, but let it touch the tarantula and it will be at once attacked. Sounds produced by a stringed instrument or a tuning fork remain without effect unless the bottom of the box is set vibrating. The sense of smell, also, seems to be, if not quite absent, at any rate very poorly developed. Only strong irritants such as formalin, glacial acetic acid, osmic acid, chlorine und some oils (clove, lavendar, bergamotte) when brought on the end of a glass rod close to the leg of the tarantula, force it at the end of fifteen seconds or more, to lift the leg. Grasshoppers, crickets and certain beetles having a strong odor, when placed at the same distance, produced no effect whatever and the question whether *Dugesiella* possesses a real, if poor sense of smell or reacts to the direct irritation of the skin, caused by the vapors of the reagents, remains unanswered. So much is clear, however, that *Dugesiella* neither recognizes nor perceives the presence of live insects or spiders from their odor. There remain, therefore, two senses by means of which *Dugesiellas* may be supposed to recognize other individuals of their own species and their prey, the sense of sight and the sense of touch. Since they possess four pairs of eyes, it was necessary that their sense of sight should be thoroughly investigated before a definite conclusion could be reached. I have used the same methods as in my previous study of the sense of sight in spiders, but have also made some experiments and observations with the object of controlling the results.

The eyegroup of *Dugesiella*, represented in Textfig. B consists of three types of eyes, two of which are new to science.

The following measurements are taken from the male described above.

Anterior middle eyes have a circular lens: diameter 0,2622 not counting the iris.

Anterior side eyes have a lens shaped like an imperfect elipse; long axis 0,4140; short axis 0,2622.

Posterior middle eyes are more or less oval in shape; long axis 0,2622; short axis 0,1794.

Posterior side eyes have almost the same shape as the anterior side eyes but are a little smaller; long axis 0,3450; short axis 0,1794.

The anterior middle eyes have the same structure as the corresponding eyes in all other spiders. They form clear and sharp images without aberration, but the diameter of the rods in so great that the image of one square centimeter at a distance of 20 centimeters from the lens falls only on a single rod. The remaining six eyes are with inverted retina but differ from the corresponding eyes in true spiders in that they have no vitreous body, t h e c e l l s o f t h e r e t i n a l y i n g d i r e c t l y u n d e r t h e l e n s. The diameter of the rods is a trifle greater than in the anterior middle eyes, the largest rods being found in the posterior middle eyes, where the entire retina is composed of comparatively few cells. In these eyes there is a distinct membrane dividing the retina into two almost equal parts, a distal and a proximal. More material is, however, necessary in order to obtain a thorough understanding of this structure.

The dioptric apparatus of the side eyes differs from that of the posterior middle eyes. In the latter it is represented by a lens which appears almost flat when looked at from above, but which is, in reality, slightly convex-concave, of the same thickness as the surrounding chitin and with the concave surface toward the retina. It forms rather indistinct images which are almost twice the size of the images in the anterior middle eyes, without aberration but with a considerable loss of light, so that a black square appears through them a light grey. It is interesting to note that the image shows no distortion when the square is rotated round its axis, although this eye has an oval lens.

The dioptric apparatus of the anterior and posterior side eyes consists of ellipsoidal lenses and in consequence the images formed by them show remarkable distortion. A square appears as a rectangle, the ratio of its sides being in direct proportion to the ratio of the axes of the lens. The distortion increases when the square is rotated round the eye axis and reaches its maximum when the sides of the square form an angle of 45^0 with the long and short axes of the lens. The shape of the image is that of a long rhomb. It is easy to see that the long diagonal of this rhomb occupies more rods on the retina than the long side of the rectangle. With other words the image of an object stretches rapidly at every turn either of the tarantula or of the object and in doing this, stimulates a greater part of the retina. It is doubtful whether such distorted images can convey a correct conception of the object under observation. It seems to me to be more probable that these eyes serve merely to perceive light and shade, for which they are certainly better adapted than eyes forming correct images under all angles.

The following obversation shows that *Dugesiella* perceives direct sunlight. As soon as a ray of sunlight strikes its eyes it covers them up by drawing all its legs together so that their patellas touch. At other times there is not this reflex action but *Dugesiella* invariably walks away and tries to get into the shade. Although I have shown that images of dark objects are formed in all eyes, yet *Dugesiella* certainly does not perceive such objects. Neither male nor female reacts in any way to the presence even of such large things as a mouse or the human hand. It is interesting to observe the difference in behavior between a *Dugesiella* and a *Lycosa nidicola* when both are placed in the same box. *Dugesiella* pays no attention to *Lycosa* no matter at what distance they are from each other. Quite different *Lycosa*! This beautiful hunting spider will run without hesitation toward *Dugesiella* until it is about 20 to 10 centimeters from the latter, when it invariably stops and no teasing can force it to go on in the direction of its powerful enemy. I have repeated the experiment time and again and always with the same result. An insect that having come close enough to touch *Dugesiella*, by some chance escapes her attack, is in no further danger from pursuit. *Dugesiella* does not pursue and has no instinct for pursuing its prey, an instinct which would be of no avail without organs of perception. But the most instructive evidence is furnished by the courtship. The male, if he once loses contact with the female, continues his courtship alone, beating helplessly with his front legs on the ground and walking aimlessly about, unaware of the female he is courting even if she is not farther than a centimeter from him! The sudden change in his behavior when he happens to touch her again, even with his hind legs, is so marked, that no other explanation is possible than that both sexes are entirely dependent upon their sense of touch.

This sense in all spiders is very highly developed, but especially the tarantulas are noted for their hairy appearance. The body and legs of *Dugesiella* are thickly clothed with hairs of several different kinds. Some are very thin and plumelike, others much stiffer, while still others may be regarded as regular bristles. The base by which they are attached to the skin is also variously structured, being characteristic for each kind of hair. But since it is not my purpose to study the morphology of the hair, I do not give a detailed description. Suffice to say that every single hair is connected with the nervous system by means of one or more terminal sense cells and a sensory nerve. Sections through the skin show the heavy chitin to be perforated by innumerable canals running from the hypoderm to the base of each hair. The terminal sense cells are located not in the hypodermis but in the canals of the chitin, about half way between their outer and inner openings. The sternum is so heavily covered with hair that it looks almost like a brush. Hair is, however, absent in six places called the sigilla which represent the outer marks of the lower processes of the endosternite where they are connected with the chitin. The nerves running from the central nervous system to the hairs in the sternum may be seen in great numbers on each section, the thoracic ganglion being close to the skin and the nerves short and rather thick. We have in the hairs of *Dugesiella* sense organs capable of perceiving the slightest touch and, probably, of distinguishing between various degrees and kinds of touch by means of the various kinds of hair. A light breeze or even the mere breath of one's mouth makes *Dugesiella* jump. If a cricket but touches the hair covering the leg of *Dugesiella* with the end of one of its antennae, this touch is sufficient to convey to the mind of *Dugesiella* the fact of the presence of prey. Touching with a silk thread sometimes produces the same effect as the touch of an insect. *Dugesiella* will try to seize the thread as it does the insect. But if a pencil is used the contact is too rough and *Dugesiella* goes away, assuming, if further molested, the characteristic threatening position. These experiments show that *Dugesiella* is able to distinguish between at least two kinds of touch. The light touch awakens in her the association between touch and food and the rougher, between touch and the enemy. That we have here to do with associations and not with mere reflexes we may gather from the different answers to the same stimulus under different conditions. If *Dugesiella* is not hungry or if the weather is cold, a cricket or spider may creep all over her body with impunity. She does not make the slightest attempt to catch it but tries merely to get rid of it by brushing it off with her legs.

Touch, then, is the main sense of the tarantulas. We should, however, be making a grave error if we would deny to their sense of sight all influence upon their lives. The enemies of the tarantulas are chiefly active by day, quite particularly the "tarantula hawk", *Pepsis formosa*. If the tarantula were unable to distinguish between night and day, it would expose itself to a great many dangers it avoids by hiding in its hole which the enemy must find and enter.

Construction of the spermweb and the filling of the palpi with sperm.

I have observed fifteen times the construction of the spermweb by the male. The observations were made on five different specimens, in each case from the very beginning to the end, and in all fifteen cases the behavior of the male did not show the slightest variation. The necessary conditions appear to be: right time of year, plenty of food and drink, comparatively warm weather, presence of mature sperm in the spermducts and absence of direct sunlight. In twelve cases the web was constructed in the morning, in three, in the afternoon. None of the males which came under my observation constructed a web at night. Judging from the identity of the actions of the five males in fifteen separate instances as well as from the analogy with the actions of other arthropods in captivity, keeping in mind that instincts are as a rule subject to small variations, we have to assume that the male *Dugesiella* constructs its spermweb in nature also, by day. The whole performance requires some three or four hours for its completion, during which the male is exposed to great dangers since the web must be constructed outside of the hole. The difference in temperature of the room by day and by night was almost nothing in eight cases while in the other seven, it was very great, but since an instinct once fixed by nature, is not subject to change, we may suppose that the construction of the web by day, is in some way dependent upon the higher temperature of the atmosphere then, in the natural habitat of the tarantula.

A distinct restlessnes of the male precedes the construction of the web. He walks about in his box and if the lid is not on, tries to get out. Finally he choses a place and begins to weave. The shape of the box has no effect upon the web. In round jars as well as in square boxes, in boxes containing earth, dry branches and high plants and in glass boxes with nothing on the bottom, the web is always constructed in the same manner and has the same shape. All the tarantula requires is a wall from which to spin the web in the form of a sheet which is fastened on the other end to the ground. The height of the wall-end of the web above the ground is dependent upon the size of the spider. While attaching the threads to the wall the male stands on his front feet (Plate 10, Fig. 3), at times quite straight head downward and spinnerets up. He fastens their other ends to the ground, drawing each thread taut. The width of the sheet is about equal to the length of the body of the male. Besides the longitudinal threads the male spins threads in all directions so that the structure of the sheet much resembles that of the web of an Agelenid. In some instances the middle is strengthened by extra threads as we see it on Plate 11, Fig. 8. The male's next step I call the testing of the web. He creeps under the web and lying on his back, spends considerable time in that position. If he were weaving his spinnerets would move and the thread produced by them would be visible, but this is rarely the case. During most of the time he moves only his legs, holding the sheet with the claws and lifting his body by pressing the patellas against the ground. On Plate 10, Figs. 4 and 5 the same male is represented in two different moments of this curious attitude. In Fig. 5 one may even see that the web is considerably bent upward by the pressure of the body. At times he will cease testing and begin to spin from below; then after a while, he will again stop spinning and begin testing his work anew by lifting himself on his patellas and pressing the whole ventral surface of his body against the sheet. He next finishes the anterior edge of the spermweb by strengthening it and at the same time making it semicircular. This semicircular edge was made in all fifteen cases. Now, still lying on his back, the male brings his palpi to his mouth and from time to time puts them alternately deep into it. Finally he creeps out from under the spermweb, bringing first his front legs and palpi up over the semicircular edge. One of the males was photographed at this moment and this photograph is reproduced on Plate 10, Fig. 6. In creeping over the semicircular edge, the male drops his sperm on top of the web, about one centimeter from the edge. The drop is about $^1/_8$ of a cubic centimeter in size. The male now turns on the web so that he comes to lie on it with his mouth over the sperm. Both palpi are lowered over the semicircular edge and brought under the web and the drawing of the sperm into the bulbs of both palpi begins. During this process which lasts for more than an hour (an hour and 55 minutes in one instance), both bulbs are alternately, rhythmically, at a rate of from 80 to 100 times a minute, lowered and pressed against the spermweb in the spot over which the spermdrop was placed. The spermdrop is therefore drawn into the bulbs through the web. The process is represented in Figs. 6—8 in all of which we see the drop of sperm photographed from below through the web and appearing as a light grey spot. In Fig. 7 one may even see that the bulb is actually pressing the web upward. During the process of sperm filling, the male is so preoccupied with it that the box may safely be carried about without disturbing him and even direct sunlight will not always stop the performance. The great length of time required for the accomplishment of the act would seem to indicate that the sperm is not really pumped by suction produced by contraction and expansion of the receptaculum, but rather that it is gradually drawn into it through capillary attraction. During the whole time of its duration, the entire dorsal surface of the male remains exposed to danger.

When all the sperm has been drawn into the palpi the male leaves the web never more to return to it. Some of my males filled their palpi three separate times after mating with the female and each time a new spermweb was constructed. After leaving the web the male quiets down for a while and at least a day must elapse before he can be induced to court a female. What the reason may be, would be hard to say. Perhaps the sperm needs to undergo some change in the bulb or perhaps the energy of the male is too highly taxed and he requires rest. The next day he again becomes restless and this is a sure sign that he will mate if he gets a chance. In one instance a male filled his palpi on August 29th and attempted mating in the middle of November, when he was already quite stiff and half dead. This goes to show how long the sperm remains active in the palpus since my observations leave no room for doubt that a male with empty palpi does not court and avoids contact with the female.

I do not know whether the male constructs the web and behaves in the manner described when he is doing it for the first time in his life. My specimens were all mature when captured. But it seems likely that the process is always performed in the same way since in those cases where the males repeated it, their behavior was invariably the same. I regret also that I do not know whether in nature courtship and mating take place by night or by day. Flashlight would disturb them and to photograph them would be totally impossible even in a room with subdued light. Neither male nor female, however, showed any aversion to mating in diffused daylight. I mated the same female 13 times with four different males, sometimes twice on the same day, in the morning with one male and in the afternoon with another.

Behavior of the female.

The behavior of an immature female and that of a mature one toward a courting male are entirely different. The immature female does not accept the male and tries to get away, meeting an aggressive male as an enemy. If flight is impossible she will fight and in one instance a small female struck a clumsy male in the sternum with her fangs (the male was forcibly teased into courting). He was at once paralyzed and without recovering his ability to move, died on the fourth day, thus proving that courthip in tarantulas is combined with real danger. When a mature female which has been mated several times does not want to accept the male, she behaves somewhat similarly to the immature female. She tries to run away or else assumes a threatening attitude, without, however, opening her fangs or doing so only when the male is not directly in front of her. It should be stated that females and males that happen to meet at a time when the males are not sexually excited, on touching each other assume the threatening position but never attack and soon separate. A female never molests a female. A mature but unwilling female is certainly able, if she has memory, to distinguish between an aggresive, courting male and an enemy. No experiments have been made upon Theraphosids to show whether they possess memory but true spiders undoubtedly have good memories as the experiments of Peckham proved and as I myself have had occasion to observe. The behavior of the mature female *Dugesiella* when molested by a male at a time of sexual rest, showed distinctly that she did not treat him as an enemy. It is only at the first moment when the male touches her that she assumes a threatening attitude. Even then she does not rise so high as she does when tapped with a pencil when she will remain in this attitude sometimes for over half a minute. Moreover, if the tapping with the pencil is continued, she will rise as high as possible on her hind legs and opening her fangs, will hold them open for a considerable time, as in Fig. 1, whereas if the male continues his courtship, she will lower her body so as to prevent him from getting under her and catching her mandibles. The difference is difficult to put into words but it is clear to one who has opportunity to observe it repeatedly when the conclusion is that she learns by experience not to remain standing too long on her hind legs and to avoid opening the fangs when unwilling to be courted by a male.

It is different when she is inclined to accept the male.

Courtship and mating.

When the restlessly wandering male happens to touch with his legs some part of the body or a leg of the female, he at once stops short and begins to strike simultaneously and violently with his anterior, sometimes with all four front feet. After waiting for a while he raises them slowly and again beats rapidly. In doing this he hits with his tarsi whichever part of the female he happened to touch and if, pausing, he feels that she is moving away from him, he follows her, keeping his front legs in contact with her. He is not, therefore, apt to lose a female if he first touches her with his front legs, but if it happens to be one of his hind legs that touches her, he is liable on turning round, to lose contact with her. If then he walks in a direction different from that of the female, even though as sometimes happens, their paths be parallel but a little distance apart, he is not able to find her again but continues to hit the bare ground with his front feet, eventually moving quite away from her though the slightest move in another direction would bring him again in contact with her. This continuous beating with the front legs upon the body or legs of the female, constitutes the first step in the courtship on the part of the male. In case the female does not attempt to run away, the male soon shifts his position until he is facing the female. The behavior of the female during the first stage of the courtship is composed of two elements. At the first touch she raises the front legs and assumes the attitude of defence and threat. The subsequent touching results in her rising high on her hind legs while still holding up the front legs. Finally she opens the fangs and the male catches them with the hooks on his front legs (Fig. 9). As this was done in every one of the 13 cases, it is evident that the hooks cannot be regarded as mere secondary sexual characters and their origin should not be sought in sexual selection. They serve admirably to guard the male against possible injury or even death while at the same time aiding him in the act of coitus. For he now forcibly pushes back the cephalothorax of the female with his front legs and drums with the patellas of the palpi on her sternum, all the time advancing (Fig. 10). The female, on the other hand, is entirely disabled and either remains motionless or is passively pushed backward along the ground until she strikes some obstacle. The second part of the courtship is soon at an end. The male introduces one of his bulbs into the genital opening of the female (Fig. 11). All the muscles of the female relax in this moment. She rests heavily with the end of her abdomen on the ground, her hind legs, automatically extended by the elasticity of the cuticle (the legs of spiders have no extensors) drag behind her. Her cephalothorax is often pushed back so violently by the front legs of the male, that it almost forms a right angle with the abdomen. The front legs remain lifted but they, too, show a complete relaxation of all muscles. The sperm is injected into one of the receptacles, the walls of which are rich with chitinous sense organs of special structure. The coitus lasts about half a minute. Then the palpus is withdrawn. If the male intends to introduce the other palpus he continues to hold the fangs of the female and after resting for a few moments, begins once more with the second stage of the courtship, i. e., he drums with the patellas of the palpi upon the sternum of the female until he manages to introduce the second palpus.

When the coitus is finished both male and female begin to back slowly away from each other (Fig. 12), the former still holding his front legs stretched out in front of him between the front legs of the female. The relaxation of muscles in the legs of the female gradually disappears. In the next moment both male and female make a sudden jump away from each other and go their separate ways.

As long as the palpi of the male are filled with sperm, he invariably courts the female if brought into contact with her, but when his palpi are empty he will not court, nor will any amount of teasing or forcible pushing him toward her, make him do it. He does all in his power to escape even when the female is sexually excited. Several days elapse after mating before he will construct another spermweb and fill his palpi again with sperm. The instinct of propagation with its complicated set of actions, necessary for the preservation of the species but endangering the life of the male as an individual, disappears with the accomplished mating and the inhibited instinct of self protection comes again into play and dominates his behavior.

Explanation of figures.

All figures are photographs from life and represent different moments in the life of *Dugesiella hentzi.*

Plate 10.

Fig. 1. A mature female in threatening attitude with fangs open.

Fig. 2. A mature male a moment after he has struck at an insect. The hooks on his front legs are well visible.

Fig. 3. A male fastening the first threads of the spermweb to the walls of his box.

Fig. 4. A male testig the spermweb from below.

Fig. 5. Another aspect of the same male a few moments later. The web is being pushed upward as shown by its curvature.

Fig. 6. The male creeping from under the spermweb over its semicircular edge.

Plate 11.

Figs. 6, 7, 8. The male drawing the sperm into his palpi by alternately lowering and pressing the bulbs against the spermweb in the spot over which the drop of sperm is hanging in the web. The drop appears as a light grey spot.

Fig. 9. First part of courtship in its last moment. The male is already holding the fangs of the female by means of the hooks on his front legs.

Fig. 10. Second part of the courtship. The male pushes the female before him and creeping at the same time under her, drums with the patellas of his palpi on her sternum.

Fig. 11. Coitus. The palpus introduced. All muscles of the female in a state of relaxation. She rests heavily on the ground on the end of her abdomen.

Fig. 12. Coitus finished. Male and female cautiously backing away from each other. Male with palpi lifted and front legs still stretched out in front of him between the legs of the female.