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THE ARACHNIDA

This book aims at giving the study of Arachnology something of the unity and status possessed by Entomology. The Arachnida have been increasingly studied in recent years, and this is the first book to summarise all the modern knowledge in a comprehensive description of these eight-legged animals.

Part I describes the Class as a whole ; the structure of the Arachnid, its habits, distribution, evolution and classification.

Part II considers in detail the various Orders, including fossil forms, and carries their classification down to the Families they contain.

Part III is concerned with the science of Arachnology as a whole, with especial reference to its economic and practical aspects.

With its numerous half-tone and line illustrations, the book should appeal not only to the zoologist but to many laymen interested in natural history.

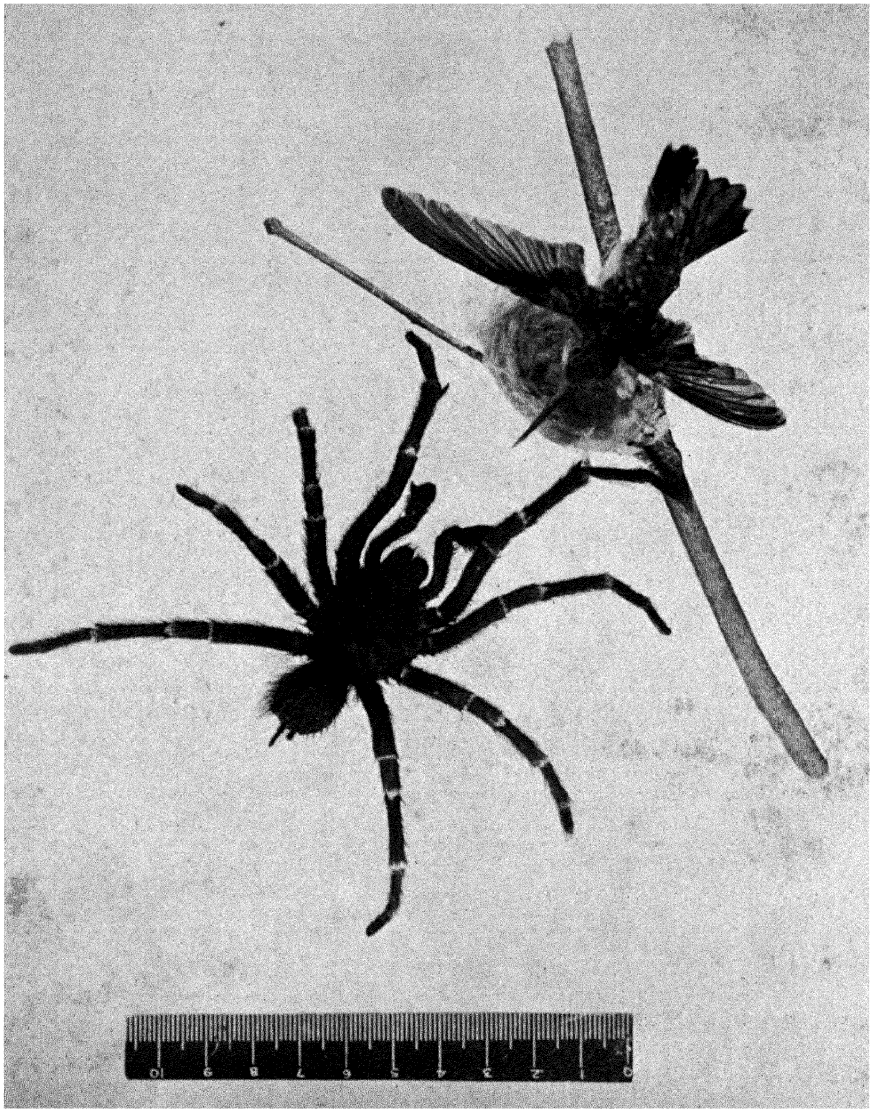
THE ARACHNIDA

Uniform with this Volume

A TEXT-BOOK OF PRACTICAL ENTOMOLOGY

By FRANK BALFOUR-BROWNE. viii + 191. 18*s*.

PLATE I



MYGALE, BIRD AND NEST

THE ARACHNIDA

BY

THEODORE H. SAVORY, M.A.

FORMERLY EXHIBITIONER OF ST. JOHN'S COLLEGE, CAMBRIDGE
AUTHOR OF "THE BIOLOGY OF SPIDERS," ETC.

"Est locus, in geminos ubi bracchia concavat arcus
Scorpios, et cauda flexisque utrimque lacertis
Porrigit in spatium signorum membra duorum."

OVID.



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PREFACE

My purpose in writing this book is to make a first attempt to give Arachnology something of the unity and status of an individual science that is possessed by Entomology. The Insect is not only better advertised by its beauty than is the Arachnid; it also sustains attacks on the bodies, crops and possessions of man with a greater success. The result has long been a natural dominance of Entomology over most other branches of Zoology.

Arachnology has, however, shown an increasing activity during recent years. The works of Nuttall and Warburton on Acari, of Roewer on Opiliones and Solifugæ, of Petrunkevitch on Araneæ and of Chamberlin on Chelonethi have brought our knowledge of some of the most important Arachnida into a satisfactory condition. And simultaneously the smaller Orders have not been neglected.

Room should therefore be found for a book which presents an account of all these eight-legged animals. Most of the existing works on the Arachnida are more than twenty years old; moreover, most of them are specially concerned with a single Order, which thus gains undue emphasis. For example, in the fourth volume of the *Cambridge Natural History*, 107 pages out of 221 are given to Spiders, in Comstock's *Spider Book*, 606 out of 700, in Berland's *Les Arachnides*, 325 out of 485, and in the present writer's *Biology of Spiders* 320 out of 350. In this book an attempt has been made to secure a more balanced treatment, though Spiders still demand most room.

It need scarcely be pointed out that a textbook is not a work of original thought or a description of original research and my indebtedness to my co-workers in the field of Arachnology is naturally very great. It is a pleasure to pay special tribute to the immortal labours of Octavius Pickard-Cambridge, Eugene Simon and T. Thorell, but thanks are also due to others. I must particularly mention Professor Alexander Petrunkevitch, of Yale, who, in addition to giving me his valuable works, has sent me kindly criticism and advice; Mrs. Florence D. Wood, of New York, who sent me her publications as well as a most acceptable collection of rare Arachnida; and Professor C. F. Roewer, of Bremen, and Dr. J. C. Chamberlin, of Idaho, both of whom sent me, in exchange, copies of their magnificent monographs. All these I thank sincerely.

Others have been no less ready to help in ways too numerous to tell; and for the gift or exchange of publications or for the sending of specimens I am indebted to many who have written to me since the publication of my earlier book. I would

ask the following to accept my thanks and great appreciation of their kindness: In Great Britain—Dr. W. S. Bristowe, Dr. W. T. Calman, Dr. Susan Finnegan, Dr. Mary L. Hett, Rev. J. E. Hull, Dr. A. R. Jackson, Mr. H. W. Kew, Mr. G. H. Locket and Mr. D. R. Pack-Beresford. In France—M. L. Berland, Dr. P. Bonnet, M. L. Fage and Professor J. Millot. In Germany—Professor U. Gerhardt, Dr. Marie Harm, Dr. H. Peters and Professor H. Wiehle. In Belgium—Dr. L. Giltay. In Switzerland—M. R. de Lessert. In Denmark—Dr. E. Nielsen. In Russia—Professor Charitonov and Professor S. Spassky. In America—Dr. S. C. Bishop, Professor C. R. Crosby, Dr. H. E. Ewing and Dr. N. E. McIndoo. In Africa—Dr. C. Akerman, Dr. R. F. Lawrence and Professor E. Warren. In Malaya—Mr. H. C. Abraham. In Japan—Mr. M. L. Peelle. In Australia—Mr. L. S. G. Butler and Dr. R. H. Pulleine. It is no exaggeration to say that without this help I could not have written this book, which in one way or another owes something to almost every active Arachnologist in the world.

Recently I have been collaborating with my good friend Mr. Gordon Hayes in the writing of two volumes on Polar Exploration, and during their preparation it became an increasing satisfaction to us both to find that to whomsoever we turned for advice we met the same readiness to help. How much we learnt that we could not publish! But the fine spirit of the great explorers which thus we had cause to admire is, I believe, in no way superior to the good fellowship I have encountered in my own more specialist work. A zoologist, not attached to a University but living in the isolation of the provinces and working in his own private laboratory, meets obstacles to progress which would be altogether insuperable were it not for the courtesy of those who regularly correspond with him and forward him copies or reprints of their writings. It is a great testimony to the unity of Arachnologists that these sources of information have never failed me, but have continued to arrive regularly, even unsolicited, from all parts of the globe.

I have, further, been extremely fortunate in receiving the assistance of two such illustrators as Mr. E. A. Robins and Mr. R. Allsop Telfer. Mr. Robins has now helped me in four separate publications. His photographs have no need of commendation from me and it is safe to say that there exist few other photographs of Arachnida as perfect as his. They are a real embellishment to the book. In meeting Mr. Telfer I discovered an artist who is not only a biologist but who from the first saw eye to eye with me as to the kind of drawing required. Whereas a photograph gives an idea of what an animal may *look* like, a drawing must show what the animal really *is* like. I am grateful indeed to Mr. Robins and Mr. Telfer who have provided, as I think, the best part of the book, and have enabled anyone to gain, without reading the text, much essential information about the Arachnida.

Experience has shown me, and no doubt many other writers will agree, that the most pleasing return for their labours comes from their critics and correspondents. To the readers of this book I would like to address these concluding remarks. When they discover errors of omission, I shall be unconcerned. To write a book and then

to seek a publisher is the most soul-destroying occupation imaginable : a wise author obtains his publisher's agreement first. If this predetermines the length of the book, the writer's problem is often what to omit, not what to include. When they discover errors of fact, I shall be grateful. However one may strive for accuracy, perfection is elusive, and I shall always be comforted by the words of an American professor who, in correcting some statements in my former work, referred to " the mistakes which *invariably* occur in the first editions of scientific books." When they discover errors of judgment or differences in matters of opinion, I shall be most interested and shall welcome their suggestions and discussions. In any event I beg leave to remind fellow-worshippers at the shrine of Arachne that this work is a by-product of other professional duties, and that I claim only to be *parcus deorum cultor et infrequens*—both as Arachnologist and author.

T. H. SAVORY.

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My daughter, who provided the material for Fig. 95.

My son, who contributed Fig. 68.

My former colleague, Mr. J. E. M. Mellor, M.A., late of Cairo, who sent me Solifugæ, and Mr. G. Raffle, of B.N.P., who sent me Scorpions.

My colleagues, Mr. C. B. O'M. Owen, M.A., who read parts of the manuscript and gave me help in other ways, and Mr. E. C. Kennedy, M.A., whose wide knowledge of classical literature has always been at my disposal.

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The staff of the Malvern Public Library for their ever-ready courtesy and assistance.

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THE ARACHNIDA

I. PROLEGOMENA

I

THE ARACHNIDA: GENERAL CHARACTERISTICS

JEAN BAPTISTE DE MONET, CHEVALIER DE LAMARCK, the great French philosophical biologist, founded the Arachnida in 1815, when he split Linné's heterogeneous group Insecta into three Classes. The Linnean Insecta were exactly equivalent to the Phylum Arthropoda as defined in 1845 by C. T. E. von Siebold and H. Stannius, and it therefore included a number of wingless forms, which were united in a common Order, the Aptera. For the true Insecta, with wings and six legs, Lamarck instituted the Class Hexapoda, but this name has not been universally adopted, that of the parent group, Insecta, being more frequently retained.

Two Classes were made by Lamarck from the Aptera; lobsters, crabs and water-fleas constituted the Crustacea, while scorpions, spiders and mites together with the Myriapoda and Thysanura (silver-fish) composed the Arachnida. The Thysanura are now known to be primitive Insecta and the Myriapoda are classed separately. The Arachnida living to-day are grouped into ten Orders; Acari, mites and ticks; Araneæ, spiders; Chelonethi, false-scorpions; Opiliones, harvestmen; Palpigradi, tailless whip-scorpions; Pedipalpi, whip-scorpions; Ricinulei; Scorpiones, scorpions; Solifugæ, sun-spiders; and Xiphosura, king-crabs. In addition to these are several Orders of extinct forms, and a few groups of Arthropoda whose claim to be considered as Arachnida is of doubtful validity.

In the Phylum Arthropoda, the major divisions are the five Classes Onychophora, Insecta, Crustacea, Myriapoda and Arachnida. The first of these, which includes Peripatus and its allies, is clearly distinguished as the most primitive of living Arthropoda; the rest divide themselves naturally into a crustacean-insect-myriapod moiety and an arachnid moiety; that is to say, the Crustacea and Insecta are more closely related to each other than either is to the Arachnida.

The chief **external feature** of the Arachnida is the division of the body into two parts, properly called the prosoma and opisthosoma. The former, composed of a united head and thorax, is commonly known as the cephalothorax and the latter is also called the abdomen. The only objection to the use of the term cephalothorax is that it is also used for other animals in which its constitution is not the same as

in the Arachnida. The prosoma of Arachnida is made up of nine segments. Some of the terga of these prosomatic somites, and often all of them, are fused to form a dorsal carapace, upon which the eyes, when present, are situated. Except in the Mites of the degenerate family Eriophyidæ, six segments of the prosoma carry a pair of appendages. One pair only of these appendages is pre-oral, the cheliceræ. One or more of the remaining pairs possess gnathobases, which assist in compressing and breaking up the food particles.

In contrast to this comparative uniformity of the prosoma, there is a much greater diversity in the appearance of the opisthosoma and of its appendages. This part of the body is composed of twelve segments, which are sometimes separable into a mesosoma and a metasoma, each of six segments. It may wholly retain the segmented form or it may be quite unsegmented, and it may have several pairs of appendages or it may have none. In only two ways do the opisthosomas of all Arachnida agree—in having the genital orifice on the first somite and in having the anus on the last somite.

Much may be learnt about the Arthropoda by a study, such as has been made by Ray Lankester [54*a*], of the relations between the mouth and the anterior somites of the body. As the arthropod evolved from a primitive annelid-like ancestor, its anterior segments became increasingly concerned in the formation of a distinct head. This process of cephalisation involved a regression of the mouth, which thus came to have in front of it more than the simple pre-oral lobe or prostomium, familiar in the Oligochæte worms. The somites which in this way became pre-oral and from which the head was composed, are known as prosthomeres. In the Onycophora and in the Myriapoda there is but a single prosthomere, and the jaws or mandibular hemignaths are borne on the second segment. The Arachnida have two prosthomeres and their jaws are on the third segment, while Insecta and Crustacea have three prosthomeres and their jaws on the fourth segment.

In tabular form and technical phrasing:

Onycophora, Myriapoda.	Monoprosthomerous.	Deuterognathous.
Arachnida.	Diprosthomerous.	Tritognathous.
Insecta, Crustacea.	Triprosthomerous.	Tetarthognathous.

The diprosthomerous condition of the Arachnida is found only in the adults; in the embryo the maxillary bases of the palpi are not in front of the mouth. The importance of this fact is increased when it is realised that in order to place the mouth parts of the Arachnida on the third somite, the rostral or primitive second segment must be omitted from the count. The rostral segment carries the antennæ of insects and the first antennæ of crustaceans: there is practically no trace of it remaining in the adult Arachnida, but evidence of its fugitive existence during development is not lacking. When it is included, the number of somites in the prosoma becomes nine and the number in the whole body twenty-one. This brings the Arachnida into a closer relationship with the Crustacea and Insecta, in the bodies

of which a twenty-one somite plan can also be detected ; and it limits Lankester's distinctions to the adult forms.

The most satisfactory survey of the arachnid body may be made by taking the somites in turn.

The first is the original pre-oral somite of the ancestral annelid. In modern Arachnida, this somite is separate and distinct only in the embryo, but its existence is also demonstrated by the presence of cœlomic hollows and by a nerve ganglion belonging to it. The anterior median or direct eyes are usually considered to represent its appendages.

The second somite is the one which in insects and crustaceans is called the rostral segment and whose appendages are the antennæ. The absence of antennæ is one of the chief negative characteristics of the Arachnida and the segment is never present in the adult. Vestiges of the appendages which belong to it have been seen during embryonic development, as by Jaworowski [49] in the spider Trochosa.

The third somite carries the only pair of pre-oral appendages, the cheliceræ. The cheliceræ may be large and important weapons, as in the Solifugæ, or small and relatively inconspicuous as in the Scorpions. They are usually prehensile, but may be, as in the Spiders, unchelate.

The fourth or first post-oral somite bears the first appendages of which the gnathobases function as jaws. These are the pedipalpi, which may be simple tactile organs outwardly resembling the legs, as in the Spiders, or chelate weapons of great size, as in the Scorpions, Pedipalpi and Chelonethi. They may also have secondary specialisations, as in the Spiders, where they act as accessory male organs, and in the Solifugæ, where they terminate in suckers. An important fact, which does not seem to have received much attention, is that the important and actively functional weapon of the Arachnida is sometimes the cheliceræ, sometimes the pedipalpi, and that the more active organ increases in size at the expense, as it were, of the other. The two pairs are never found enlarged together.

The fifth, sixth, seventh and eighth somites carry the four pairs of legs in all the Arachnida. These may be all alike, as in most Scorpions and Spiders ; but in the Pedipalpi, Solifugæ and some of the Acari the first pair are not used for walking. They are directed forwards and carried aloft as tactile organs. In the other Arachnida the two anterior pairs are usually directed differently from the two posterior pairs and the number of tarsal claws is not always the same. Further, the number of pairs of legs which bear gnathobases is different in the different Orders. In Limulus and in many Opiliones all the coxæ assist in masticating the food ; in the Spiders this duty is performed by the maxillæ or bases of the palpal coxæ only, and none of the legs shares the work.

The ninth somite is of more diverse character. In Limulus it marks the posterior border of the mouth and carries the chilaria, the organs which in the Eurypterida are represented by the metastomatic plate. In the Scorpions and in the other Arachnida in which the prosoma and opisthosoma are joined across their whole

breadth, the somite is not present in the adults, but its temporary existence has been observed in the embryo Scorpion. This somite persists in the Spiders and the Ricinulei, and probably also in the Pedipalpi and the Palpigradi, where it forms the waist or pedicle, uniting the two portions of the body. The somite is usually called the pregenital, since it lies next in front of the reproductive orifice. The occasional existence of both a tergite and a sternite, the lorum and plagula, above and below the pedicle, clearly indicates its nature as a separate somite, even when much reduced in size. It forms the last somite of the prosoma when the body is divided into prosoma and opisthosoma, but is often taken as the first segment of the abdomen when the terms cephalothorax and abdomen are used.

The twelve remaining somites form the opisthosoma. They may be visibly separable into a mesosoma and a metasoma, each of six somites, as in the Eurypterida and the Scorpions, or the somites may be all alike, as in the Chelonethi and Solifugæ, or they may be altogether obliterated, as in the Spiders and the Mites.

On the tenth, or first opisthosomatic, somite the reproductive organs open, and its appendages have become variously modified to form the genital operculum.

The eleventh somite is peculiar in the Scorpions. It bears the pectines, or comb-like sense-organs. In structure these closely resemble the gill-books of Limulus, the first pair of which belong to the same somite. In the other Orders the eleventh somite has no appendages.

Somites twelve to fifteen carry the second to the fifth pairs of gill-books of Limulus and the four pairs of lung-books of the Scorpions. The spinnerets of the Spiders belong to the fourth and fifth opisthosomatic somites, and their terminal position is due to an elongation of the third somite.

The remaining somites are separable and recognisable in some Orders but not in all. The Eurypterida and the Scorpions retain the full number, in others the number is reduced by suppression of one or more somites.

The twenty-first and last somite carries a telson in some Orders. Limulus possesses its characteristic spine, the Scorpions have a poison sting, the Pedipalpi a tail and the Palpigradi a jointed flagellum.

A summary of the external structures of the Arachnida is given in Table I.

One of the most important distinctions between different Orders of the Arachnida lies in their methods of **respiration,** for the respiratory organs are diverse both in nature and position.

Like its extinct allies the Eurypterida, Limulus is a marine animal and breathes dissolved oxygen. Its respiratory organs consist of clusters of branchial lamellæ or plates, which, from their resemblance to the leaves of a book, have given rise to the name of gill-books. There are five pairs of gill-books, borne on the insides of the five pairs of opisthosomatic appendages which follow the genital operculum.

All the other Arachnida are terrestrial and the gill-books are replaced by lung-books or by tracheæ or both. In the Scorpions there are four pairs of lung-books. These take the form of small hollow sacs filled with clusters of lamellæ and

TABLE I

Segmentation of the Arachnida

Prosoma.	Somite 1	Pre-oral ? Direct eyes.
	2	(Rostral).
	3	Cheliceræ.
	4	Pedipalpi.
	5	Legs i.
	6	,, ii.
	7	,, iii.
	8	,, iv.
	9	Chilaria, Metastoma or Pedicle.
Mesoma.	10	Genital operculum.
	11	Gills i, Pectines or Lung-books i.
	12	Gills ii or Lung-books ii.
	13	Gills iii or Spinnerets i.
	14	Gills iv or Spinnerets ii.
	15	Gills v.
Metasoma.	16–21	No appendages.
Telson.		Spine, sting, tail or absent.

opening by spiracles on the sternal plates of the last four somites of the mesosoma. During embryonic development the mesosoma of the Scorpion possesses vestigial limbs and it is behind the bases of four pairs of these transient appendages that the lung-books appear. Examination of their structure shows that they very closely resemble the gill-books of Limulus, and that there can be no doubt the gill-books of the marine forms are strictly homologous with the lung-books of the terrestrial forms.

Similar lung-books are found in the Pedipalpi, the Araneæ and the Palpigradi. The Pedipalpi have two pairs, on the two segments of the opisthosoma following the genital segment. The same is true of the more primitive Spiders, but in the majority the second pair have disappeared and tracheal tubes take their place, opening at a pair of spiracles on the lower side of the opisthosoma.

The five remaining Orders of the Arachnida breathe by tracheæ, but these are not all found in the same situation. A summary of the facts of their distribution is best given in tabular form.

TABLE II

Tracheal Respiration in the Arachnida

1. Acari.	Eight, or fewer, spiracles in various situations. See Table XX.
2. Chelonethi.	Four spiracles on third and fourth opisthosomatic somites.
3. Opiliones.	Two spiracles on second sternite.
4. Solifugæ.	Seven spiracles on second to fifth sternites.
5. Ricinulei.	Two spiracles on prosoma above third coxæ.

Internally all the Arachnida possess a skeletal structure, known as the **endosternite,** in the prosoma. The existence of this is interesting, for a small endosternite of similar structure is found in Apus and in some of the decapod Crustacea, between the bases of the mandibles. In no crustacean does the endosternite attain a great size, but if the position of the Trilobites as common ancestors of the Arachnida and Crustacea be ever confirmed (see pp. 32–34) then the endosternite may be looked upon as persisting evidence of the relationship between these two otherwise somewhat isolated Classes. The endosternite in Arachnida is a cartilaginous plate, slightly chitinised, lying between the nerve ganglia and the alimentary canal. To it are attached muscles—as many as fifty in Limulus—from the limbs, the carapace and the pharynx. In the Scorpions, dorsal and ventral outgrowths connect it with the body wall, so that it separates the prosoma internally from the opisthosoma, and was originally described as a " diaphragm."

The internal structure of the Arachnida also includes a characteristic alimentary canal and an excretory system of coxal glands.

The **mouth** is a small opening in all the terrestrial Arachnida and is seldom easy to find. From the mouth a tubular pharynx leads to a sucking organ by the action of which the juices of the prey are imbibed (Fig. 1). This suctorial organ is

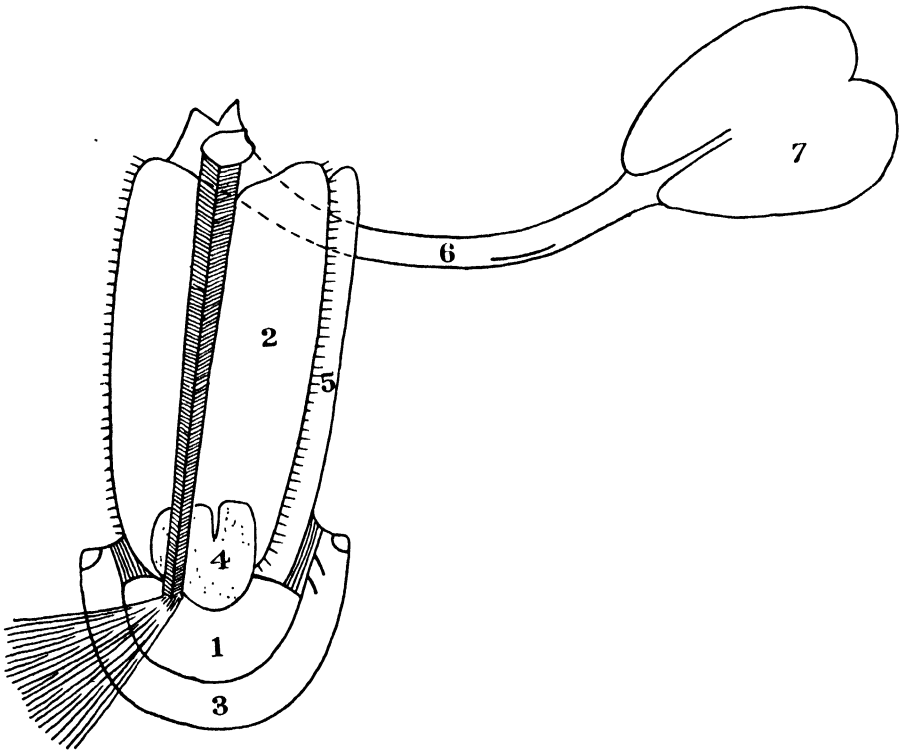


FIG. 1.—Fore-gut of the Spider *Araneus diadematus.*

1. Rostrum; 2. Epipharynx; 3. Labium; 4. Pharyngeal gland; 5. Hypopharynx; 6. Œsophagus; 7. Sucking stomach.

followed in the mesosoma by the mesenteron, but before this is reached a series of lateral cæca diverge from the canal and run forwards into the prosoma. These **diverticula** have lately been fully studied in spiders by Millot [62*d*], who finds that they may be divided into four types. In the first or simple type there are but two short sacs directed forwards (Fig. 2). Each has a more or less clearly defined secondary portion, but the two sides are not always symmetrical. The second or intermediate type shows three or four diverticula on each side, by no means clearly divisible from each other and not reaching the coxæ of the legs (Fig. 3). In the third or classical type, so called because earlier workers described this type only, there are five pairs of diverticula, one anterior and four lateral, reaching the bases of the legs and entering the coxæ for a short distance (Fig. 4). The customary

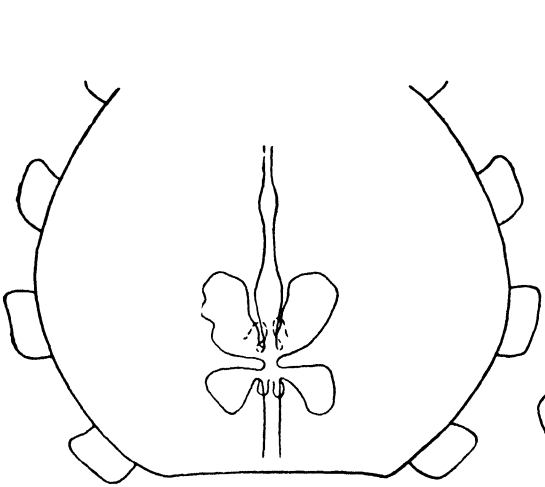


FIG. 2.—Intestinal Diverticula of *Scytodes thoracica*. After Millot.

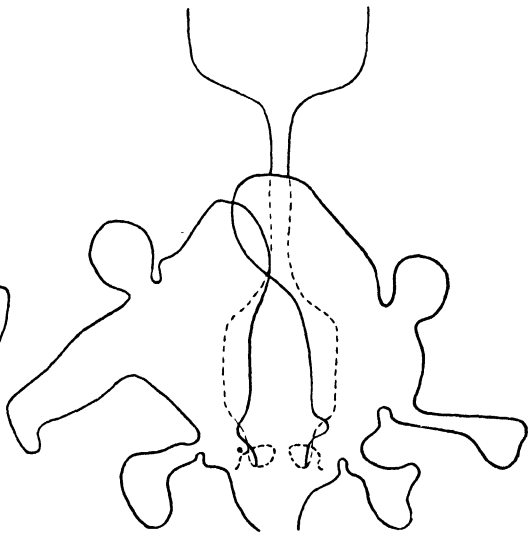


FIG. 3.—Intestinal Diverticula of *Dictyna civica*. After Millot.

statement that the anterior diverticula meet and form a complete ring is incorrect. The fourth or complex type differs from the third in a great development of either the anterior or the lateral diverticula so that these divide or branch and are so large that they quite change the appearance of the interior of the prosoma (Fig. 5). Millot found that, although individual modifications are common, the type of arrangement is constant within the limits of a family.

Into the **mesenteron** open Malpighian tubes in all the Arachnida except the aquatic Xiphosura. From it there leads a complex system of branched tubules which occupy most of the opisthosoma. This great mass functions partly as a digestive gland, and partly as a reservoir. Large quantities of food-products pass into it, so that the Arachnida are well able to undergo long periods of fasting.

The **coxal glands** are the chief excretory organs of the Arachnida. They are nephridia, homologous with the large nephridia of segments 6 and 7 of Peripatus. In their typical form, many modifications of which are, however, found, they consist of a large excretory saccule, lined with cubical or flattened epithelium, lying outside the endosternite opposite the coxæ of the first legs. This discharges its products into a convoluted tube, the labyrinth, the coils of which occupy the space from the first to the fourth coxa, or beyond. At the distal end of the labyrinth there is sometimes a swelling, regarded as a "bladder," and from this there runs forward a straight tube, the internal limb of the labyrinth, which lies inside the convoluted

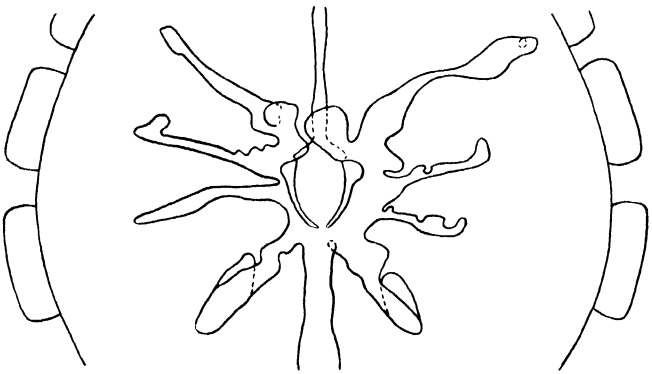


FIG. 4.—Intestinal Diverticula of *Zoropsis spinimanus*. After Millot.

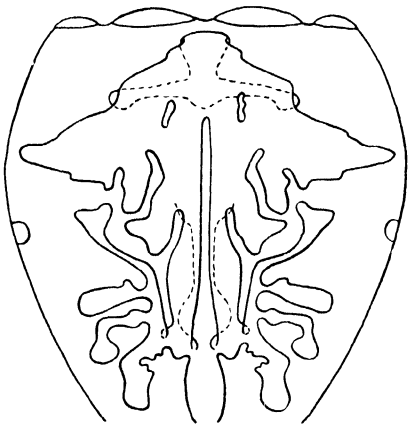


FIG. 5.—Intestinal Diverticula of *Ballus depressus*. After Millot.

portion and from which short exit tubes open to the exterior at small orifices behind the first and third coxæ.

In the Solifugæ and the Palpigradi, there is an additional tube, the labyrinth sac, lined with secretory cells, between the saccule and the labyrinth. The orifice in these forms is on the pedipalpal somite.

The following table shows the variations which occur among the different Orders of the Arachnida. The most variable Order is the Araneæ, in which four types exist showing a progressive simplification, correlated with a corresponding increase in complexity of the silk-glands. The resemblance between the coxal glands of the Epeiridæ and those of the Palpigradi is interesting.

TABLE III

Coxal Glands in Arachnida

	Saccule.	*Labyrinth Sac.*	*Labyrinth.*	*Exit.*
Scorpiones . . .	In segments 5 and 6	Absent	Many coils in segment 5	On third legs
Pedipalpi—				
Amblypygi . . .	In segment 3	,,	Very extensive coils, back to segment 6	On first legs
Uropygi	In segments 4 and 5	,,		
Araneæ—				
Mygalomorphæ .	In segments 3 and 5	,,	Large, coiled, common to both saccules	On first and third legs
Arachnomorphæ .	In segment 3	,,	Straight tube, reduced in highest to a vesicle	On first legs
Palpigradi. . . .	In segment 2	Present extending to segment 8	Small vesicle	On palpi
Solifugæ	In segment 2	Present, extending to segment 4	Coiled, extending to segment 6	On palpi

[Note.—" Segment " in the above table corresponds to appendage, i.e. the prosoma is of six segments ; not as in Table I.]

The difference in **size** between the largest and smallest of the Arachnida is not excessive. Compared with others, the Arachnida are all " small " animals, but only a few of them are excessively minute. The following table gives the lengths of a large and a small, probably the largest and smallest, species in each Order. The range would be enormously increased if extinct forms were included, for some of the Eurypterida are nearly three metres long and are the largest of all invertebrates.

TABLE IV

Size of Arachnida

Scorpiones	*Pandinus dictator*	16 cm.	*Microbuthus pusillus*	1·3 cm.
Pedipalpi	*Mastigoproctus giganteus*	7·5 cm.	*Schizomus perplexus*	·3 cm.
Araneæ	*Theraphosa leblondii*	9 cm.	*Microlinypheus bryophilus*	·06 cm.
Palpigradi	*Koenenia draco*	·28 cm.	*Koenenia grassii*	·065 cm.
Ricinulei	*Ricinoides afzelii*	1·05 cm.	*Cryptocellus emarginatus*	·39 cm.
Chelonethi	*Garypus litoralis*	·6 cm.	*Cheiridium museorum*	·11 cm.
Solifugæ	*Galeodes caspius*	7 cm.	*Eusimonia orthoplax*	·8 cm.
Opiliones	*Metaphalangium propinquum*	1·2 cm.	*Nemastoma dentigerum*	·15 cm.
Acari	*Amblyomma clypeolatum*	3 cm.	*Eriophyes ribis*	·01 cm.

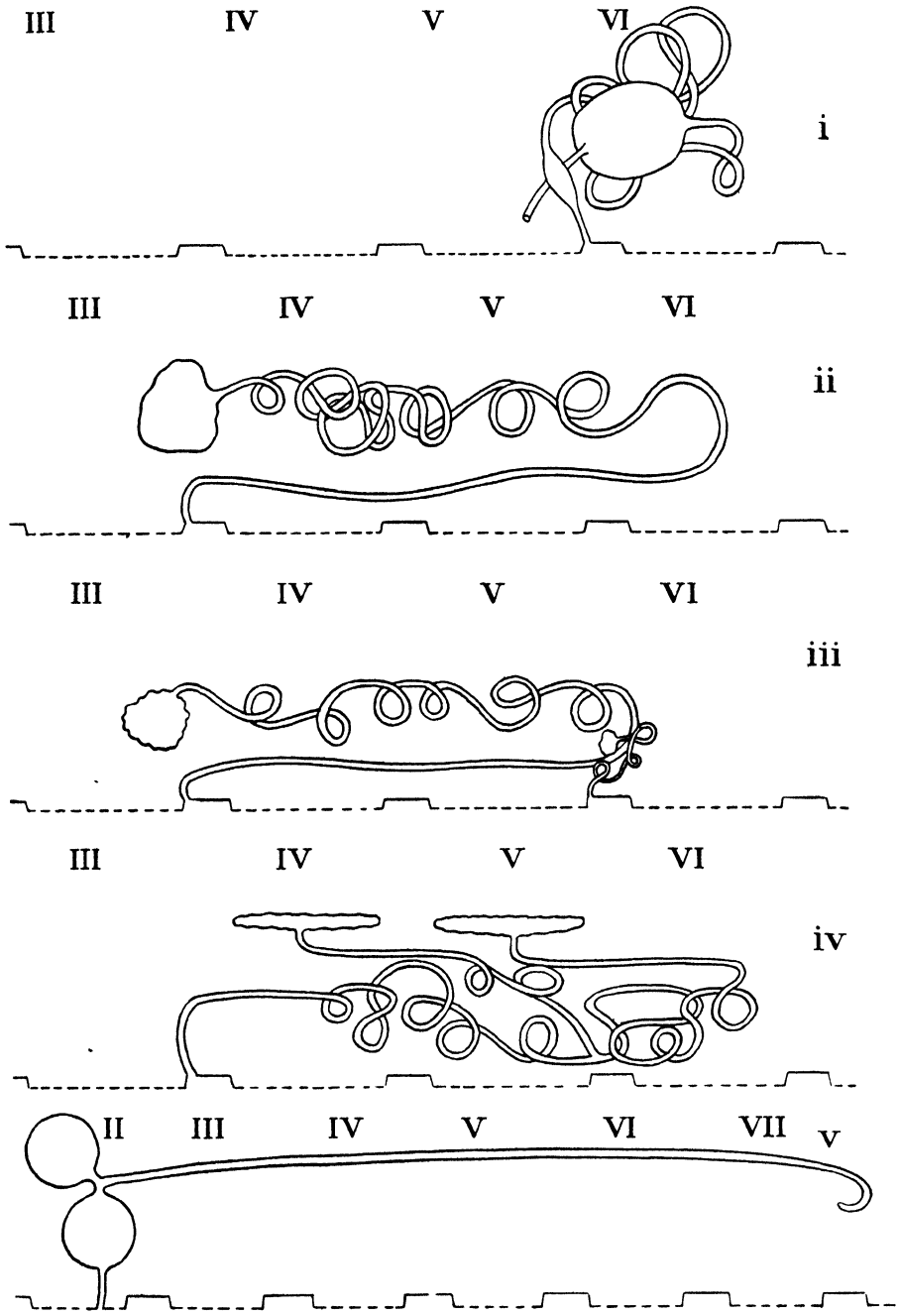


FIG. 6.—Diagram of Coxal Glands. After Buxton.

i. Arrangement in Scorpiones; ii. Arrangement in Tarantulini and Phrynini; iii. Arrangement in Charontini; iv. Arrangement in Thelyphonidæ; v. Arrangement in Palpigradi.
III–VII. Prosomatic somites.

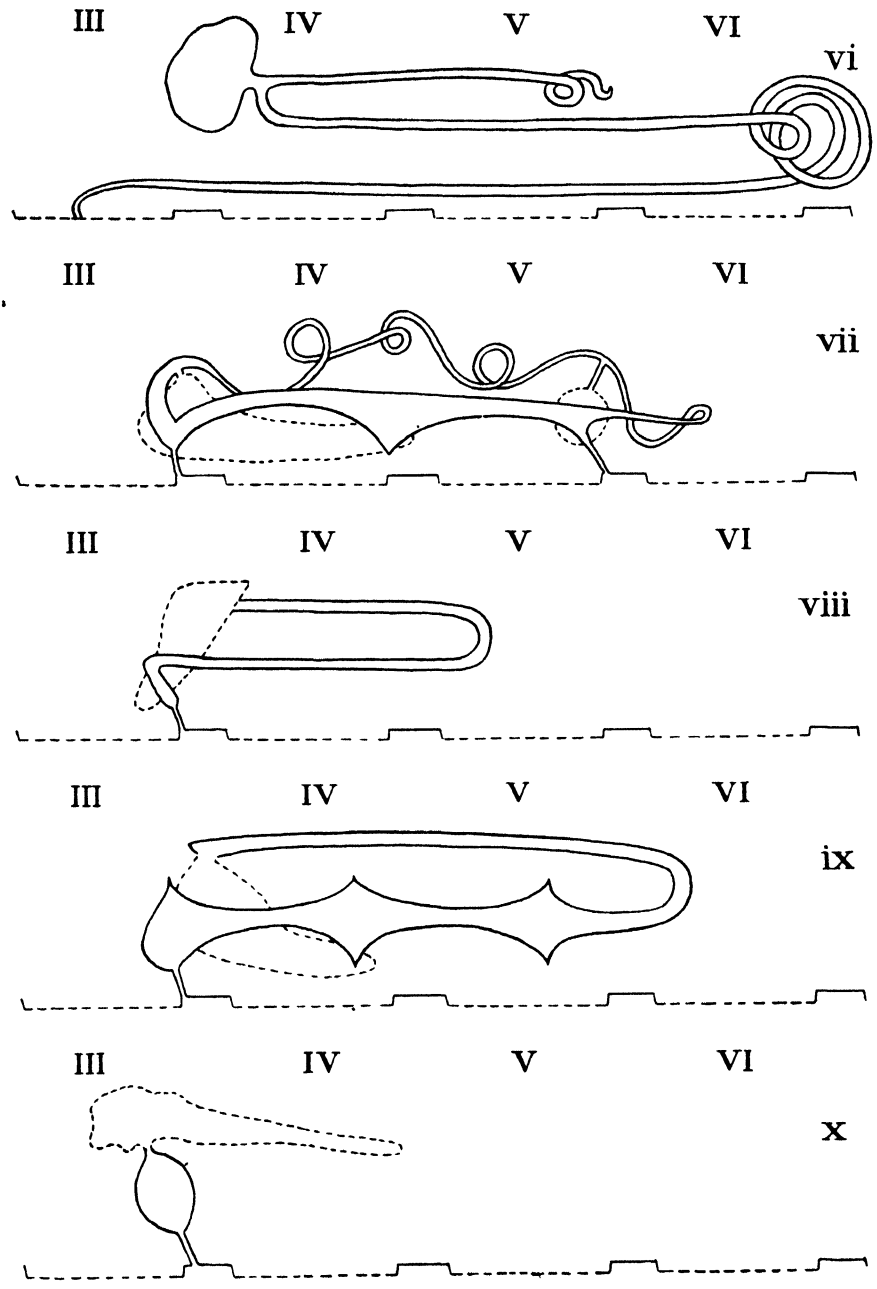


FIG. 7.—Diagram of Coxal Glands. After Buxton.

vi. Arrangement in Solifugæ; vii. Arrangement in Mygalomorphæ and Liphistiomorphæ; viii. Arrangement in Dysderidæ, Oonopidæ, etc.; ix. Arrangement in Lycosidæ, Thomisidæ, Attidæ, Agelenidæ, etc.; x. Arrangement in Argiopidæ, Pholcidæ, Filistatidæ, etc.

III–VI. Prosomatic somites.

A broad resemblance runs through the general **habits** of the majority of the Arachnida. They are usually animals of nocturnal activity, lying at rest during the day in their nests or holes or crouching under stones, logs or fallen leaves. The chief exceptions to this are the Scorpions, which are often active in daytime, a few Solifugæ and a number of Spiders whose hunting is done by day. For most of the others sunlight inhibits movement, so that their ways are not easily determined and their habits but slightly known.

In general the Arachnida are predatory. They either lie in wait for their prey and leap upon it when it approaches or they wander about and pursue it, sometimes, as in the Solifugæ, at a surprising speed. There are at least two conspicuous exceptions to this. Many of the Mites are parasites and their mouth-parts are modified to form a piercing or sucking proboscis, and the Web-Spiders spin to trap and entangle insects a silk net which is almost without parallel elsewhere in the animal kingdom. One of the features of the feeding of the Arachnida is their extreme voracity. Their habits are often such that prolonged fasts are common and therefore they seem concerned to extract the last drop of moisture from each capture. The bodies of their victims are pierced or crushed by the cheliceræ, mangled by the endites of the pedipalpi and legs and all liquid sucked from them by the action of the pumping pharynx within.

Among the **protective adaptations** of the Arachnida colour is one of the most important. Conspicuous or bright colours are rare although they are found among tropical spiders and some others that live among flowers and foliage. The majority are soberly coloured, to achieve invisibility against a sandy or stony background and the best of them do so with astonishing success. Protective resemblance is also found, for there are Spiders which look like the fruits of the plant they live on, and others that look like twigs or thorns. Special cases of this type of protection are found, in which the Spider makes a cocoon which resembles itself or adds a band or ribbon of silk to its web and rests inconspicuously in the middle of this addition. More specialised still are the zigzags of silk which tend to distract the eye of the observer from the Spider itself.

Protection by flash-colouring also exists and is mentioned later; protection by mimicry is not uncommon. There are many Spiders that very perfectly mimic ants, and others that mimic snails or beetles.

One of the most characteristic methods of protection shown by nearly all the Arachnida is their ability to cast a limb and so to escape, purchasing life and freedom at the price of a leg. This widespread action has been closely studied by Dr. F. D. Wood [86], and she has found it necessary to divide the circumstances in which a limb is lost into the following:

(i) **Autotomy** is the act of reflex self-mutilation or automatic severance of a limb from the body. This does not exist in the Arachnida, but does exist in the Crustacea.

(ii) **Autospasy** is the casting of a limb when pulled by some outside agent, like the forceps of an experimenter.

(iii) **Autotilly** is the pulling off of a limb by the animal itself, as when an injured leg is seized in the cheliceræ and thus severed from the body.

(iv) **Autophagy** is the act of eating a part of the body, usually after severance from the rest.

In addition to these a fifth term, **autosalizy,** has been coined by Pieron [68] with much the same meaning as autotilly but involving, apparently, an element of

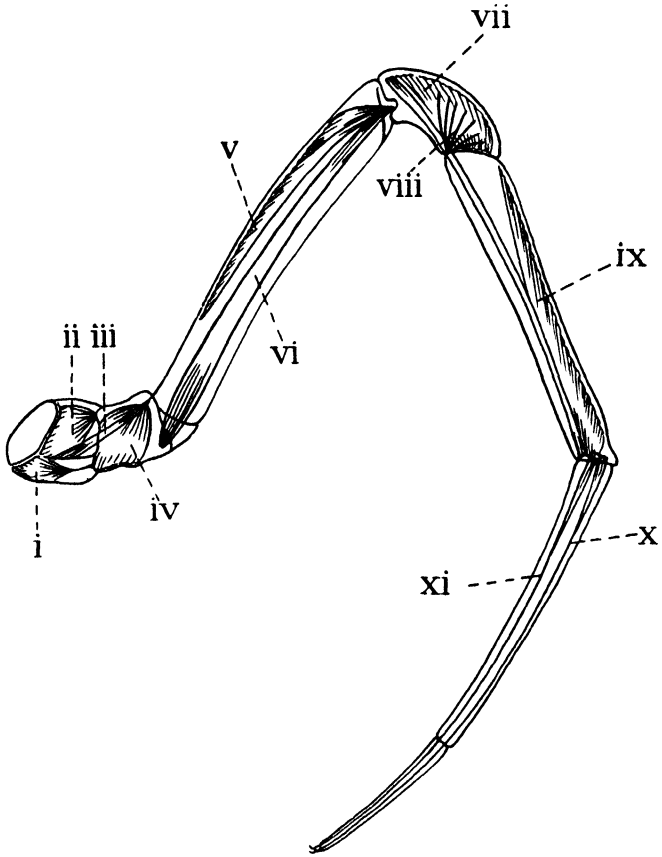


FIG. 8.—The Muscles of a Spider's Leg. After F. D. Wood.

[Species *Theridion tepidariorum*—pro-surface of left leg.]

i. Extensor trochanteris; ii. Flexor trochanteris; iii. Flexor longus femoris; iv. Flexor bilobatus femoris; v. Flexor bilobatus patellæ; vi. Flexor patellæ; vii. Protractor tibiæ; viii. Flexor tibiæ: ix. Flexor metatarsi; x. Extensor tarsi; xi. Flexor tarsi.

choice or decision on the part of the animal. According to the view of the Arachnida developed in the next chapter this phenomenon could not be exhibited by them. It is impossible to admit that the Arachnid as it pulls on its imprisoned leg, shall come to a decision to run away on seven legs rather than perish.

Dr. Wood's experiments showed conclusively that the shedding of a limb is not the result of a reflex action or of a special mechanism as had previously been believed.

It is simply the inability of the skeletal and muscular components of the leg to resist more than a certain force. The leg, when pulled, parts at its weakest point. Consequently all Spiders cast their legs at the coxa-trochanter articulation, all Opiliones at the trochanter-femur articulation and all Pedipalpi at the patella-tibia articulation. On the other hand, in the Scorpions, the Xiphosura and some of the Mites there is no predetermined locus of weakness. The musculature is evenly arranged throughout the legs and the chitin is well provided with longitudinal fibres at all the inter-articular membranes. These factors, combined with the lack of response on stimulation, make autotomy and autospasy impossible and autotilly very unlikely.

Limbs which are thus sacrificed are not in general permanently lost, but reappear. All the Arachnida undergo periodic **ecdyses** or moultings of the exoskeleton, a process which is associated with both growth and regeneration. The actual moult, which may take place in a special rest-cocoon or in an almost unprotected situation, involves an easy sloughing of the carapace and abdominal cuticle, a prolonged and tedious extraction of the legs and palpi from their old cases, and a period of rest and recovery during which the new cuticle hardens.

Bonnet [22] has made a full study of the **regeneration** of lost limbs, which reappear at ecdysis. He found that a limb is regenerated when the interval between its autotilly and the next moult is more than three-quarters of the time separating the two moults. If this time is available, the length of the new limb is almost equal to the one that was lost, and a new limb attains its full size after three moults. Hence in order to ensure a perfect replacement, the loss must occur before the ante-penultimate moult. These generalities are as applicable to complex organs like the pedipalpi of male spiders as to simple legs. If a male palpus has to be regenerated in one or two moults an imperfect and often a weird form is the result. It appears that a leg may be regenerated as often as it is removed, and in one instance a leg was renewed ten times. Similarly, more than one limb can be replaced at a single moult and some of Bonnet's Spiders regenerated all eight legs simultaneously.

Another important feature in the lives of the Arachnida is the prevalence of pre-nuptial activities when the sexes meet. These actions, generally described under the name of **courtship,** are common throughout the animal kingdom ; they are found at least as low as the Annelida and extend up to Man. Our present knowledge of the courtship of Arachnida is incomplete and is unevenly distributed among the different Orders.

The courtship of the Scorpions has been briefly described by Fabre [34], who has stated that the sexes perform a kind of dance, a *promenade à deux*, in which their tails are raised and entwined, until the male grasps the female and leads her away to a sheltered spot where he digs a burrow for her reception.

The courtship of the Pedipalpi is known only from the observations of Fischer [35*a*] and of Graveley [40], and appears to resemble that of the Scorpions. Fischer's description of the behaviour of *Thelyphonus sepiarius* states that the female crosses her front legs which are then seized by the cheliceræ of the male. In this position

the two walk slowly about, face to face, the male now and then approaching the female more closely and touching her with his front legs.

The same kind of behaviour is shown by the Chelonethi, a widely quoted account of whose ways has been given by Kew [51], with the addition of some degree of display by the male. The male, meeting the female face to face, grasps her cheliceræ with one or both of his own, and either exhibits before her the peculiar ram's-horn organs he possesses, or he shakes a palpus or his first pair of legs in a characteristic way.

The courtship of the Solifugæ seems to be known only from the account given by Heymons [44] of *Galeodes caspius*. It is a much more rapid and vigorous affair, for the male merely seizes the female with his legs and cheliceræ, grasping her body but seldom wounding her. The caresses of his legs then so strongly affect the female that she falls into a cataleptic or hypnotic state, in which she remains quite motionless.

There seems to be no courtship among the Opiliones and nothing is known of the ways of the Palpigradi or of the Ricinulei.

The courtship of Spiders, on the other hand, has been very carefully studied, first of all by Peckham [64] in America and lately by Gerhardt [37] in Germany and by Bristowe [24] and Locket [58] in this country. Here the manner of courtship is varied. Male Jumping-Spiders undertake quite elaborate dances before their females, and in these displays they are seen to exhibit their black or coloured patches. The females carefully watch the dance, which is ended by their joining in it. Courtship of this nature is obviously only appreciable by Spiders with good eyesight, and the Lycosidæ or Wolf-Spiders are thus another family which behave in a similar way. Some male Wolf-Spiders have black palpi or darkened leg-segments or tufts of hair, and these decorations they wave about before the female, raising and lowering palpi or legs as if semaphoring. In other wandering Spiders courtship is limited to a stroking or tickling of the female. Web-Spiders almost invariably pay court by sending messages along the threads of the web. The wandering male, on reaching the outskirts of a female's web, drums on it with his palpi or plucks at it so as to cause it to vibrate in some way which evidently does not affect the female in the same manner as do the vibrations set up by a captured fly.

A general survey of the courtship of the Arachnida seems to show that the result of the male's activity is an inhibition of the female's normal food-securing reflexes. Thus a courting male can approach a female without being slain. When near enough he can touch her, as invariably in some way or another he does, with the result that the necessary physical preparation for mating commences, and in Spiders with prominent epigynes actual movement of this part has been seen. The male, too, is stimulated so as to be able to exert the considerable effort necessary for the ejaculation of spermatozoa. In many cases this physical stimulus is so potent that the female falls into a cataleptic state.

It seems that in Spiders the details of courtship differ for all different species,

and much of the recent work has been devoted to describing specific behaviour. What is now needed is an intensive study of the behaviour of a single species, so that the stimuli for each separate reflex can be perceived and the whole process analysed into its elements as Peters [65] has done for the catching of web-ensnared insects.

The **mating** which follows courtship is differently performed in the different Orders and is often very remarkable. Only in the Scorpions and Pedipalpi is direct contact of the genital apertures found. In the Opiliones, the male organ is a very long protrusible tube, which is thrust forwards into the female oviduct as the two Harvestmen stand face to face. In the Aranеæ, the male organ is found in the Pedipalpi. The Spider secretes its seminal fluid either upon the ground or upon a specially spun web—the only web a mature male Spider spins—and charges its palpal organs by picking up the fluid in them. These elaborate palpi then convey the sperm to the spermathecæ of the female. The position occupied by the two Spiders in the act is not always the same, but varies according to their habits and relative sizes. In the Ricinulei, the third leg of the male is similarly elaborated and it is assumed therefore that it fulfils a similar function to that of the palpi of male Spiders.

In the Chelonethi and Solifugæ the methods are more curious still. The male False-Scorpion at the end of his courtship deposits a spermatophore on the ground. This consists of an almost erect rod bearing at the top a round globule of the vital fluid. When free from this he backs away, and thus leads the female over it, so that the spermatophore is thrust into her oviduct as she passes. The male Solifuge turns the cataleptic female over and opens the genital orifice with his cheliceræ. He then deposits a mass of sperm upon the ground, picks it up in his cheliceræ and thrusts it forcibly into the oviduct. He then closes the aperture and presses its lips together. At this point the catalepsy of the female vanishes and the male leaps away to escape at his best speed.

This last detail, which is shared by many other Arachnida, shows how the inhibiting effects of the original courtship have disappeared by the time the mating is accomplished, and the male is once again in danger of his life from his cannibal mate.

Young Arachnida hatch from eggs in all the Orders except the Scorpions, which are viviparous. Young Scorpions, like young Wolf-Spiders, are carried for a time on their mother's back, but maternal care is not conspicuous among the Arachnida as a whole. In some cases the young share the nest or burrow until they migrate, but direct mothering such as is found among the Theridiid Spiders, the young of which feed from their mother's mouth, is exceptional.

While most Orders of the Arachnida depend for **dispersal** upon their own efforts, some interesting methods are adopted by others. Of these the gossamer thread of young Spiders is unquestionably the first to deserve mention. The young Spider climbs as high as possible, turns its head to the breeze and raises its abdomen.

The spinnerets secrete a drop of silk which the slightest breath of air draws out into a long thread. When this streamer is pulling with sufficient buoyancy, the spider lets go and floats away on the silk. This habit is shared by the young of several families, but only the Linyphiidæ seem to be represented among the adult migrants, probably because they alone are small enough to float through the air.

There is no doubt that this strange method of undirected flight, which in favourable circumstances may carry Spiders more than two hundred miles, is an important factor in the distribution of the Order. There are, however, many objections to the assumption that it is almost entirely responsible for the geographical distribution of Spiders as found to-day, not the least among which is the present scarcity of observations on the actual species known to adopt the habit. The records of arachnologists who have identified a dozen or a score of aeronaut species are insufficient material—and would still be insufficient if they included ten times as many species—for discussion of the distribution of an Order numbering many thousands.

A somewhat similar method of dispersal is found among the very small Mites which are parasitic on fruit-trees. These migrate in the summer, either by crawling about, or by grasping the legs of passing Insects, or by standing erect and leaping vertically if they feel a puff of air. The leap may then help them to be blown some distance.

The subject of aerial travel cannot be left without reference to the great heights attained by the aeronauts. The recent work of Coad [28] has shown that a surprisingly numerous "aerial plankton" drifts through the upper regions of the atmosphere. His calculations point to a population, in a column of air one square mile in area between the heights of 50 and 14,000 feet, of twelve million Arthropoda in January and three times this number in May. Both Spiders and Mites have been found at 10,000 feet. It is clear that the ability of wingless creatures to reach such altitudes must greatly help their distribution.

Other Arachnida achieve dispersal by clinging to the legs of insects, like the common British Mite *Belaustium nemorum* which is often to be found on the legs of Tipulidæ, and the Uropod Mites which attach themselves by a thread of their own excrement to the bodies of beetles. The same habit is shown by certain Chelonethi, many species of which have been found all over the world holding to the legs of flies or of ants, or resting, sometimes in numbers, under the elytra of beetles or the feathers of birds. This mode of transport has been named **phoresy.**

The **geographical distribution** of the Arachnida can be studied in detail only when the different Orders are taken separately. When the distribution of the Class is considered as a whole, the statement may conveniently be made that the Arachnida are cosmopolitan, since they may be found all over the world except in the polar regions. A rather more accurate view perceives the Arachnida as divisible into three groups—

(i) those which are confined to the hot tropical and very warm sub-tropical belt;

(ii) those which spread to the limits of the temperate zones ;

(iii) those which do, in fact, penetrate into the polar regions.

Scorpions, Solifugæ, Ricinulei and mygalomorph Spiders belong to the first group ; Chelonethi and Opiliones are found in the second. The third group, the polar Arachnida, is in many ways the most interesting.

There is a sharp distinction between the Arctic and the Antarctic, due to the isolation of the Antarctic continent and the tempestuous character of its surrounding oceans.

The first record of an Antarctic Arachnid was the discovery of the Mite, *Penthaleus belli*, under moss at Cape Adare during the Southern Cross expedition of 1899–1900. During Shackleton's Nimrod expedition (1907–9) several species of Mites were found to be abundant in Coast Lake, near Cape Royds on Ross Island. Skins of others were found in other lakes but none was seen alive. A Mite, however, hatched among vegetable matter brought from Deep Lake after the return of the expedition to England. These Ross Island Mites were never named in the scientific reports of the expedition, but they are of interest as being the farthest south Arachnida (77° S.).

No Spiders have been found on the continent, and the farthest south Spider is must probably either *Rubrius subfasciatus* from Cape Horn or *Myro frigida* from South Georgia (55° S.).

Within the Arctic Circle are lands of comparative fertility, supporting the Esquimaux and the Samoyeds, with their herds, and producing flowering plants. At least ten species of Spiders have been found in Spitzbergen, through which the eightieth parallel of latitude passes. The farthest north known land is the northern coast of Greenland, which reaches latitude 83° N., only four hundred miles from the Pole. The best work of exploration in this region was done by the Fourth Thule Expedition, led by K. Rasmussen in 1917, and their report states that " Spiders and Earth-Mites also support life in these high latitudes."

In comparison with these records it is interesting to remember that Spiders of the family Salticidæ were found at a height of 22,000 feet on Mount Everest, in the proud position of being the highest permanent inhabitants of the world.

II

THE ARACHNIDA: HABITS AND BEHAVIOUR

Two alternative methods of discussing the behaviour of the Arachnida present themselves. The first is to survey the different kinds of activity—the hunting, the moulting, the spinning, the courtship, the mating and the motherhood—and to illustrate the account by descriptions of specific typical examples. This might be called the practical or natural history method and is outside the scope of this book. The alternative is the theoretical or scientific method, in which the types of action are classified and their characteristics defined. This method is probably less familiar and more valuable.

The simplest complete reaction of the nervous system of an animal is the form of response known as a **reflex**—" a neuro-muscular adjustment due to the inherited mechanism of the nervous system." The familiar examples of reflex action, such as the blinking of an eyelid, are often described with an emphasis on the speed with which the whole system carries out its function of appropriate response. Thus there is a tendency to neglect the fact that many important reflexes have to persist for hours at a time, an uninterrupted series of unit actions. Important examples of this are the reflexes of posture or of habitual attitude, the maintenance of which is their chief function. These are called tonic reflexes. The majority of reflex actions are quickly fatigued and quickly recover, but the tonic reflexes of posture do not tire in this way. On the other hand, they are the most easily dispossessed or overridden of all, as if they paid for the continuous use of the nerve paths by an exaggerated readiness to make way for other traffic, and in this we can perceive their nature and function. They form a perpetual substratum of nervous activity, maintaining the body in a state of dynamic equilibrium. It is clearly important that this state of equilibrium shall be upset easily, so that there shall arise that agility of response to the changing circumstances of life which produces efficiency and successful activity in the living animal.

A very large proportion of the life of an Arachnid is spent in waiting, and during these long periods of inactivity the tonic reflexes are in sole possession of the nervous system, supporting the body on its eight legs against the unceasing gravitational force. For animals like the Harvestman *Liobunum rotundum*, with its tiny body and eight long symmetrically arranged legs, the tensions in the muscles of all legs are probably almost equal, and for Spiders like the Linyphiidæ which hang inverted below their hammock-like webs, the tensions are probably not very unequal.

It can scarcely be a coincidence that these types are particularly sensitive to surrounding disturbances. In the common Garden-Spider, which hangs head-downwards in its lovely orb-web, the weight must clearly be disproportionately supported by the two hind pairs of legs and the same is true of almost any Arachnid that stands on the ground. The heavy opisthosomatic region has no legs of its own and the greater part of its support must come from the posterior pair of thoracic legs. It should not be surprising, therefore, that when the equilibrium of the tonic reflexes is upset, the readiest response is a flexion of the femora, so that the patellas tend to meet over the middle of the animal, and especially a flexion of the forelegs. This simple automatic response, which may be called the flexor reflex, is easily witnessed whenever a Spider is, as we should say, frightened, and several valuable consequences follow from its operation.

One of these is the **flash-colouring** method of protection, which most naturalists would associate with the Tree-Frogs of tropical forests, but which is also well shown by several British Spiders. A good example is *Segestria senoculata*, a common species with diamond-shaped marks on its femora and bright tawny femora. As it runs, the moving femora are conspicuous, but when it suddenly stops and draws in its legs this brightness vanishes and the observer finds the Spider invisible.

Without any help from flash colours, the flexor reflex assists in producing invisibility in other Spiders. If on the beach in certain parts of the coast the heaps of dried seaweed are turned over, there runs out a sombrely-coloured active Spider, *Philodromus fallax*. As it runs it may easily be mistaken for a grain of sand, rather bigger than the average, rolling down a slope, and, in fact, such grains of sand are often mistaken for Spiders. But there is this difference. When the pellet of sand comes to rest it can be seen ; when the Spider stops moving it is invisible. It does not bury itself nor leap suddenly aside ; it simply stops and flexes its legs. And it is gone. The writer is not short-sighted, but on the Norfolk coast he has stared straight at these Spiders and been quite unable to see them until they have moved.

This leads naturally to the obvious and probably the most important of all the consequences of the reflex, the action metaphorically described as " feigning death " and less inaccurately as the **cataleptic reflex.** In many Arachnida a sudden disturbance causes them to draw in their legs and fall motionless, and in some the caresses of the opposite sex produce the same condition. Various considerations make it clear that the animal is not in a true state of catalepsis. Often after first falling motionless it will re-arrange its legs slightly, and in some species a periodical tremor runs through the limbs. In addition to these movements, which would not be seen in true catalepsy, there is not the complete insensibility which would be expected. If the motionless Spider be gently touched it will often get up and run away. If the Spider is lying low at the end of a thread attached to its web and the web be touched with a vibrating tuning-fork, the Spider at once awakes and returns to its web.

The whole action is really nothing but a sustaining of the flexor reflex and the

more closely it is studied, the more clearly it shows the characteristics of reflexes in general. Many reflexes continue to discharge after the stimulus ceases, and in the " cataleptic " Arachnid we are witnessing the retention of the position produced by the flexion of the femoral muscles. All reflexes, however, are subject to fatigue which causes them to give up possession of the nerve-paths in favour of some other impulse, previously inhibited. Thus the quiescent Spider awakes and a response to a probably new situation occurs.

In several families of Spiders the flexor reflex operates with a different result. The common House-Spiders, Tegenaria, are familiar examples of Spiders which rest in the corner of a sheet web. Their forelegs are outstretched and their claws grasp the silk so that often the sheet can be seen to be drawn up into small cones. If an insect brush against the web, the legs are jerked inwards, plucking sharply at the sheet; and the result is not invisibility for the Spider but a further entanglement of the insect. Orb-web Spiders perform exactly the same action, the web shakes and the Spider plucks at it. Very often the Spider then turns about and repeats the jerking in another direction, an action which, despite its intelligent appearance, is only a consequence of unequal tensions in the threads of the web. The inequality may be due to the recently added weight of the captive and it is this which turns the Spider round, and not an attempt to discover whereabouts in the web the arrival has landed. Like beauty, which lies in the eye of the beholder, purposiveness lies in his interpretation of what he beholds.

A consideration of a second reflex action furnishes support for this view. If a reflex is found to have no manifest result or no meaning in an anthropomorphic sense, the observer refrains from imputing purpose to the animal and is content to describe the action itself as a mystery. Spiders often exhibit one such action. If the flexor muscles raise the femora while the extensor muscles straighten the patella, the result will be that the Spider lifts its leg into the air, stretched up at right angles to its body. This is most often seen in orb-web Spiders, for which it constitutes the normal reaction to a sudden noise. A whistle, a cough or the bark of a dog near a full-grown Araneus usually makes it shoot out its forelegs, as if reaching towards the origin of the sound. The anthropomorphic description of this action would be that the Spider is listening, but whatever it is that the Spider hears it does not proceed to any further action, and the idea that it can hear better with its toes in the air is too foolish to be suggested. Moreover, other Spiders perform the same action in quite different circumstances. Some female Spiders in charge of their egg-cocoons assume this position when driving off intruders, others similarly repel the advances of an unwelcome male. Many Spiders raise their forelegs in courtship, others do so when teased or threatened. It seems reasonable to interpret the otherwise meaningless act by suggesting that it is elicited by a different kind of disturbance from that which produces complete flexion. The femora are not drawn back so far, the tibiæ are not folded against them, the posterior pairs of legs are not moved.

Still another consequence of the flexor reflex remains to be considered. In the

performance of many mammalian reflexes there is a characteristic known as the **refractory phase.** This is the periodic recurrence of a condition of inexcitability of the flexor muscles, so that the limb is momentarily straightened by the extensors, and the result is a rhythmically repeated motion as in scratching. Arachnida do not scratch themselves, but some of them in certain circumstances will show a rhythmic repetition of the flexor reflex, which again has valuable results. Two very common Spiders, *Araneus diadematus* and *Pholcus phalangioides* possess the habit of rapidly shaking their webs so that they themselves, usually conspicuous in the centre, become blurred and indistinct. This shaking is achieved by vigorous contractions of the femoral muscles, suitably timed, but even if the stimulus continue the reflex will cease. Reflexes can be stopped either by fatigue or by inhibition from another reflex. Under inhibition the reflex fades out with no change in the frequency or extent of the beats, and this is seen if one touch the oscillating Spider, causing it to drop at once. Under fatigue the actions continue with a slower rhythm and this is seen if the Spider can be forced, as by gently blowing on it, to continue its vibratory movements.

In this account of reflex actions it is seen that the well-known reflexes of Mammals are of the same nature as the reflexes of Arachnida, and that these reflexes are responsible for many of the essential actions of an Arachnid's life. Even the familiar conditioned reflexes can be paralleled and the recent work of Dr. Pierre Bonnet [22] of Toulouse provides an instance. During his study of the Spider Dolomedes, it was his custom to keep many specimens, each in a covered glass jar. These captives were fed by presenting to them a fly held by a wing in a pair of forceps, upon which the Spiders unhesitatingly leapt. After a while, the act of raising the cover-glass caused the Spiders to turn and leap forward, although the fly had not entered the jar. The Spider's pounce, originally a response to the buzzing of the fly, became conditioned to the opening of the jar. Once again it is true that the behaviour which wears so striking an appearance of consciousness and purposive striving is but a balance of physiological processes, stimulation and inhibition, which take place in a body or bio-chemical system of alternating equilibrium-states.

A very extensive group of actions which cover a large proportion of an Arachnid's activities are known as **tropisms.** A tropism is a directed reflex, concerned with bodily orientation in response to a particular type of stimulus, so that symmetrically placed sense-organs receive equally intense stimulation. Light, water and gravity, responsible for phototropism or heliotropism, for hydrotropism and for geotropism, are the most familiar external causes of tropistic behaviour and Arachnida provide good examples of them all.

The effect of **light** is often very marked, and ordinarily its most obvious influence is the way in which it deadens the irritability of organisms, many of which are quiet all day and are then seized with a strange restlessness and a readiness of response during the night. The most familiar Spiders spin their webs in the evening, and Harvestmen provide an even better example. When living in captivity they

are so still during the day that to a casual observer they seem to be dead, while at night they are active and eat the food which has been supplied to them and which they have neglected while the sun shone. On the other hand Wolf-Spiders and Jumping-Spiders are generally busy in the sunshine, but disappear as if by magic in response to a passing cloud.

Reactions to **gravity** are also common among Arachnida, and many Spiders when kept in captivity invariably climb to the highest part of the cage. Several Hunting-Spiders become geonegative and climb into the undergrowth when they are mature, while Harvestmen hunt on the ground at night but generally climb up trees or houses for rest during the day. The most pronounced example of negative geotropism is shown by the young Spiders which are dispersed by an aerial flight on a gossamer thread, for the little Spider always climbs to some height before it sets sail.

But many other kinds of tropism besides these three can be detected in the study of the habits of small animals. Stereotropism is a reaction to bodily contact, hygrotropism to water vapour, chemotropism to different chemical compounds, thermotropism to heat, vibrotropism to vibrations, galvanotropism to electric potential, rheotropism to visual images and anemotropism to wind pressure. The Arachnida can provide good examples of all these types of tropistic behaviour.

Anemotropism is a term used by Wheeler [83] to describe the orientation of insects to the direction of the wind, so that they fly with equal pressure on their wing surfaces. As far as the Arachnida are concerned, an especially good example of this not very common tropism is provided by young Spiders, during their migration on threads of gossamer, mentioned above. When they have climbed to the summit of their ascent, they turn head to wind before raising the abdomen and secreting the silk thread and this turning is directed solely by the wind.

Rheotropism is in part an allied phenomenon in which the pressure is supplied by water and thus is common in many animals which live in rivers and running streams. It prevents their being washed out to sea. Just as geotropism may be effective through the semi-circular canals, the eyes or the pressure upon the feet, or normally through all these, so rheotropism has apparently a dual mechanism, effective through lateral sense-organs sensitive to touch and also through retinal images. For the latter there is an apparent tendency to keep visual images at a fixed spot on the retina. Fish show this well and swim upwards if an object beside their aquarium move downwards. Spiders show the same tropism. If the hand is moved over a running Spider from behind, the Spider can be made to turn and run in the opposite direction. Opiliones, Harvestmen, do not react to a hand above them since their eyes look outwards, not upwards. But if the hands are placed one on each side of the animal and are moved up and down, the Harvestman's body rises and falls on its long legs in unison, with the most ludicrous appearance possible.

Stereotropism, a tendency to force the body into corners and crevices, is well developed among most of the Arachnida, which are impelled by its insistence,

aided by negative phototropism, to hide themselves in safety during the day. Spiders may be used to give most interesting results in experiments on this tropism by putting them into a cage (Fig. 9, i) of cylindrical form with two angles, one made of glass (B) and the other of cardboard (C). When a Spider is put into this cage it has the chance of remaining in the circle (A) or going into either the dark or the light crack, and the cage therefore not only detects stereotropic tendencies but compares stereotropism with either positive or negative phototropism. It is not to be expected that many Spiders will be stereo-neutral, but one at least, *Pisaura mirabilis*, was found never to attempt to force itself into either crevice. When a Spider, such as *Amaurobius ferox*, whose normal habit is to live in a dark corner is put into the cage, there is no delay in its entering the crevice, but it will not enter the glass angle if the dark one is available. In a cage with a glass angle only it will enter the angle instead of remaining in the circle, thus showing that its stereotropism is stronger than its negative phototropism.

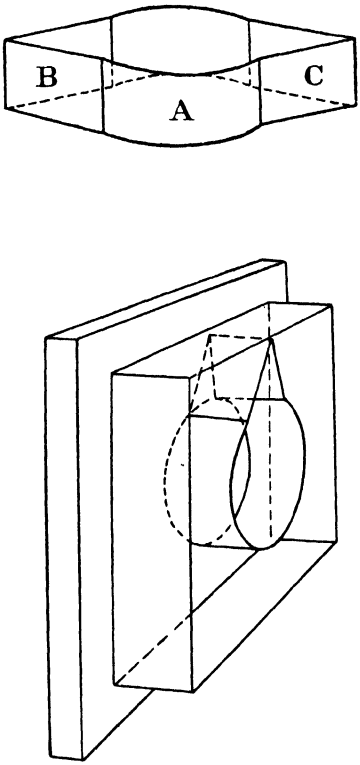


Fig. 9.—Cages used in experiments on the Tropisms of Spiders.

In the form of the cage shown in Fig. 9, ii, there is one crevice only and the floor is vertical. It is pivoted to a board by a pin through the centre of the circle, about which it can be revolved, so that it can be used to compare the strengths of stereotropism and geotropism. The Spider *Steatoda bipunctata* is stereopositive and very markedly geonegative. It invariably climbs into the crevice when this is pointing upwards, but it simply will not go down into it. Thus its negative geotropism is stronger than its stereotropism. Its phototropism is feeble, and the substitution of a glass crevice for a dark one does not change the result.

Hydrotropism, or turning towards water, is well shown by the Arachnida, many of which are habitually thirsty creatures. If a drop of water be cautiously lowered with a pipette into a cage containing a thirsty Spider, there is at first no response. The drop begins to evaporate and the vapour diffuses across the cage and so reaches the Spider. Then, after a time, there is a response ; the Spider moves its palpi, as if testing the air. Finally, as the concentration of water vapour in its neighbourhood rises, it moves towards and drinks the drop of water. This experiment shows that the thirsty Spider does not move about seeking water, as a man would,

but that, if its internal organs are sufficiently desiccated, its forced response is such that it is led towards the liquid it requires.

Hygrotropism, a term apparently first introduced by the present writer [73], differs from hydrotropism since it is solely a reaction to atmospheric water vapour. Water vapour is an extremely active component of an invertebrate's environment, and many creatures, and especially the Arachnida, are sensitive to hygroscopic change. This tropism is responsible for many of the peculiarities in the localisation of Spiders to small areas within their total range.

Vibrotropism is the response of an animal to vibratory disturbance of its surroundings and among several examples Web-Spiders are undoubtedly the animals in whose lives it plays the greatest part. By it they are guided directly to the source from which the vibrations of their webs originate. The Spiders that run on the surface of water respond in the same way to the ripples produced either by struggling insects or by the prong of a vibrating tuning-fork. It can readily be seen that this tropism is a direct consequence of the flexor reflex. Let it be supposed that the Spider is standing with all eight legs on the surface, as shown in Fig. 10.

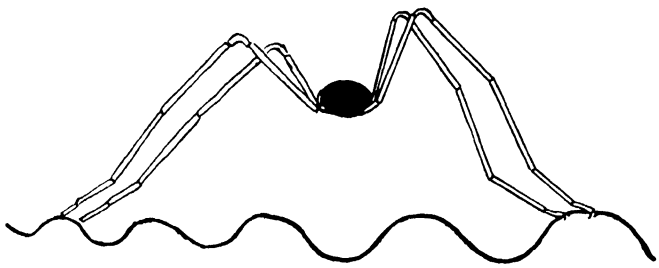


FIG. 10.—Diagram to illustrate the Mechanism of Vibrotropism.

The ripples passing under the right legs will have a smaller amplitude than those passing under the left legs, and thus there is a more intense stimulation of the right legs, followed by a greater degree of flexion of the femoral muscles. The consequence of this forced movement is that the extended left legs exert a turning effect relatively to the less extended right legs so that as the spider runs it is automatically directed towards the origin of the disturbance.

The number of recognised tropisms indicates an important aspect of animal behaviour, for if an organism be subject to ten or a dozen modes of tropistic response to external conditions, it is seldom that in natural circumstances a single tropism can act alone, holding the animal as it were at its sole mercy. Thus we are led at once to consider an interplay of tropisms, and to regard the organism as a particle subjected to a number of possibly contending forces and obedient to their algebraic sum. In this very fact there is always the risk of a facile statement that some tropism is involved without any proof of the truly tropistic nature of the actions. By constant usage one may commit the peculiar type of fallacy known as a reification of words, and come to regard a tropism as if it were a thing which, like a gland,

may or may not be found in an animal. But a tropism is not a thing, it is a way in which organisms behave. The body reacts to changes in its environment by secretion or by movement. When movement has occurred its direction is governed by tropistic principles.

An examination of the distribution of the Arachnida shows that they are found in situations where the conditions are most nearly constant; they are to be found in ditches, under stones, leaves and logs of wood, and in caves. This apparently ascribes the selecting agency to the activity of the animal. But the boot is on the other leg: the real selector is the environment. It is not drought or flood, cold or warmth that disturbs the invertebrate, but the change from one to the other. Should the conditions alter so as to overstep the various thresholds, the animal is affected and must respond. Thus it is inexorably moved on, as if by a merciless policeman, until it reaches a station in which it can remain. Here it is a prisoner, until further change releases it.

This conception of an animal, devoid of behaviour in a constant environment, is, unfortunately, contrary to ordinary ideas and ordinary experience. But it is a fact that *ordinary* experience is seldom derived from the study of animals in their normal surroundings. A naturalist usually meets small animals just after he has disturbed them. He belabours the hedges and ploughs up the leaves or at least goes crashing through their neighbourhood, his titanic feet shaking their world, his shadow obscuring the sun, his scent lingering behind him. Only a few observers realise how large a proportion of an animal's time is spent doing nothing.

Here is the true place of the study of tropisms in animal behaviour. Any particular tropism can, of course, be understood only after experimental study under laboratory conditions, yet in nature animals exhibit tropistic behaviour although no mechanistic biologist stands by to measure their angles of deviation.

The customary description of animal behaviour as "instinctive" demands further consideration. **Instinctive acts,** like reflexes, do not have to be learnt and they are adaptive in the sense that they tend to the preservation of the animal and of the race when they are normally performed in normal circumstances, but when circumstances change it is often found that the animal neither modifies nor reverses its instinctive procedure, continuing its course unchecked with useless or even fatal results. But, unlike reflexes, instinctive acts demand an intact nervous system, and they are often directed towards a relatively distant goal. Many of the deeds that animals perform on behalf of their young will bear fruit only in the future, while reflexes are always concerned with affairs of the moment. Further, instinctive actions are sometimes capable of modification.

All these characteristics of instinctive actions are well illustrated by the Arachnida. The spinning of the Spider's web, the building of the False-Scorpion's nest, the making of an egg-cocoon, the courtship of Scorpions, Solifugæ, Spiders and False-Scorpions and the elaborate behaviour involved in the life-histories of Mites and Ticks are all instances of typically instinctive actions. As long as we are

studying the Arachnida we are dealing with instinctive actions in which their cast-iron routine is well displayed. The well-known experiments of Fabre [34] and the even more critical studies of Hingston [46*a*] have uniformly emphasised this fact, that instinctive behaviour may develop in an irreversible sequence and is usually quite unable to deal with any situation outside the ordinary. This is a description of the nature of instinct and not a criticism of the animal's ability, for the instinctive actions normally suffice for the animal's survival. The young Spider spins its first web quite perfectly—and a year or so later it may spin its last. The last will be no better and no worse than the first, it will not be spun more quickly or in a better place. The Spider has not profited from past experiences, and so has robbed us of all the evidence we might have had that the experiences were conscious ones. All its life it has just spun—instinctively, irresistibly, irrationally—for it has no consciousness, it has no mind.

Such instinctive behaviour is, in general, largely governed by internal physiological conditions, just as tropistic behaviour is governed by external physical conditions. The habits of the Water-Wolf Spider, *Pirata piraticus*, illustrate this particularly well. These Spiders spin a tube-like retreat leading to the water's edge and, as mentioned above, react to water ripples as Web-Spiders react to the vibrations of their snares. When the female has laid her first cocoon she remains in the tube but neglects to repair it. It is not that she never spins, for at regular intervals she detaches the cocoon from her spinnerets, holds it in her third pair of legs and turns it about while adding more silk to the outside. She will then lay it aside for a short while and add a little silk to her home, but her instincts are those of a mother, not of a builder, and the tube soon becomes a wreck. By the time that the first cocoon has hatched and the young have dispersed, the ovaries will be maturing for a second family, and shortly before this cocoon is laid, the Spider reverts to her maiden habits and spins a new and perfect home. This process of alternating neglect and replacement is repeated between the second and third cocoons, after which the summer is almost over and the winter torpor is approaching. When a number of these Spiders are being kept at the same time, the influence of approaching and receding maternity upon their normal instincts is particularly striking.

Thus one important aspect of the nature of instinct begins to appear. To the older naturalists this presented such great difficulties that they were usually forced to be content with description and metaphor. Thus they spoke of instinct as " racial habit " or as " inherited memory " or as " lapsed intelligence," but these were mere verbalisms and no progress results from sheltering behind words. Some advance has now been made from that position, so that we now look upon instinctive actions as being reflex acts, following one another in predetermined succession, coming often under the influence of external circumstances, so that a symmetry of activity is produced, and often also under the influence of internal conditions, so that new types of activity constantly appear. This union of external and internal factors and the realisation of the nature of the latter is important. Instincts are something more

than reflexes, but this " something " is of a material nature, secreted by glands ; it acts as a chemical compound distributed by the blood. Thus it becomes at once subject to direct study, and mere difficulties of technique are the obstacles to a full knowledge of the nature of every hormone, of the way in which it is produced and the physico-chemical nature of its mode of action.

An exceptionally fine analysis of an instinctive action in this way has been made by Peters [65], in his study of the capture of insects by the common Spider *Araneus diadematus*. He concludes that a series of stimuli, each followed by a characteristic reaction, produces the habit and that a psychical factor nowhere encroaches in the chain. The capture of a fly is thus analysed by Peters into five separate elements, as follows :

i. Movement towards Prey. The Spider is guided by the vibrations of the web, or if the prey does not move, by the change in tension of the threads. The stimulus for this forward movement is the sudden movement of the web.

ii. The Reflex of the Long Bite. The stimulus for this is the vibratory movements of a struggling fly : stationary objects are not bitten in this way.

iii. The Wrapping or Enshrouding Reflex. This familiar act is a compound reflex, legs and spinnerets being involved, the stimuli for which are both chemical and tactile. These stimuli are received when the prey is touched with the forelegs and palpi, and when it is bitten.

iv. The Reflex of the Short Bite. This follows the wrapping of the prey and the stimulus is a tactile one received from the silk threads with which it is covered.

v. The Carrying Reflex. The wrapped prey is carried to the Spider's waiting-place ; the stimulus is the chemical one received from the short bite.

Peters succeeded in calling out some of these reactions isolated from the process of capture. " If," he writes, " one holds to the Spider in forceps a struggling fly, the insect is bitten (long bite). If one cautiously touch the palpi with a freshly-killed fly, it is immediately wrapped up. If one use an already wrapped fly, it is bitten (short bite)."

In later work he has further investigated the fifth element, the " carrying reflex." It is well known that this spider sometimes carries away its booty in its cheliceræ, but sometimes it attaches the wrapped packet to its spinnerets. Peters [65*a*] has shown that the weight of the prey determines the method of transport, relatively heavy objects of about 80 mg. being carried on a thread with the help of the hind legs, while lighter ones of about 10 mg. and the same dimensions are carried in the cheliceræ. His papers contain many other valuable observations, of great interest to those who believe in his method of studying and analysing the behaviour-patterns of Spiders.

EXCURSUS I

On Theories of Animal Conduct

Our knowledge of our own behaviour is obtained from two sources. We may study our actions as it were from the outside, observing their consequences to others and their effects upon matter ; or we may consider what appear to us to be the reasons for which we performed them and the purposes for which, as we believe, we undertook them. Such introspection cannot be used as a method of obtaining trustworthy data on which to found a scientific hypothesis, for it is limited to observation of ourselves alone, a wholly insufficient basis. Moreover, whenever our behaviour becomes most worth observation, as when we are hungry or angry or in love, at these very times are we least able to make a detached and unbiassed analysis of our motives.

The actions of other people we can study from the outside only, a fact which many writers of drama and fiction have found cause to regret. Yet there is such an obvious resemblance between our actions and the actions of others, that it is reasonable to suppose that they possess minds, dictating these actions, similar to our own. We may not be certain of this, and our uncertainty may be mildly expressed by merely remarking, as Bertrand Russell has done, that " most people would rather die than think, and in fact they usually do " ; or, it may be expressed more emphatically, as do the solipsists, who wish to deny even the existence of all persons other than themselves.

The actions of animals form a third stage. They can be studied only from without, but the resemblance between our actions and theirs is not so close. It is seen that men would not always behave as animals do in the same circumstances, and that this difference increases our doubt as to the existence of the animal mind. " It would be very difficult," writes Dale Collins [29], " to write a novel with the worm as hero and to get within his walls of pink skin to learn what passed there."

Some biologists do not admit any difficulty, but confidently endow the animals observed by them with conative or with emotional or with conscious states for which there is no justification. For example, Bristowe [24*b*] writes of a Spider attracted to a vibrating tuning-fork—" The owner of the web immediately rushed forth, and with considerable excitement seized upon the fork and walked up it, biting it continually and trying to find a tender spot." It is to be supposed that if we ask this observer why the Spider bit the fork so often, the answer will be, " Because it was excited." If we press the matter and ask, " How do you know it was excited ? " the only answer can be " Because it bit the fork often." In the same way, the words " trying to find a tender spot " have no real meaning. It is quite impossible to know that the Spider is trying and equally difficult to know that tenderness in the fork would induce a change in behaviour. It may be said in defence that the writer means only that the Spider behaved *as if* it were excitedly seeking a tender spot ; to which the obvious

reply is that, since words have meanings, it is well to choose those which express what the writer wishes to convey.

There must always be an element of doubt in the interpretation of animal behaviour and a need for caution in describing what has been seen. There are three ways in which these doubts and difficulties may be diminished.

One of these is to make the naïve assumption that all animals are knowing, feeling and striving subjects, similar to ourselves and differing only in degree. This is the method of vitalists, such as MacDougall [60], who writes, "Mind whenever and wherever it exists operates teleologically and is thus operative in all living organisms, certainly in man and probably in all animals."

The second way is to assume that organisms are mindless automata, mere physical objects governed by physico-chemical reactions, and that mind exists only in man. This is the method of all mechanists, from Descartes to Loeb and Pavlov. Its great advantage is that it does not assume the existence of a mind where that existence cannot be proved, and it opens the way to much experimental work.

The third method is to assume that some animals are mindless automata, while some are enminded. This ought to please both sides, but it raises the difficulty of drawing the dividing line, and presents in an acute form the problem of the relation between mind and body. When these facts are considered it is not surprising that there are various theories concerned with animal conduct.

One of these is the Tropism Theory. In its extreme form the purely tropistic hypothesis cannot admit mind, or mental functions acting teleologically, as ultimate causes or governing factors in an animal's behaviour. This is the essence of mechanism. Its most confident exposition is found in the works of the late Professor Jacques Loeb, whose many experiments led him to express a theory with two principal statements :

(i) The movements of an organism to or from a centre of stimulus are caused by action of the stimulus on the receptors, and through these on the organs of locomotion, in consequence of which the animal turns until its body is symmetrically stimulated and an equilibrium obtained between the two sides.

(ii) These movements occur mechanically, as a result of physical and chemical changes in the receptors and effectors, with no real effort on the part of the organism.

Loeb endeavours to extend this conception to make it include the actions of all animals and even of human beings, an extrapolation of mechanistic biology into animal psychology, a tendency to overdrive the theory until it produces a caricature of an organism. Hence as an alternative Kühn's [53] theory of animal taxis may be considered. A "taxis" is a movement of an organism in response to simple external stimuli, such as light and gravity, which produce sensations in the animal. Kühn thus divided the movements of animals into four groups, named as follows :

(i) Trophotaxis : the animal directs itself symmetrically.

(ii) Menotaxis : the animal preserves a fixed direction with respect to the stimulus.

(iii) Mnemotaxis : movements in which memory plays a part.

(iv) Telotaxis : movements directed towards a goal.

It is clear that the first group of movements closely resemble the tropisms of Loeb. The distinction is based on the idea that trophotaxis involves sensation, in other words it makes the assumption that the animal has a conscious appreciation of the stimulation it receives, and turns, for example, towards the light because of the sensation of brightness and not because of the chemical changes which it produces. Such a conception is unable to explain the fact that the behaviour of certain animals, such as Eudendrium, is in agreement with the physico-chemical law which involves the intensity of illumination. The sensation of brightness is not proportional to the intensity of the stimulus, but the concentration of the products of the photo-chemical reactions is, and the behaviour of many animals agrees with the latter, not the former.

The essential difference between the tropism theory and the taxis theory is a difference in interpretation, the former being mechanistic, the latter teleological. If a biologist can convince himself, in spite of the impossibility of obtaining direct evidence of the animal's subjective state, that the animal has a conscious appreciation of sensations, then the taxis theory will afford an acceptable appreciation of many facts. For instance, Kühn states that flies move towards the window if they are chased and that on the theory of tropisms such a sudden change in the sign of the reaction is inexplicable, as in any other such change when it appears as a result of suddenly approaching danger. As an innate reaction to " the simple sensation of danger," such behaviour may be intelligible.

The taxis theory cannot be accepted by those who do not admit that there is evidence for the existence of appreciation of sensations. It is, however, most interesting to perceive the similarity in behaviour of animals which move either by tropism or trophotaxis, since this may have been responsible for confusion in the past. When similar consequences result from different causes, the difficulty of a correct explanation is greatly increased.

The modern bio-chemists who support the hypothesis of neo-mechanism realise that they can only proceed in their work when they argue AS IF mechanism were true, but that in so doing they are not compelled to any dogmatic assertion as to the nature of life-processes. In the same way the behaviourists can only found a philosophically valid science in which experiment plays its proper part when they work AS IF animals are machines. They must study the results of an animal's actions and leave its purpose as unknown and unknowable.. It is in this respect that the Arachnida are the behaviourists ideal animal, for intelligence, consciousness or " mind " are practically imperceptible in all that they do.

III

THE ARACHNIDA: EVOLUTION AND CLASSIFICATION

One of the most interesting problems afforded by the Arachnida is that of their evolutionary history. The puzzle is a dual one, the earlier question being the origin of the Arachnida as a Class, and the later one their division into the different Orders.

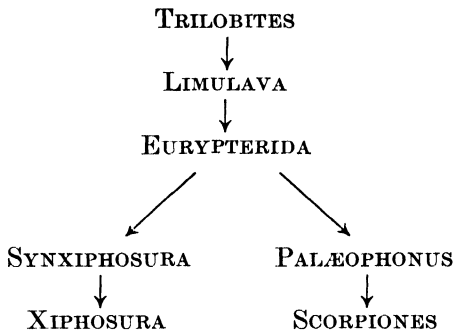
The geological record is, briefly, as follows. The most primitive form which can with certainty be classed as Arachnida, the Eurypterida, are wholly palæozoic; their earliest forms are found in the Upper Cambrian and their last in the Devonian. The most ancient of living forms, the Scorpions, are found in the Silurian; Spiders and Pedipalpi occur in the Carboniferous and all the principal Orders of modern Arachnida are represented in the Tertiary strata. The first problem is therefore the origin of the Eurypterida during the Cambrian era.

According to what may perhaps be called the classical or traditional theory expounded during the last century by Ray Lankester [54*a*] and Pocock [69*a*], a possible ancestor for the Eurypterida is to be sought among the Trilobites, the dominant organism of the Cambrian. The early Trilobites had a prosoma of five and an opisthosoma of a large but variable number of somites. Each opisthosomatic somite except the last had a pair of biramous appendages. As evolution proceeded, the number of opisthosomatic somites grew less, with a definite stage in which the numbers of somites in the whole body was eighteen or nineteen. Simultaneously, some of the opisthosomatic appendages disappeared, and those left became more specialised in function. The prosomatic appendages were used for locomotion and for securing food. the opisthosomatic ones ceased to be locomotor and merely carried the respiratory or branchial lamellæ.

This is an advance towards the form of the Eurypterida. The fossils known as the Limulava or Copura, an Order which contains the two genera Sidneyia and Amiella, may be regarded as intermediates between the Trilobites and the Eurypterida, and thus it may be suggested that the Arachnida arose by modifications of the Trilobites.

The King Crab, Limulus, and its now extinct allies represent a stage in which both the prosoma and the mesosoma have six somites, all with appendages, and the metasoma is at no stage represented by more than three somites. Again an intermediate form between the Eurypterida and Limulus is to be found in the Order Synxiphosura, in which the metasoma consists of three free somites and a shorter spine.

All other Orders of recent Arachnida are terrestrial, but a Silurian Scorpion, Palæophonus, was apparently aquatic and forms to some extent a link between the Eurypterida and the modern Scorpions. This view of the early history of the Arachnida may be diagrammatically represented thus :



Whether it be accepted or not, the early appearance and later disappearance of the metasomatic appendages in Eurypterida, Xiphosura and Scorpionida unites these three Orders so obviously that some common ancestor must be postulated. The similarity of their cheliceræ is also a feature which emphasises their relationship.

An alternative suggestion has been put forward by Zittel [87], who interprets the facts as supporting the inference that neither the Xiphosura nor the Scorpiones are derived from the Eurypterida, but that all three separated from a common ancestor in the Early Cambrian. According to this author, we have no clue as to the nature of this ancestor, because the Trilobites are " true primitive Crustacea." Apparently the fact that the Trilobites are the forerunners of the modern Crustacea excludes them from occupying the same ancestral position with respect to the Arachnida, but to exclude all common ancestry would be equivalent to denying evolution. Moreover, the structure of the primitive Arachnida makes it difficult to suggest an ancestor which was markedly different from the Trilobites, and it would be very strange if such an animal had existed and left as evidence no fossil remains whatever.

The great step in Arachnid history, from the water to the land, can fortunately be followed in a less unsatisfactory manner. The aquatic Xiphosura breathe by ten sets of gill-books or branchial lamellæ borne on the second to the sixth opisthosomatic appendages. The terrestrial Scorpiones breathe by eight lung-books or small internal sacs of lamellæ which open by spiracles on the third to the sixth opisthosomatic somites. During embryonic development these lamellæ appear behind the bases of four pairs of transient limbs and sink into sacs within the body wall, instead of remaining outside as do gill-books exposed to water. Even in microscopic detail the actual respiratory lamellæ of the Xiphosura and the Scorpiones resemble each other. The second opisthosomatic somite of the Scorpiones bears peculiar tactile organs, the pectines, reminiscent of the branchial exopodites of the ancestral Trilobites.

A simultaneous adaptation to land life was a forward movement of the mouth.

In the Xiphosura the coxæ of all the twelve prosomatic appendages function as gnathobases in mastication of the food. As the mouth moved forwards, the posterior pairs of limbs were freed from this duty and functioned solely for walking, and in the Spiders none of the legs has any relationship to the mouth.

Further changes in the respiratory system must, however, be mentioned here. Lung-books such as the Scorpions and Spiders possess are not the only breathing organs found in Arachnida, but tracheæ are, as already described, also present, and occupy diverse situations on the bodies of members of the different Orders. The existence of these tracheal tubes has given birth to two diametrically opposed hypotheses of the evolution of the Arachnida. The view taken by Ray Lankester and Pocock was that the lung-books of the Scorpions, Pedipalpi and Araneæ are derivable from the branchial lamellæ of the aquatic forms. Early terrestrial Arachnida therefore possessed such lung-books as their original breathing organs, and these were superseded or replaced or supplemented by tracheæ.

The alternative view, due to Leukart, Hansen and Sørensen, was that the primitive respiratory organs were tubular tracheæ, that the tufted tracheæ arose from these and the lung-books in turn from the tufted tracheæ. This implies that the primitive Arachnida were terrestrial, not aquatic, organisms. Hence Limulus and the Eurypterida, though aquatic, are derived from early land-living forms. Hansen suggests that these primitive Arachnida had a head composed of four somites and a thorax of two somites : whence the Palpigradi must be regarded as the living forms nearest to the ancestral type and the Solifugæ must be next in order. Bernard [19] described the hypothetical ancestor as an Arachnid with eighteen somites, each of which had a pair of appendages, a pair of spiracles and, internally, a pair of diverticula from the alimentary canal. Ewing [33] has lately added the suggestion that the primitive arachnid appendage was unanimous and composed of eight segments.

This latter account of the origin of the Arachnida is no more than an elaboration of the fact that the ancestor of the Class is not certainly known, but that a few more or less plausible guesses may be made about some of its features. There is an obvious determination to exclude the Trilobites, which are held to be the forerunners of the Crustacea, even to the extent of assuming that the primitive Arachnida were terrestrial. The fact that Limulus shows unmistakable crustacean characters must then be disregarded or supposed to be due to a fortuitous convergence.

It cannot be said that either hypothesis is wholly satisfactory, but the present state of our knowledge is not able to supply more definite information. All that can be said is that if the ancestor of the Arachnida were not a Trilobite, it was some early Cambrian or pre-Cambrian Arthropod. The ancestry of the Arachnida must then be sought in a study of the Onycophora, as Versluys and Demoll [80] have done.

The relationship of the different Orders of the Arachnida, that is to say, the course of evolution within the Class when once it was established, is the second major problem of arachnid phylogeny. This, too, is difficult to solve satisfactorily, and little more than possible suggestions can be made.

There is a general agreement that the Orders of the Arachnida cannot be arranged in an ascending series from the most primitive to the most specialised. This is due to the fact that primitive features, such as the possession of a distinctly segmented body or many pairs of gnathobases, and specialised features like a complex glandular system or an elaborate mode of life, seem to be distributed as it were indiscriminately among the different groups. The Scorpions are generally admitted to be the most primitive of the land-living forms, though as has been mentioned above, the Pedipalpi and the Solifugæ also have claims to the lowest place. The Araneæ are certainly to be placed at the top of the ascent as the most highly organised, and the Acari are as certainly degenerate. But over the relative positions of the rest, authorities have differed in the past and still differ to-day; their various solutions of the problem are expressed in their various systems of classification, and it is as difficult to disregard any one of them as to reconcile them with one another.

The nature, and the fascination, of the problem may be well appreciated by selecting a number of pertinent characters and displaying their distribution among the Arachnida in tabular form. This is done in Table V. The features chosen are such as possess alternatives: for example, the chelicerae or the pedipalpi may be large or small, the opisthosoma may be segmented or uniform, the telson may be present or absent, and so on.

TABLE V

DISTRIBUTION OF CERTAIN CHARACTERS AMONG THE ARACHNIDA

	Chelicerae. Large (A) or Small (B).	Pedipalpi.		Prosoma. Segmented (G) or Uniform (H).	Opisthosoma. Segmented (I) or Uniform (J).	Pedicle. Present (K) or Absent (L).	Prosomatic Glands. Active (M) or Suppressed (N).	Telson. Present (O) or Absent (P).
		Large (C) or Small (D).	Chelate (E) or Unchelate (F).					
Scorpiones	B	C	E	H	I	L	N	O
Pedipalpi	B	C	E	G	I	K	N	O
Chelonethi	B	C	E	H	I	L	M	P
Araneæ	A	D	F	H	J	K	M silk	P
Palpigradi	A	D	F	G	I	K	M venom	O
Ricinulei	B	C	E	H	I	K	N	O
Solifugæ	A	D	F	G	I	K	N	P
Opiliones	A	D	F	H	J	L	N	P
Acari	B	C	E	H	J	L	M odorif.	P

How are these facts to be interpreted? A reasonable suggestion seems to be as follows.

In Cambrian times, the ancestor of the Arachnida, whether Trilobite or not, was an organism of tremendous potentialities. These potentialities were of a peculiar nature. They did not achieve the preservation of the animal itself, which, like the Trilobite, has become extinct, but they were such as could and did produce a variety of descendants. These descendants, better equipped than were their forebears, have survived where the latter have disappeared, and the living Arachnida and Pycnogonida of to-day remain as evidence of their success.

The ancestral Arachnid may not unreasonably be regarded as an experiment in evolution, an experiment which, though an apparent failure, produced in the course of its existence a number of other experiments, many of which were more fortunate. These successes, the living Arachnida, are the results of different selections from the ancestral potentialities.

In this rich treasure-house there were evidently many alternatives. An experiment was made and a new group originated by the choice of some of these and the necessary abandonment of others. For example, the Solifugæ are the result of a combination of *large* cheliceræ, *small* palpi, *no* pedicle, *segmented* opisthosoma and *no* telson. The potentialities or alternatives were present in mutually exclusive pairs and the Orders are the results of various combinations.

The parallelism between this manner of evolution and the ordinary laws of Mendelian inheritance is sufficiently obvious. It is possible to express the natures of the arachnid Orders by symbols to some extent comparable to those used for Mendelian allelomorphs. Table V shows this. The characteristic formula for the Solifugæ is thus ADFGILNP while the formula for the Chelonethi is BCEHILMP, and so on.

Another way in which the alternative nature of the characteristics may be displayed is shown in Table VI which includes eight of the recent Orders.

TABLE VI

ALTERNATIVE CHARACTERS IN THE ARACHNIDA

	Segmented Body.		Unsegmented Body.	
	Telson.	No Telson.	Pedicle.	No Pedicle.
Large Cheliceræ.	*Palpigradi*	*Solifugæ*	*Araneæ*	*Opiliones*
Large Pedipalpi.	*Scorpiones*	*Chelonethi*	*Ricinulei*	*Acari*

It is only to be expected that the difficulties of determining the evolutionary history of the Arachnida will be reflected in the diversity of the schemes which have been proposed for their classification.

The earliest systems need not be considered here ; the first that will be mentioned is that proposed by Ray Lankester [54*a*] in 1904, included in the tenth edition of the *Encyclopædia Britannica*, and widely adopted for some years. In this scheme, the Class was first divided unequally into two Grades, the Anomomeristica and the Nomomeristica, depending on constancy or inconstancy in the number of body segments. The former Grade included only the fossil Trilobites. The Nomomeristica were also unequally divided into a sub-Class Pantopoda, containing three Orders of Pycnogonida, and a sub-Class Euarachnida, containing the rest. In the Euarachnida there were again two unequal divisions, the Grade Delobranchia or Hydropneustea for Limulus and the fossil Eurypterida, and the Embolobranchia or Aeropneustea for the rest. Lastly in the Embolobranchia were distinguished the Section Pectenifera for the Order Scorpiones and the Section Epectinata for the rest.

In the same year, Hansen and Sørensen [5] suggested that the Pedipalpi, Araneæ, Palpigradi and Ricinulei should be grouped together as Arachnida micrura, leaving the others in a second group for which no name was proposed.

Lankester's method of attacking the Class by successively cutting off the most aberrant group is probably to be preferred, and is in the circumstances the only way in which sub-divisions can be produced, if such sub-divisions are to be regarded from the start as necessary or desirable.

Possibly it was the contrary belief that caused Friedrich Dahl [31] in his classification published in 1913 to admit no intermediate stage between the Class and the Order, for he has given an " Ubersicht der Ordnungen " in which no such sub-division is actually named. The Class thus contains eleven Orders, which he names Scorpionida, Pseudoscorpionida, Solifuga, Pedipalpa, Araneida, Phalangida, Acarida, Pentastomata, Tardigrada, Xiphosura and Pantopoda. Since in a scheme intended for practical diagnosis, an artificial " key " may legitimately be used, this order cannot be taken as representing any opinion as to the natural relationships of the different groups.

The method used by J. H. Comstock [3] in 1912 is noteworthy only since it placed the Xiphosura in a separate but closely allied Class, the Palæostraca.

Lankester's system has been retained and modified in the classification offered by R. I. Pocock [69*a*] in 1929. In this scheme, the Anomomeristica and Nomomeristica have been preserved, but the division of the latter into Pantopoda and Euarachnida has disappeared. The Pycnogonida are now excluded from the Arachnida, and the Nomomeristica are divided into four sub-Classes, Limulava for the extinct Copura, Merostomata for Limulus and the Eurypterida, Pectinifera for the Scorpions and Epectinata for the eight remaining Orders. In the Epectinata are six new divisions known as super-Orders. One of these, the Caulogastra, includes the Pedipalpi, Araneæ and Palpigradi, the others contain but a single Order each. The features of this Classification are therefore the exclusion of the Pycnogonida and the expression of

he belief that the three Orders of the Caulogastra are more closely related to each ther than to any of the other Epectinata, and also that no two other Orders of the Epectinata are so closely related that they can share a super-Order.

TABLE VII

R. I. Pocock's Classification of the Arachnida

Grade 1. ANOMOMERISTICA.
Sub-class 1. TRILOBITA.
Order 1. TRILOBITA.
Grade 2. NOMOMERISTICA.
Sub-class 2. LIMULAVA.
Order 2. COPURA.
Sub-class 3. MEROSTOMATA.
Order 3. XIPHOSURA.
Order 4. EURYPTERIDA.
Sub-class 4. PECTINIFERA.
Order 5. SCORPIONES.
Sub-class 5. EPECTINATA.
Super-order 1. CAULOGASTRA.
Order 6. PEDIPALPI.
Order 7. ARANEÆ.
Order 8. PALPIGRADI.
Super-order 2. CUCULATA.
Order 9. RICINULEI.
Super-order 3. PSEUDOSCORPIONES.
Order 10. CHELONETHI.
Super-order 4. MYCETOPHORA.
Order 11. SOLIFUGÆ.
Super-order 5. PHALANGIOMORPHÆ.
Order 12. OPILIONES.
Super-order 6. RHYNCOSTOMI.
Order 13. ACARI.

In Dr. L. A. Borradaile's [23] *Invertebrata* of 1932 a new suggestion appeared. The Arachnida were promoted to the rank of a sub-phylum. In this sub-phylum are thirteen Classes, ten of which correspond to the Orders in Table VIII of this book, save that the Ricinulei are omitted. The other three are the Classes Pantopoda, Tardigrada and Pentastomida.

The elevation in rank of the old Class to a sub-phylum and all the Orders to Classes is not really important, as these terms are only labels of convenience. Nevertheless, there is some change in conception when sub-Orders become separate Orders. But the important feature of this revision is that it again brings the Pycnogonida, Tardigrada and Pentastomida within the confines of the Arachnida. This inclusion is discussed in the appropriate part of this book. It is improbable that the system in Borradaile's book will be generally adopted, for a division of the Arthropoda into sub-

phyla should aim at associating the Crustacea and Insecta to contrast them with the Arachnida, and three doubtful groups should occupy separate places.

Finally, the Classification adopted in this book must be considered. The Trilobita are excluded, since they are now generally held to be primitive Crustacea. This removes the first sub-division and with it the cacophonous word Anomomeristica. The other divisions are retained, following Pocock's arrangement, but an attempt has been made to attain completeness by including the fossil Orders. This is difficult, for their affinities are not always limited to a single one of the existing Orders, and it is probable that a difference of opinion may be found concerning the scheme here proposed.

The Synxiphosura clearly belong to the Merostomata and the Kustarachnæ to the Caulogastra. The Anthracomarti resemble both the Pedipalpi and the Opiliones; they have here been put with the former, which are the more primitive. The Haptopoda are more definitely like the Opiliones than the Caulogastra, hence they have to be placed in the Phalangiomorphæ, in company with the Phalangiotarbi.

When this has been done, the classification of the Arachnida is as follows:

TABLE VIII

CLASSIFICATION OF THE ARACHNIDA

CLASS: *ARACHNIDA.*
- SUB-CLASS 1. *LIMULAVA.*
  - ORDER 1. COPURA.
- SUB-CLASS 2. *MEROSTOMATA.*
  - ORDER 2. EURYPTERIDA.
  - ORDER 3. SYNXIPHOSURA.
  - ORDER 4. XIPHOSURA.
- SUB-CLASS 3. *PECTINIFERA.*
  - ORDER 5. SCORPIONES.
- SUB-CLASS 4. *EPECTINATA.*
  - SUPER-ORDER 1. *CAULOGASTRA.*
    - ORDER 6. KUSTARACHNÆ.
    - ORDER 7. PEDIPALPI.
    - ORDER 8. ARANEÆ.
    - ORDER 9. PALPIGRADI.
    - ORDER 10. ANTHRACOMARTI.
  - SUPER-ORDER 2. *CUCULATA.*
    - ORDER 11. RICINULEI.
  - SUPER-ORDER 3. *PSEUDOSCORPIONES.*
    - ORDER 12. CHELONETHI.
  - SUPER-ORDER 4. *MYCETOPHORA.*
    - ORDER 13. SOLIFUGÆ.
  - SUPER-ORDER 5. *PHALANGIOMORPHÆ.*
    - ORDER 14. HAPTOPODA.
    - ORDER 15. OPILIONES.
    - ORDER 16. PHALANGIOTARBI.
  - SUPER-ORDER 6. *RHYNCOSTOMI.*
    - ORDER 17. ACARI.

We conclude and summarise this chapter with a diagnosis of the Class Arachnida and a dichotomic table for dividing it into its Orders.

Diagnosis

Arthropoda in which the body is composed of twenty-one somites, and divided into two regions, the prosomatic somites usually more or less coalesced forming a cephalothorax with six pairs of appendages, the opisthosomatic somites free or fused, the connecting somite modified or suppressed. Genital orifice on the first opisthosomatic somite; a post-anal telson frequently borne by the last. Respiration by gills, lungs or tracheæ. Coxal glands of cœlomic origin on the second to fifth prosomatic somites. The sexes separate, but sexual dimorphism often inconspicuous; the male organs diverse. Development generally without a larval stage.

TABLE IX

Separation of the Terrestrial Arachnida into Orders

1 (2).	Arachnida in which segmentation is almost completely suppressed and the body is not divided by a pedicle	Acari
2 (1).	Arachnida with obvious segmentation or if this is suppressed, with a pedicle	3
3 (16).	With segmentation and without a pedicle	4
4 (11).	Cheliceræ of two segments	5
5 (6).	Posterior legs with malleoli on three proximal segments	Solifugæ
6 (5).	Posterior legs with no malleoli	7
7 (8).	Prosoma with wide sternum	Pedipalpi
8 (7).	Prosoma with only a very inconspicuous sternum	9
9 (10).	Pedipalpi with large, strong forceps	Chelonethi
10 (9).	Pedipalpi with small forceps	Ricinulei
11 (4).	Cheliceræ of three segments	12
12 (13).	Pedipalpi with large, strong forceps; pectines present	Scorpiones
13 (12).	Pedipalpi with small forceps; no pectines	14
14 (15).	Post-abdomen absent; pedipalpi sensory	Opiliones
15 (14).	Post-abdomen present; pedipalpi leg-like	Palpigradi
16 (3).	Pedicle present; opisthosoma with spinnerets	Araneæ

Excursus II

On Nomenclature

Universal agreement on the name of any animal or group of animals is not easily reached by all zoologists. The names used in the above Classification are well-founded by custom and are probably more widely used than any others. Nevertheless, critics of any name are seldom lacking, basing the claims for the names they adopt on laws of

priority, on rules of orthography or on personal predilections. For a certain type of mind, these questions assume an importance out of all proportion to their real value. Nothing really matters about a name save that its exact meaning shall be indubitable. A name must never offend classically trained ears, but otherwise the only justification for rules of nomenclature, whether international or individual, is that they shall help us to avoid ambiguity. No objection can be logically raised against any name as long as all biologists can recognise its meaning, and the unending discussions which try to substitute Araneida for Araneæ or Pseudoscorpiones for Chelonethi, or in either case, vice versa, are logomachy, and not Science at all.

Since the replacement of one name by another does not result in the universal obliteration of the one that has been superseded, a knowledge of the synonyma likely to be encountered is a necessity, and is given in the subjoined list.

TABLE X

COMPARATIVE NOMENCLATURE

NAMES.	SYNONYMA.	COMMON NAMES.
ARACHNIDA .	Chelicerata ; Acerata	Fr. Arachnides ; Ger. Spinnentiere
XIPHOSURA .	Palæostraca	King-crabs ; Horseshoe-crabs ; Ger. Pfeilschwänze
SCORPIONES .	Scorpionides ; Scorpiides ; Scorpionidea ; Scorpionida	Scorpions
PEDIPALPI .	Pedipalpida ; Pedipalpa	Whip-scorpions ; Scorpion-spiders ; Fr. Vinaigriers ; Ger. Giesselspinnen
ARANEÆ . .	Araneides ; Araneidea ; Araneida	Spiders ; Fr. Araignées ; Ger. Spinnen
PALPIGRADI .	Microteliphonida ; Microthelyphonida	
RICINULEI .	Podogona ; Rhignogastra ; Meridogastra	
CHELONETHI .	Chernetidæ ; Chernetes ; Pseudoscorpiones ; Pseudoscorpionida ; Chelonethida	False-scorpions ; Book-scorpions ; Ger. Afterskorpione
SOLIFUGÆ . .	Solpugides ; Solpugida ; Solpugæ ; Galeodea ; Mycetophoræ	Sun-spiders ; Camel-spiders ; Wind-scorpions ; Ger. Walzenspinnen
OPILIONES .	Phalangita ; Phalangides ; Phalangida	Harvesters ; Harvestmen ; Harvest-spiders ; Fr. Faucheurs ; Ger. Weberknechte ; Afterspinnen
ACARI . . .	Acarina ; Acarida ; Rhyncostomi	Mites ; Ger. Milben

II. PROLES ARACHNES

IV

THE ORDER XIPHOSURA

King Crabs

" Viden' limulis, obsecro, ut intuentur ? "

Plautus.

Marine Arachnida in which the prosoma is a broad semicircle, and bears two median and two lateral eyes. Opisthosoma hexagonal, broadly joined to prosoma, with six mesosomatic somites, a vestigial metasoma and a long spine-like telson. Chelicerœ of three segments, small, chelate. Pedipalpi not different from ambulatory legs, all with six segments and gnathobases, lying round the central elongated mouth. Posterior legs with exopodite, and tibial apophyses forming a scoop. Chilaria behind mouth. Mesosomatic appendages plate-like, the first genital opercula, the rest bearing gill-books, on the exopodites.

The **prosoma** of the Xiphosura is semicircular or horseshoe-shaped in outline with steeply sloping sides enclosing the space in which the appendages lie. The exoskeleton is of tough chitin, smoothly polished : a ridge runs down the middle of the body and a slight groove a little distance away on each side gives to some extent a trilobed effect. The prosoma is also furnished with seven spines. One of these near the centre of the fore-edge is just behind the pair of small black median eyes. Across the middle is a row of three spines and at the bases of the outside ones lie the large lateral eyes, staring outwards. The posterior margin of the prosoma is a three-sided re-entrant with a short erect spine in the middle and one at each corner. The postero-lateral margin is fringed with delicate hairs.

The median **eyes** of Limulus are simple ocelli with a single lens ; the lateral eyes are compound eyes, that is to say, each consists of many lenses placed close together with a simple ommatidium beneath each lens, the optic nerve terminating therein.

The **opisthosoma** fits into the re-entrant mentioned above. It is a broad hexagon with hardly any trace of segmentation and with three spines along its middle line. Its postero-lateral margins carry six small spines and terminate in a seventh much larger one. Between these, six small movable spines are articulated. The posterior margin is a three-sided concavity similar to but smaller than that of the prosoma. It carries the telson, articulated from its central edge.

The **appendages** of the King-Crab cannot be seen until the animal is turned over, for they lie wholly within the cavity formed by the sloping sides of the prosoma. The sides of the latter turn in to form a flat rim surrounding this inverted basin. The

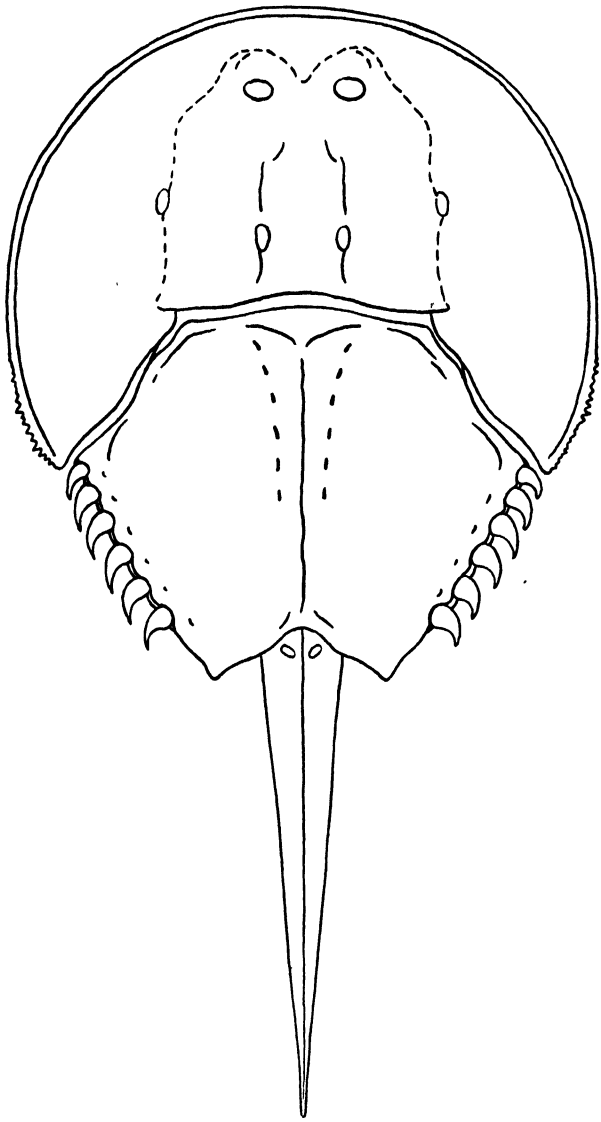


FIG. 11.—*Limulus polyphemus*—Dorsal Aspect.

cheliceræ are small chelate organs of three segments : the chelæ are smooth and finely pointed. They are situated centrally, just in front of the mouth, but between their bases and that aperture is a small ridge, comparable to the crustacean labrum.

The second pair of appendages, which in all other living Arachnida are known as

the **pedipalpi** do not in the Xiphosura differ in any essential particular from the limbs which follow them and, like Kœnenia, Limulus may with complete accuracy be said to have five pairs of **legs.** These are of gradually increasing size from the first to the fifth. All are composed of six segments, but a mark to be seen across the tibia of some may perhaps indicate a patella and restore the number of segments to seven, the normal Arachnid condition.

The coxæ are sub-triangular in shape with the longest side of the triangle attached

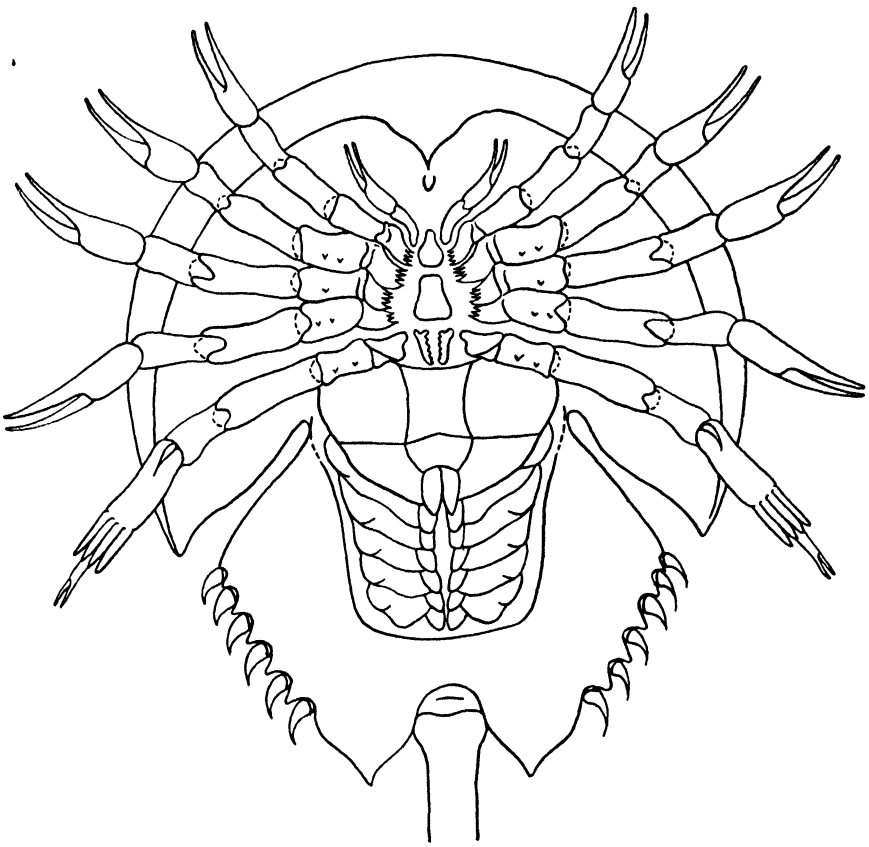


FIG. 12.—*Limulus polyphemus*—Ventral Aspect.

to the body. The inner side, next to the mouth carries a masticating gnathobase which is largest in the first and second pairs. In addition the coxæ of the first, second and third (true) legs bear a small movable outgrowth known as the epicoxite. To the last coxa, which has no epicoxite, is articulated an exopodite, an unjointed rod with a knob-like termination. The trochanters of all five limbs have short sharp spines on their inner surfaces. The species differ in the nature of the tarsi ; in some the pedipalpi are chelate in the female but not in the male ; in some all the first three legs are chelate and in some the pedipalpi and first legs are unchelate, even in the female. Males can

usually be distinguished from females by their smaller size and by their shorter stouter pedipalpi. The tarsi of their anterior legs are also modified to enable them to grasp the female.

The last pair of legs is specially modified in all species. The tibia which is fringed

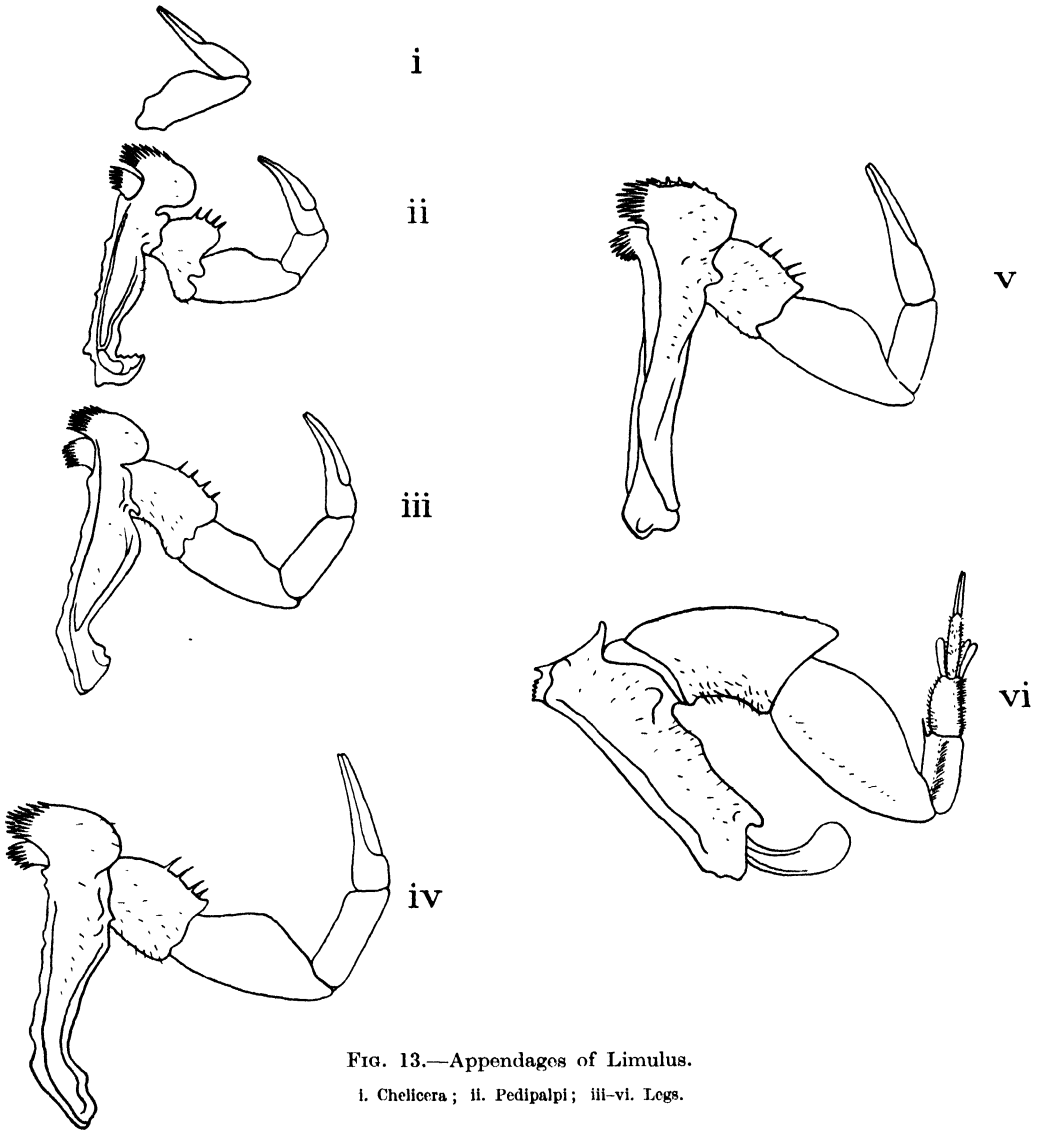
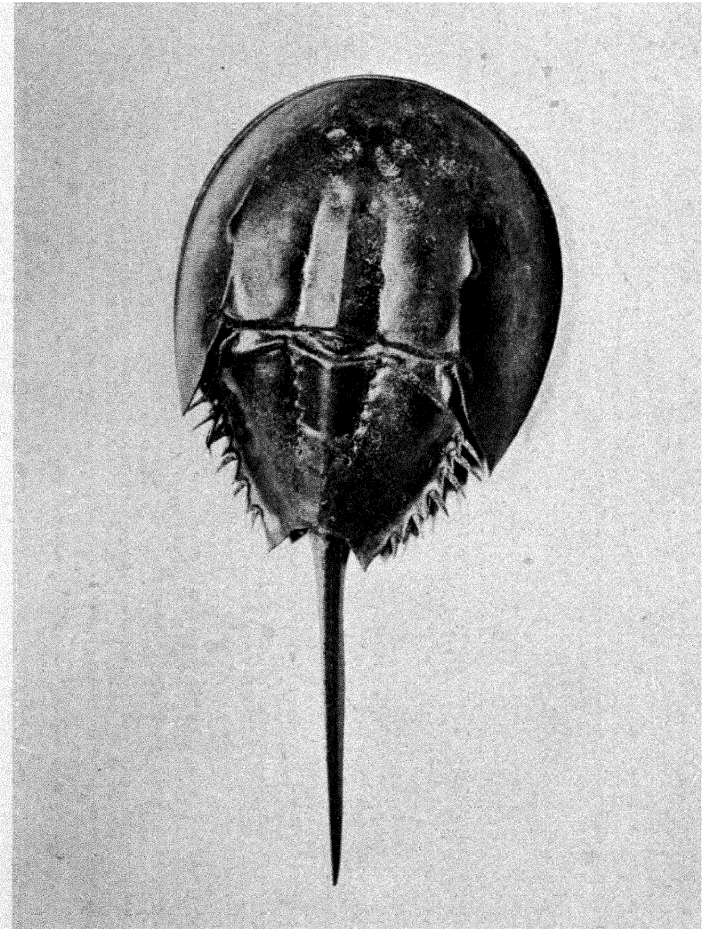


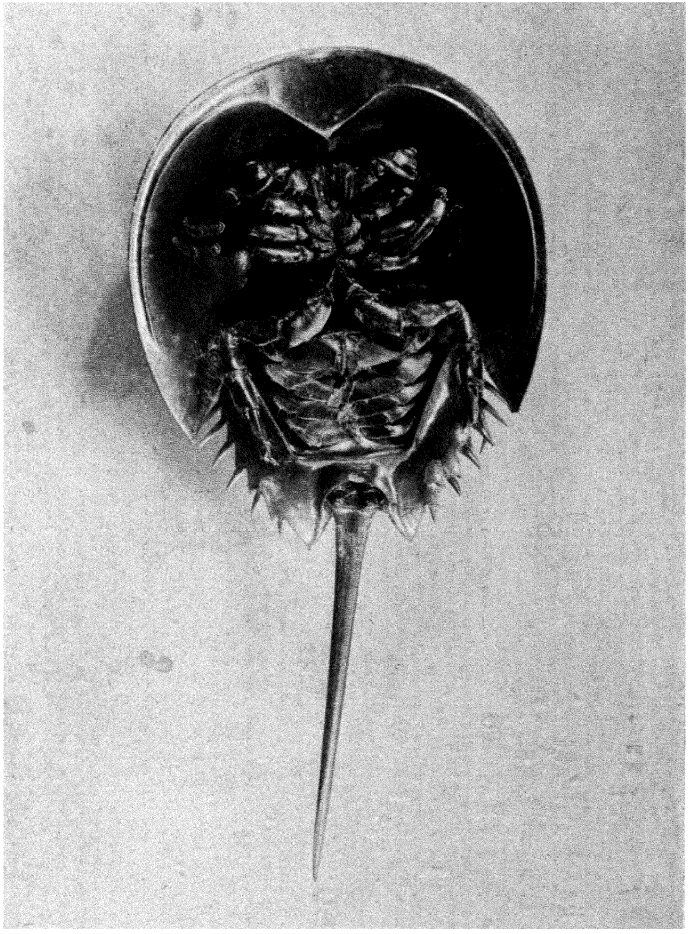
FIG. 13.—Appendages of Limulus.

i. Chelicera; ii. Pedipalpi; iii–vi. Legs.

with hairs carries three flattened outgrowths at its distal end by the side of the tarsus which is itself forked. When the legs are drawn forwards these appendages lie closely together, but when the legs are thrust back the resistance of the water opens them fan-wise and they form a scoop with which the animal pushes away load after load of sand as it buries itself at the bottom of the sea.



(i) Dorsal View



(ii) Ventral View

LIMULUS POLYPHEMUS

PLATE II

Behind the mouth is an apparent seventh pair of appendages, the **chilaria.** These are small round plates, joined together at the base, of doubtful function. Morphologically they seem not to be true appendages, but to be homologous with the pentagonal sternal plates of the Scorpions.

One of the chief characteristics of the Xiphosura is the existence of six **mesosomatic appendages.** Although the tergites of this region are all fused in the adult to form the opisthosomatic shield, the segmental nature is fully maintained on the inferior surface. The mesosomatic appendages are flattened plates of roughly semicircular form. The first is known as the **genital operculum** since below it lie the two simple orifices of the reproductive system. It is larger than the following appendages and overlaps the first one or two of them.

These five appendages are similarly shaped plates which lie regularly overlapping each other, but which can, in life, be opened and moved to and fro. Each consists of a simple flat median endopodite of two joints and an elongated exopodite which points sideways and carries on its forward edge the respiratory organ or gill-book. Each of the ten gill-books contains from a hundred to two hundred oval leaves in which the blood flows.

The **metasoma** is much reduced. In the embryo three separate metasomatic somites can be distinguished but the rest have disappeared and in the adult the whole of the metasoma is represented only by the small area anterior to the anus.

The **telson** or post-abdomen is a smooth pointed spear, almost as long as the rest of the animal and triangular in section with the vertex uppermost. It is used by the King-Crab as a means of righting itself when it falls upon its back, and it is also thrust into the sand or mud behind as the animal moves forwards.

The eggs of the Xiphosura are either laid in batches of some hundreds buried about two inches deep in the sand under shallow water or they are carried about by the female. From each egg there hatches an interesting little creature, known as the trilobite larva because of its superficial resemblance to that fossil. The larva is very active, burrowing in the sand as its parents do, and also swimming freely. It soon moults, when the segments of the opisthosoma which had at first been separate, become more closely united. The larva has no spine ; this appears at the first ecdysis and increases in length at each subsequent change of the exoskeleton.

From the foregoing account it is manifest that the Arachnid character of Limulus is not obvious from its general form. Its affinities with the Arachnida were first described by Straus and Durkheim in 1829 and were based on the existence of an internal endosternite and the arrangement of the appendages around the mouth. The question was very fully investigated between 1881 and 1888 by Sir E. Ray Lankester, who found so close a resemblance between many organs of Limulus and the Scorpions as to leave no doubt of the truth of the relationship. Nevertheless, in some systems of classification the Eurypterida and the Xiphosura are still put together in a separate Class. There is no great justification for this. The chief differences between the Xiphosura and the other Orders of Arachnida are the presence of gills

and the absence of Malpighian tubules from the former, and both these features are related to an aquatic life.

Distribution

The Xiphosura are found in comparatively shallow water on the east coast of North America and Mexico from about 45° N. to about 20° N. (Fig. 14). In the east, the Order is represented by two genera, Tachypleus, which is widely distributed in

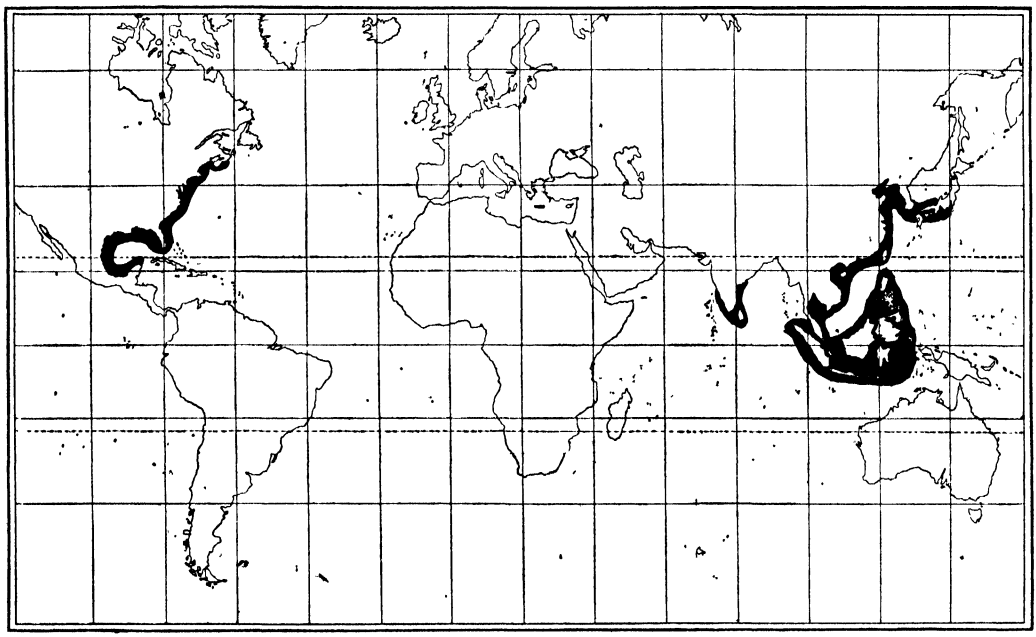


Fig. 14.—Map showing Distribution of the Xiphosura.

Malaysia and reaches the coasts of China and southern Japan, and Carcinoscorpius, which occurs on the shores of India, Bengal and Penang.

Classification

The Order consists of but a single family, with only a few living species, arranged as follows :

Family Xiphosuridæ	
Sub-family *Xiphosurinæ*.	Genus Xiphosura = Limulus.
Sub-family *Tachypleinæ*.	Genus Tachypleus.
	Genus Carcinoscorpius.

Some zoologists, however, include all species in one genus, Limulus.

The King-Crab remains to-day as the sole representative of Arachnida in the waters of the seas. Curious indeed is its outward form, so that it may well be said to eye

askance the occupants of other territories. Perhaps it is justified in its superiority, for it holds a proud position as a primitive animal, affording us clues to problems mysterious and perplexing.

Excursus III

The Arachnid Origin of Vertebrates

One of the major problems of biology, naturally of interest to man who counts himself a vertebrate, is the problem of the origin of the vertebrate phylum. Claims have been put forward for several groups to be considered as candidates for the honourable post of man's ancestors' ancestors, among them the Cœlenterata, the Annelida and the Arachnida. Nevertheless, the question cannot be said to be answered. The Arachnid hypothesis has, however, been so elaborately expounded that it deserves notice.

In any theory the first difficulty is the fact that the Invertebrata possess a ventral nerve cord and a dorsal alimentary canal, positions which are reversed in the Vertebrata. It will be remembered that in the Annelid theory of Dohrn [32], this was overcome by the assumption that the Vertebrate brain corresponds to the sub-œsophageal ganglion of the Annelid and that the mouth has migrated from a ventral to a dorsal position. On this assumption the erect Vertebrate is presenting not its front but its primitive dorsal surface to " a hostile and not incurious world."

Patten's [63] hypothesis of the origin of Vertebrates was founded on a study of the ancient fishes, such as Pterichthys, Bothriolepis and Trematapis. He substituted Arachnid for Annelid in Dohrn's argument and postulated a necessity for a reversal of surfaces in order to preserve the relative position of the internal organs. According to him these ancestral fish were still in the " Arachnid stage " and were swimming on their backs, but the stage of the reversal is obscure. In any case, the discovery that the pineal body was originally an eye makes the conception of surface reversal hard to accept. It would imply that the pineal eye looked downwards—a most improbable state.

This was followed by Gaskell's [36] well-known hypothesis. Discarding Amphioxus as degenerate, he began by taking the ammocœtes larva of Petromyzon, the lamprey, as the type of primitive Vertebrate and indicating its resemblances to the primitive Arachnida such as Limulus. The alimentary canal of the primitive Arachnid is assumed to have become the central nervous system of the Vertebrate, while the alimentary canal of the Vertebrate is a newly acquired formation derived from the branchial chamber of the Arthropod. Thus the infundibulum is the Arachnid œsophagus, the ventricles of the brain are the Arachnid stomach and the spinal canal is the Arachnid intestine. The underlying feature of this bold hypothesis is that there is no necessity for a reversal of surfaces.

Pursuing this line of thought, Gaskell finds many really remarkable analogies between his two types. He points out the homology between the branchiæ of Ammocœtes with those of Limulus and is led to derive the Vertebrate auditory apparatus from the flabellum. The uterus of the Arachnid is said to have produced the thyroid gland and the series of coxal glands give rise to the pituitary gland, thymus, tonsils and adrenal glands. The cartilage cells found in Limulus show that its skeleton had arrived both in structure and position exactly at the stage at which the Vertebrate skeleton starts. There are many other such parallelisms.

His general conclusion is that the Vertebrate arose from an ancestor which was not purely an Arachnid nor purely a Crustacean but partook of the characters of both. He adopts the term Protostraca invented by Korschelt and Heider to denote this primitive Arthropod group and believes it to have been the ancestor of the Crustacea, the Arachnida and the Vertebrata.

V

THE ORDER SCORPIONES

Scorpions

" Citra Cynamolgos, Æthiopas, lato deserta regio est, a scorpionibus et solpugis gente sublata."
PLINY.

Arachnida in which the prosoma is uniform and bears two median and six or ten lateral eyes, and the opisthosoma is divisible into mesosoma and metasoma, each of six somites. Pedicle absent; telson in the form of a poison-sting. Chelicerœ of three segments, small, chelate. Pedipalpi of six segments, large, powerful, chelate. Legs of seven segments, tarsi with three claws. Sternum triangular or pentagonal. Second mesosomatic somite bears a pair of characteristic pectines. Respiration by four pairs of lung-books on third to sixth opisthosomatic somites.

The **prosoma** of the Scorpions is uniformly covered with a hard cephalic shield or carapace, its width equal to or even greater than its length. A transverse groove not far in front of its posterior margin possibly marks one of the original somites, and a pair of lateral depressions in front of this may mark another, but there are no extensive traces of the primitive segmentation. There is also a median furrow in the middle of the carapace, running from behind the eyes to the posterior margin where it widens to form a triangular depression: this is an uncommon feature among the primitive Orders of the Arachnida.

The median **eyes** are placed close together on a low ocular tubercle usually some way from the anterior border of the carapace, but genera occur in which its position is either farther forward or farther back than the normal. The lateral eyes form groups of two, three, four or five small ocelli almost equal in size. A few Scorpions are blind. Although the eyes are outwardly similar they differ in development. The median eyes are derived from two layers of hypodermis and are therefore described as diplostichous; while the lateral eyes are monostichous and more closely resemble the eyes of Limulus.

The **cheliceræ** (Fig. 16) are of three segments. The first of these is ring-like and is concealed by the edge of the carapace; the second is somewhat longer, convex above and outside, coated with setæ on its inner surface and produced on this side into a pointed and toothed process. The third segment is the movable portion and is articulated to the second outside this process. Like the fixed process it is curved

and toothed, but it is rather longer and ends in two points between which the tip of the fixed process rests. The teeth with which these parts are provided are much used in classification.

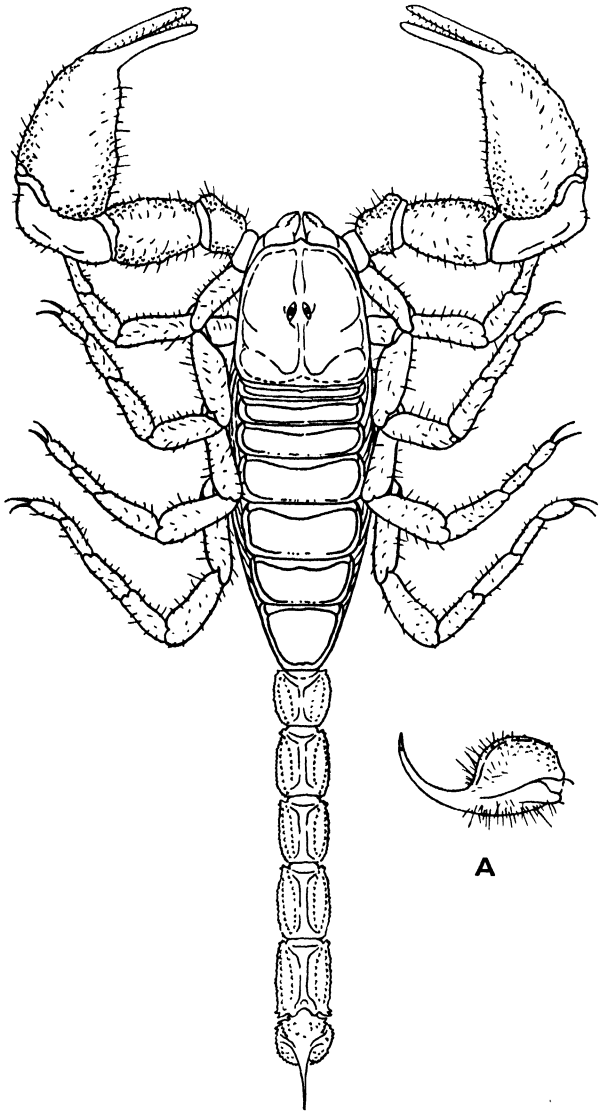


FIG. 15.—A Scorpion—Dorsal Aspect. [Species, *Buthus occitanus*, a Sudanese specimen, 1933.]

The **pedipalpi** are of six segments and are large efficient weapons, very characteristic of the Order.

The coxa is almost cubical and possesses no maxillary process ; the trochanter is also quite short. The third segment is long and when at rest lies directed backwards, parallel with the side of the carapace. The fourth segment lies at right angles

to the third, pointing outwards, and the fifth, making another right angle, points forwards. This penultimate segment is often very large ; it is continued on its inner side into a pointed toothed process, against which the freely moving sixth segment closes, repeating the plan of the chelicerae on a much larger scale. The edges of the forceps are provided with pointed tubercles, which may be regular or irregular in size and disposition.

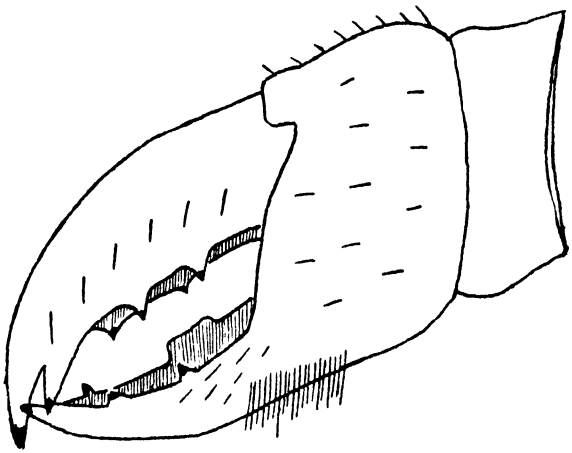


Fig. 16.—Chelicera of Buthus. Drawn from inside.

The **legs** are of seven segments : the first pair are the shortest and the fourth the longest. The coxæ are very large and in such close contact with one another that they form practically the whole of the lower surface of the prosoma. The two posterior pairs are immovable, but the first two pairs are movable and being provided with manducatory lobes form accessory mouth parts. The arrangement here is unique. The second coxa is the larger and more conspicuous ; it is subtriangular in form, the base of the triangle lying to the outside, somewhat indented where the trochanter articulates with it. On the fore-edge of the coxa near the apex of the triangle is a strong forwardly-directed blade or apophysis which, at its distal end, meets its fellow in the middle line. The first coxa is the smallest. It lies in the angle between the second coxa and its process and has a similar smaller process of its own which lies outside and close against that of the second (Fig. 17). Thus the mouth

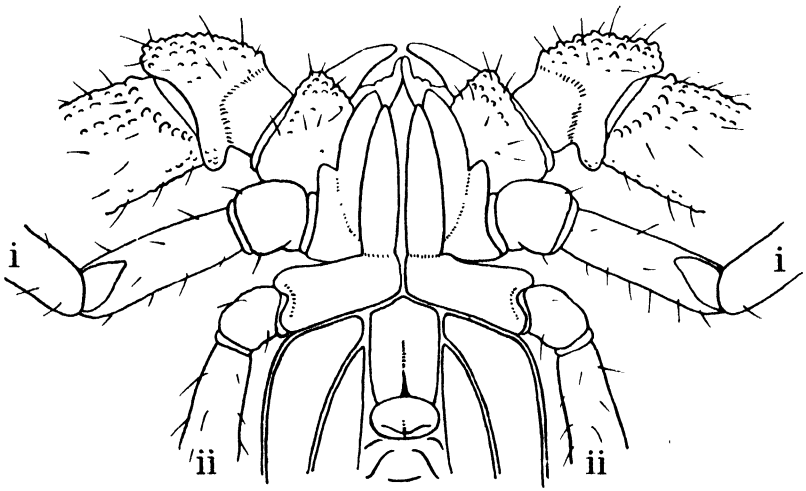


Fig. 17.—Diagram of Mouth parts of a Scorpion, showing the Coxal Processes of Legs i and ii.

is furnished with four blades from pedal coxæ, which slowly triturate the food as it is held in the cheliceræ.

The third coxæ resemble the second in shape, but they have no apophysis and are about twice as large. The fourth are even longer: they do not broaden so much towards their distal ends, which reach past the centre of the first abdominal sternite.

The remaining segments of the legs are normal in form: their homologies are discussed later (pp. 68–69). The tarsi bear two large curved claws (Fig. 18) without teeth, and below and between them is a third median smaller claw. Some of the segments before the last may bear spurs at their distal ends.

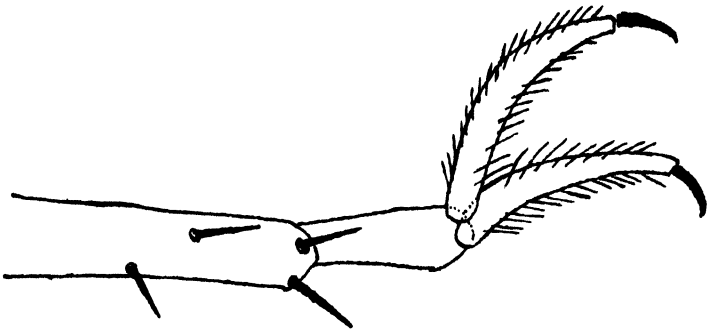


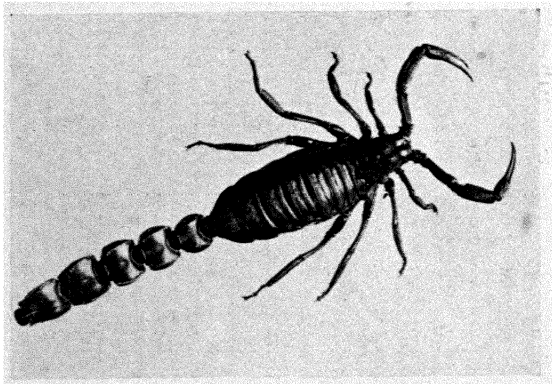
FIG. 18.—Tarsus and Claws of Scorpion. [Species, *Buthus occitanus*. A Sudanese specimen, 1933].

The **sternum** of all Scorpions is a very small plate between the third and the fourth coxæ. In some genera it is only a narrow transverse strip of chitin, in others it is a small triangular plate and in the rest it is pentagonal.

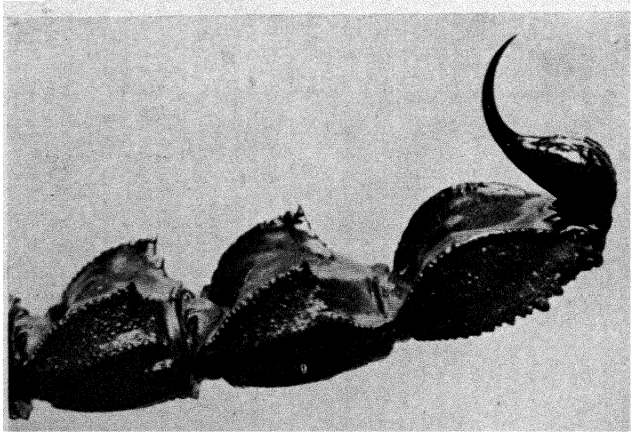
Close behind the sternum (Fig. 19) is the plate-like **genital operculum**, simple and inconspicuous, and immediately behind this, lying close to the fourth coxæ, are the **pectines.** These are peculiar appendages, quite characteristic of the Scorpions which have derived them from the first gill-books of Limulus. They appear to be special tactile or perhaps olfactory organs, although sexual and other rôles have been suggested for them. The back of the pectine is made of three pieces, the proximal part the longest and the middle one the shortest. The number of teeth is different in different species and varies from four to over thirty.

The **opisthosoma** is manifestly divisible into a mesosoma and a metasoma, each of six somites. The mesosoma has six tergites, of gradually increasing length and four wider sternites. The softer pleura between them have no sclerites and are much distended during pregnancy. The sternites bear the slit-like apertures of the gill-books, a pair of which belongs to each somite.

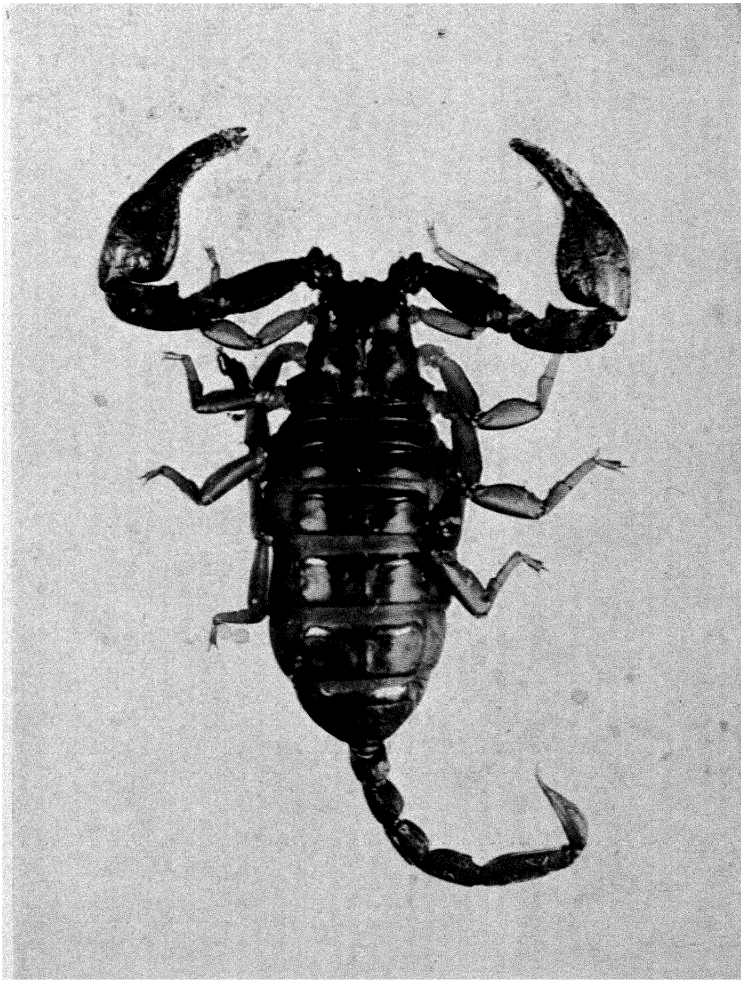
The first somite of the metasoma is conical in shape, with trapezoid tergites and sternites. This is followed by five subcylindrical somites of the scorpions "tail," in each of which tergite and sternite are united to form a complete ring of chitin. The upper side has a median groove, while the sides and lower surface bear a varying number of parallel longitudinal ridges of small spines. The last segment bears the



(i) *BUTHUS BICOLOR*



(ii) STING OF *BUTHUS BICOLOR*



(iii) *BUTHUS OCCITANUS*

PLATE III

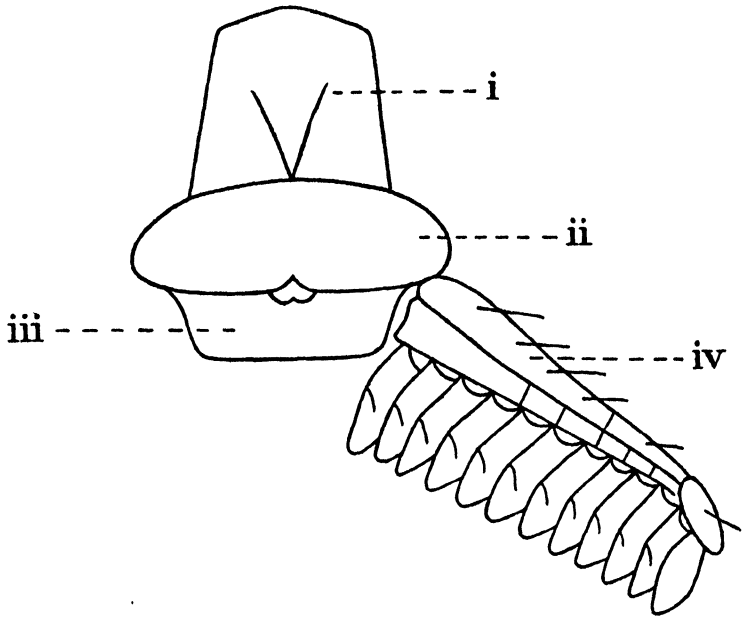


FIG. 19.—Sternum and Pectine of Euscorpius.
i. Sternum; ii. Genital operculum; iii. Sternite; iv. Comb.

telson, a bulb-like reservoir which contains the poison-gland and which is produced into the sharp curved point of the sting (see A, Fig. 15).

DISTRIBUTION

Scorpions are found only in the warmer parts of the world (Fig. 20). In the northern hemisphere they occur in the countries bordering the Mediterranean and in America reach on the west coast as far north as the 45th parallel. In the southern hemisphere they are widespread, but are absent from New Zealand, Patagonia and the oceanic islands.

The **Bothriuridæ** are mainly a South American family, but one genus, Cercophonius, is Australian. The typical genus, Bothriurus, is remarkable for a white patch of membrane on the poison-reservoir, just behind the base of the sting.

The **Scorpionidæ** are the largest family and are spread throughout the whole of the tropics. They include five sub-families. The Diplocentrinæ are a small mainly neotropical group, whose type, Diplocentrus, is Mexican and is also found in Texas and California. The Urodacinæ include the Australian genus Urodacus, with two lateral eyes, and the Hemiscorpioninæ are another small group peculiar to Arabia. Most of the species of the family, including the largest individuals, belong to the Scorpioninæ, which is widespread. The Ischnurinæ are found in both Africa and America and have sometimes been classified as a separate family, Ischnuridæ.

The **Buthidæ** are also widely distributed, and nearly half the American Scorpions

belong to this family. Most of these belong to the sub-family Centurinæ, which is typically western, but one familiar species, *Isometrus maculatus*, is now of worldwide distribution. As its name suggests it has a yellow body with a number of black spots, and is peculiar in that the tail of the male is twice as long as that of the female. It has travelled far hidden on ships and is even found on several islands where it has established itself. The other sub-family, the Buthinæ, is mostly an Old World group, but Ananteris is a small South American genus. The best known Scorpion, *Buthus occitanus* (= *europœus*), the common yellow Scorpion of the Mediterranean, belongs

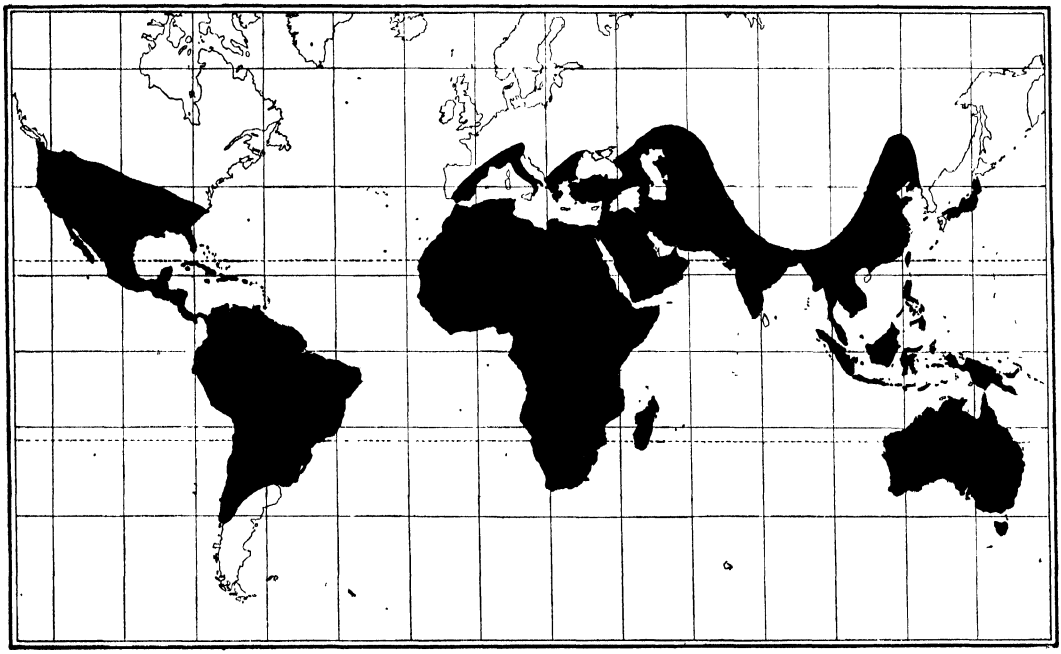


FIG. 20.—Map showing Distribution of the Scorpiones.

to this sub-family, as also does *Microbuthus pusillus* from Aden, which is only 13 mm. long and is the smallest Scorpion.

The **Vejovidæ** are a small family, mostly American where seven genera are found, but Jurus is Mediterranean and Scorpiops lives in India.

The **Chærilidæ** contain but one genus, Chærilus, from tropical Asia.

The **Chactidæ** are mainly an American family, but the well-known black Euscorpius is found in France, Corsica, Italy and Algiers. It is sometimes transported accidently to other parts, but unlike Isometrus fails to survive and establish itself in distant regions. This family also contains *Belisarius xambeni*, the blind Scorpion of the Pyrenees. The sub-family Megacorminæ is purely Mexican and the Chactinæ occur in South America and the West Indies.

Classification

The classification of this group, given in 1899 by Karl Kraepelin [52], in *Das Tierreich*, has never been superseded nor even seriously criticised. This divides all Scorpions into six families, separable by the following table. Lawrence [55], however, added a sub-family in 1928 to receive a South West African species, *Lisposoma elegans*.

TABLE XI

Separation of the Scorpiones into Families

1 (2).	Sternum longer than or as long as broad	3
2 (1).	Sternum of two transverse plates and thus much broader than long, sometimes scarcely visible	Bothriuridæ
3 (4).	Proximal end of tarsi with two stout spines sternum often pointed anteriorly	5
4 (3).	Proximal end of tarsi with one external spine ; sternum clearly pentagonal	Scorpionidæ
5 (6).	Three or five lateral eyes on each side	7
6 (5).	Two lateral eyes on each side, rarely none	9
7 (8).	Sternum triangular or rarely almost pentagonal ; often a spine beneath the poison-sting	Buthidæ
8 (7).	Sternum wide, with parallel sides and median depression ; three lateral eyes ; never a spine below poison-sting	Vejovidæ
9 (10).	Bright yellow spot behind the lateral eyes ; palpal claw with many lines of granulations	Chærilidæ
10 (9).	No spot behind lateral eyes ; palpal claw with but a single or a faint second line of granulations	Chactidæ

TABLE XIa

Sub-Families of the Scorpionidæ

1 (2).	With an obvious spine or tubercle under the sting	Diplocentrinæ
2 (1).	No such spine or tubercle.	3
3 (4).	Tarsus with rounded end, the edge of which forms an acute angle with the dorsal claw-lobes	5
4 (3).	Tarsus not rounded, forming a right angle with the dorsal claw-lobe	7
5 (6).	Tail with one median ventral ridge ; two lateral eyes on each side	Urodacinæ
6 (5).	Tail with two ventral ridges ; three lateral eyes on each side	Scorpioninæ
7 (8).	Carapace with median groove with Y-shaped fork anteriorly	9
8 (7).	Carapace without groove or fork	Lisposominæ
9 (10).	Tail with one median ventral ridge on all somites	Hemiscorpioninæ
10 (9).	Tail with two ventral ridges on the first four somites	Ischnurinæ

TABLE XIb

SUB-FAMILIES OF THE BUTHIDÆ

1 (2).	Proximal segment of tarsi of posterior legs with sharp spine	BUTHINÆ
2 (1).	Proximal segment of tarsi of posterior legs without spine .	CENTURINÆ

TABLE XIc

SUB-FAMILIES OF THE CHACTIDÆ

1 (2).	First four somites of tail with median granular ridge; whole of lower surface granular	MEGACORMINÆ
2 (1).	First four somites of tail with no ridge or with two ridges; lower surface smooth	3
3 (4).	Forceps of pedipalpi flattened; Old World . . .	EUSCORPIINÆ
4 (3).	Forceps of pedipalpi rounded or angular; New World .	CHACTINÆ

The Scorpion shares with the Crab the distinction of being the only Invertebrates among the Signs of the Zodiac. It had impressed itself upon the Ancients to this extent—and more, for the later " chastisement with Scorpions " has become proverbial. So essentially a creature of the East that a New World Scorpion seems almost an impossibility, it has acquired a rather unenviable reputation, albeit one that is not wholly deserved. The zoologist sees it as a somewhat primitive Arachnid, with much that is of interest in its structure and habits.

EXCURSUS IV

On Arachnid Venom

All the Arachnida are not venomous. Scorpions, Spiders and False-Scorpions are possessors of poison-glands, but the Solifugæ and Pedipalpi, which are generally accused of being poisonous, are not so, for they have no glands which could secrete a fluid of that character. Little or nothing is known of poisoning powers among the other Orders.

The paired poison-glands of the Scorpions are situated in the last segment of the post-abdomen, with two ducts which join just in front of the point of the sting. When a Scorpion strikes, muscles simultaneously squeeze the glands so that the fluid is forced into the wound. This reflex also occurs when the point of the sting is not embedded in any victim; the liquid is then ejected and has been shot over two feet in front of the animal. The venom may be artificially extracted for examination by electrical stimulation either of the living Scorpion or of its recently severed tail.

It seems to be established that some genera of Scorpions are more severely poisonous than others. The common European Euscorpius is harmless to man and the Mexican genus Vejovis is also without serious effect. On the contrary the stings of both the North African Buthus and the South American Centurus are dangerous and have brought death to children and others. In less serious cases the results of a Scorpion sting are usually pain of greater or less intensity in the neighbourhood of the wound and a temporary salivation. The pain usually disappears within twenty-four hours. As a general rule, warm-blooded animals are less susceptible to the effects of the poison than are the smaller creatures on which the Scorpion preys. The treatment of scorpion stings recommended by Mme. Physalix [67] includes the application of a ligature, removal of venom from the wound by suction and bathing the infected spot with very dilute calcium hypochlorite, potassium permanganate or 1% gold chloride solutions. Ammonia, alcohol and strychnine are without effect.

The bite of an ordinary Spider is not in general any more serious than the " bite " of a gnat, and usually results in no more than local irritation or pain with temporary swelling. The cheliceral poison of Epeira has been shown by Walbum and by Levy [57] to be a strongly alkaline fluid containing proteids, coagulating between 65° C. and 75° C. and soluble in water. It is less noxious to mammals than to arthropods. Spiders also resemble Scorpions in that some genera appear to be much more dangerous than others. Yet species which are as a rule harmless have occasionally been fatal to small animals and even to man.

There is little doubt that most of the serious results ascribed to Spiders' bites are really due to concomitant septicæmia. Bacteria may be carried into the body from the outside of the chelicerae and the worst cases are probably due to Streptococcus, perhaps *S. hæmolyticus*. Septicæmia so caused may even be fatal and such cases are known for wasp stings and various insect " bites." These observations would of course apply to Scorpions as well as to Spiders and in occasional instances the same type of fortuitous infection may give the bites of Solifugæ and Pedipalpi an appearance of venom.

But again there are Spiders whose bites are undoubtedly dangerous because of the secretion itself. The most important of these are certainly the various species of the genus Latrodectus, which have so long been known and so widely been feared as to have received popular names. There is the " black widow " of America and Australia, which is *Latrodectus mactans*, the " katipo " of New Zealand, *L. scelio* the " vancho " of Madagascar and the " malmignatte " of Corsica. The bites of these Spiders, which belong to the family Theridiidæ, are always dangerous and sometimes fatal to horses, camels and men. Dr. Bogen [21] has lately described fifteen cases of " arachnidism " treated at Los Angeles General Hospital. The symptoms were pain in the legs and abdomen, extreme abdominal rigidity, a high blood pressure and high temperature. The remedies prescribed were warmth and large doses of opiates.

Butler reports that since 1926 seven fatal cases of Spiders' bites have been

recorded in Australia. Some of these were due to Latrodectus; one at least was caused by a trap-door Spider, *Euctimena tibialis*.

In the Argentine a dangerous Spider, *Glyptocranium gasteracanthoides*, locally known as the Podadora, inhabits the vine-growing districts. Workers gathering grapes may get bitten in the hand, or in the foot when the Spider has dropped to the ground. The bite becomes inflamed and swollen, and takes from six to ten days to heal. Fatal cases have been known in which the patient was bitten in the throat and death was due to suffocation and septicæmia.

Chelonethi are presumably able to inflict a poisonous bite, for their pedipalpi contain poison-glands in many species. In some there is a gland in the metatarsus and another in the opposed tarsus, but either or both these glands may be absent. The poison-ducts open just below the tip of the last tooth, but the Chelonethi are so small that their bites are dangerous only to their even smaller prey.

VI

THE ORDER PEDIPALPI

Whip-Scorpions

" Quæ deletas potuit componere Thebas
Phryne, tam multis facta beata viris."

Propertius.

Arachnida in which the prosoma is uniform or has the posterior somite free, and is joined by a pedicle to the segmented opisthosoma. Telson of few or many segments present, except in Amblypygi. Chelicerœ of two segments, unchelate, without poison-gland. Pedipalpi normally large chelate weapons, with trochanterial processes and tibial apophyses. Sternum of three segments, elongated. First pair of legs used as tactile organs, with many-jointed tarsi. Ambulatory legs with two claws. Respiration by lung-books. Sexual dimorphism slight. Ommatoids of unknown function and odoriferous glands at extremity of opisthosoma.

The **prosoma** of the Pedipalpi is covered by a uniform carapace except in the family Schizonotidæ, in which the segments bearing the third and fourth pairs of legs are separate from those in front of it. The carapace is elongated in the sub-Order Uropygi and heart-shaped in the sub-Order Amblypygi. In the family Schizonotidæ a pointed beak or epistome projects in front.

This opening paragraph clearly illustrates one of the main features of the Order Pedipalpi : it is far less homogeneous than is the rule in the other Orders of Arachnida. In a description of the general structure of an Arachnid Order, it is usually possible to give an accurate impression of the facts, occasionally qualified by mentioning some rare exception. But in the Pedipalpi, it is almost always necessary to mention the condition in the two sub-Orders separately, and often to refer to the family Schizonotidæ as well. In fact the curious position exists that in many ways the sub-Order Amblypygi more closely resembles the Order Ricinulei than its own congener the Uropygi. This seems to point to the necessity for a reclassification, but no authority has done this and indeed to redistribute the Orders now would produce far more confusion than the slight gain in accuracy could justify.

In the Amblypygi, which are also known as Phrynes, there are two median or direct **eyes** with a group of three indirect eyes on each side, eight in all, as in the Araneæ ; the Thelyphonidæ have either eight or twelve, that is to say the lateral

groups consist of five indirect eyes, and in the Schizonotidæ there are either no eyes or mere eye-spots, without a smooth lens and therefore incapable of functioning as organs of true vision, representing the positions of not more than two lateral eyes.

The **cheliceræ** are composed of two segments and are not chelate (Fig. 24).

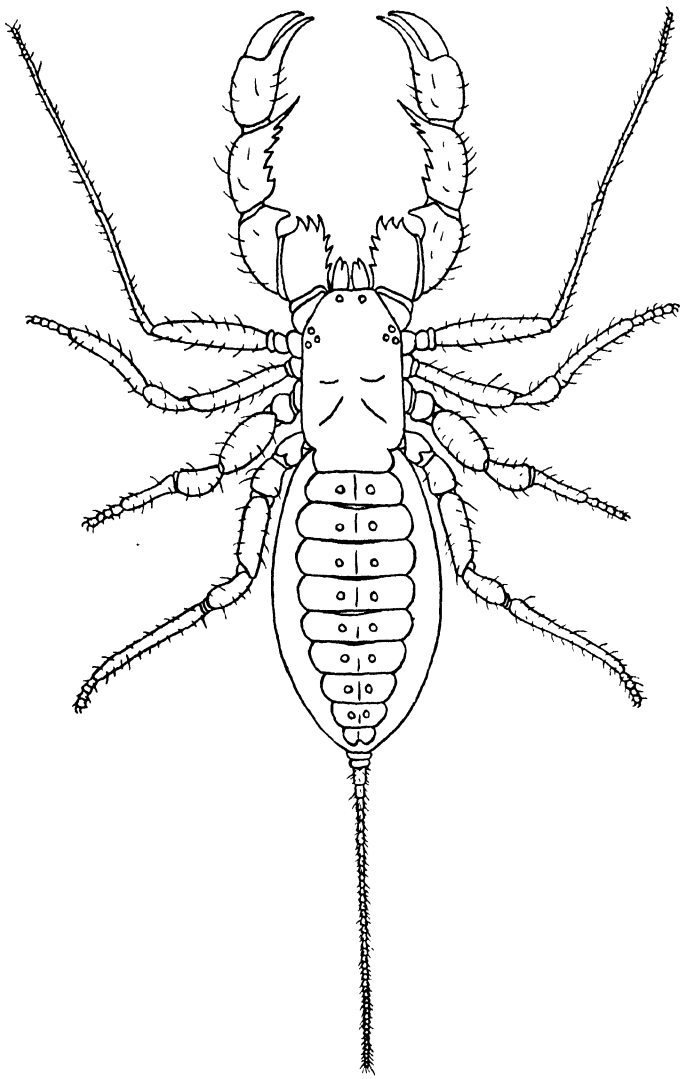


FIG. 21.—Uropygi—Dorsal Aspect. [Species, *Thelyphonus insularius*.]

The proximal segments lie parallel to each other and possess a certain amount of longitudinal freedom as well as the ordinary lateral freedom. They are thus far more loosely set than is customary. The second segment is a downwardly moving point of hard chitin, whose work is assisted by spines at the distal end of the first

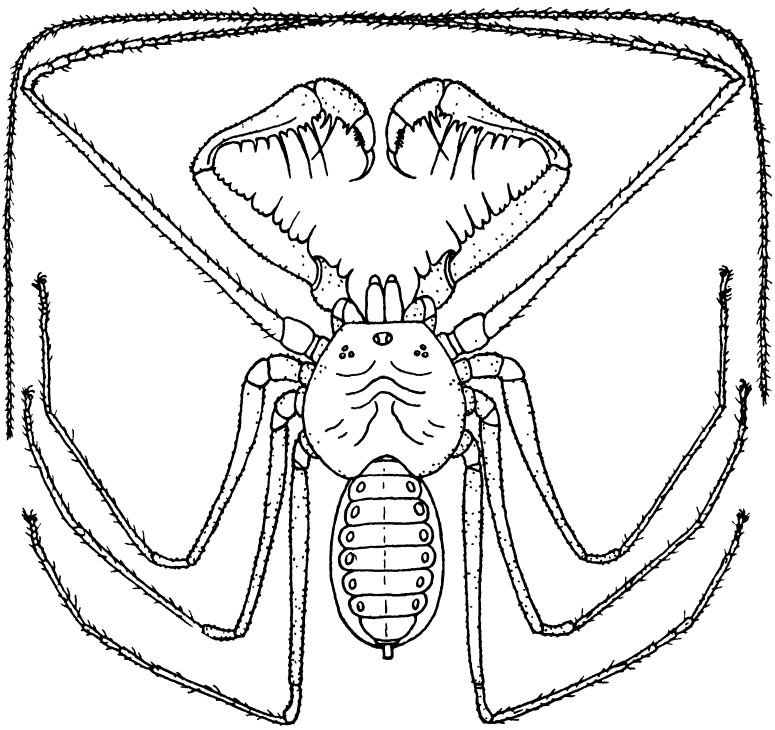


FIG. 22.—Amblypygi—Dorsal Aspect. [Species, *Stygophrynus dammermani.*]

joint. These appendages therefore closely resemble the cheliceræ of Spiders, but they have no poison-glands within.

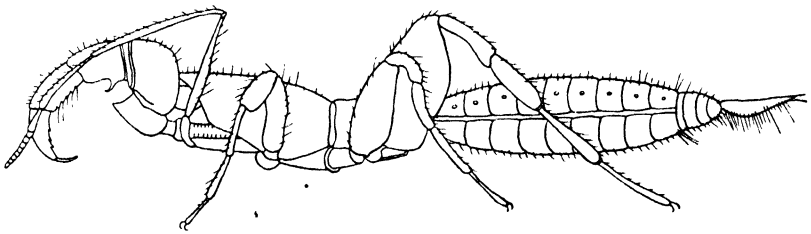


FIG. 23.—Schizonotidæ—Lateral Aspect. [Species, *Nyctalops crassicaudata.*] After O. Pickard-Cambridge.

The **pedipalpi** are powerful limbs of six segments, save in the Schizonotidæ. In the Thelyphonidæ their coxæ are fused below the mouth and thus they have no masticating function. In place of this, each trochanter has a large semicircular process on its inner side armed with several sharp teeth: these processes can be pressed upon each other or they can be opposed to the femora by bending the coxo-femoral articulation and thus are well adapted to crushing the prey (Fig. 25). The tibia also has a conspicuous toothed process at its distal end on the inner side, against

which the metatarsus closes and the metatarsus ends in a " fixed finger " on its inner side with the tarsus closing against it on the outer side. The tarsal segment is much longer than the metatarsal process, so that the terminal chela is not as exact as in most Arachnida, and the existence of virtually two pairs of forceps on each pedipalp is characteristic. In the Tarantulidæ the pedipalpi are not chelate, but end in sharply-pointed tarsi, and the coxæ, which are movable, have masticatory endites.

The **legs** of the anterior pair are not used for walking, but are held stretched out in front as tactile organs. They are composed of six true segments, but the tarsus is

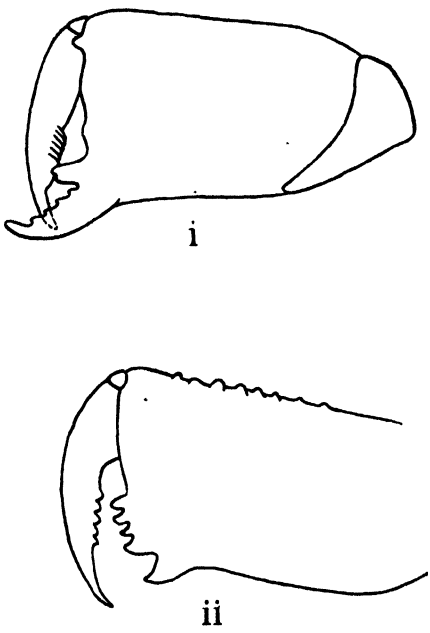


FIG. 24.—Cheliceræ of Pedipalpi. After Kästner.
i. Uropygi; ii. Amblypygi.

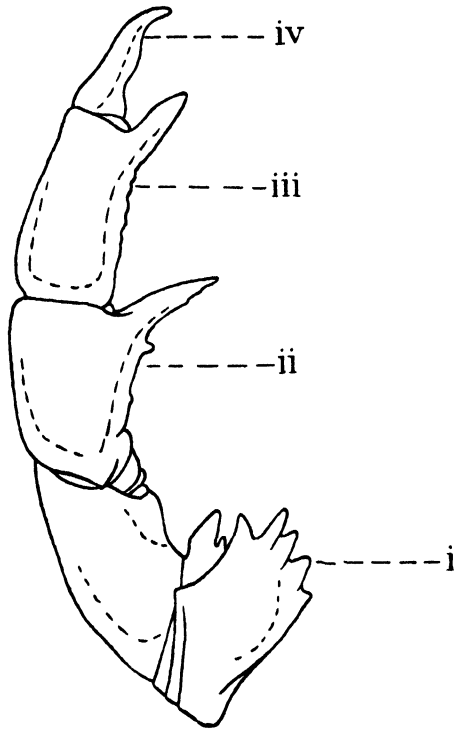
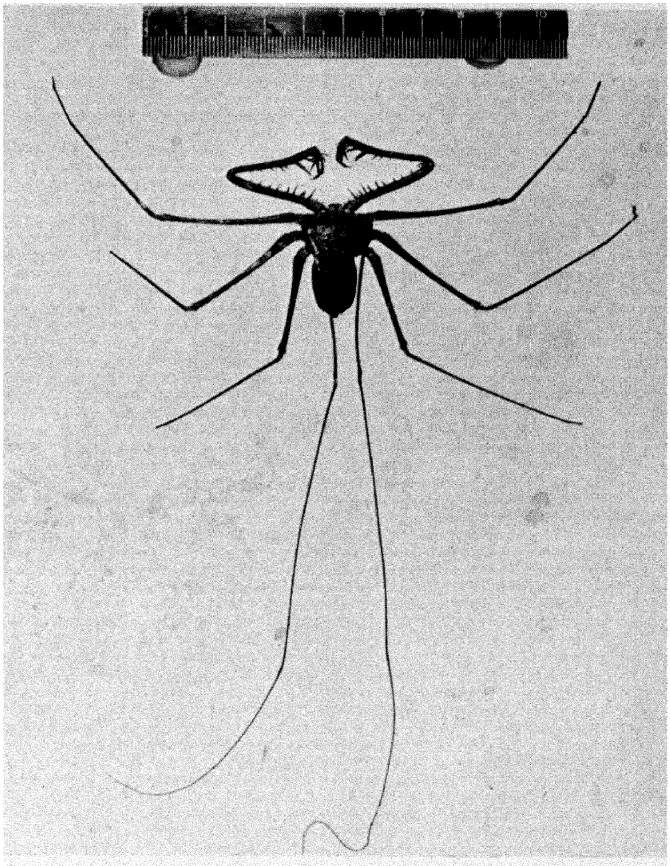
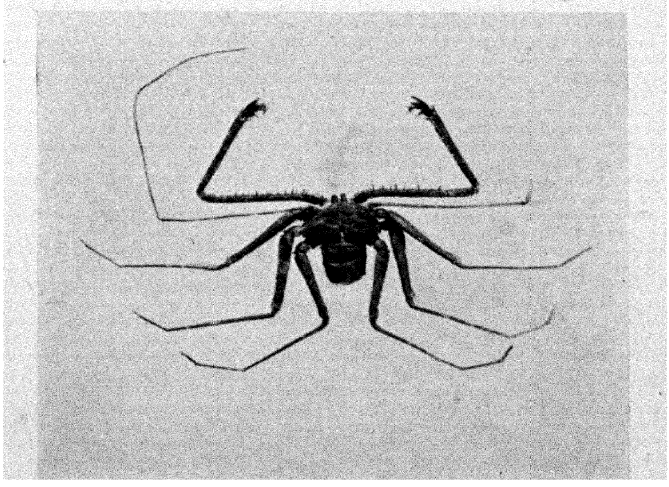


FIG. 25.—Pedipalp of Thelyphonus. After Graveley.
i. Trochanter; ii. Tibia; iii. Metatarsus; iv. Tarsus.

made of nine segments in the Thelyphonidæ and many more in the Tarantulidæ. It forms a delicately sensitive whip-like termination to the limb. In females of Thelyphonus these tarsal segments are swollen or variously modified in other ways. The true ambulatory limbs have seven segments and the tarsus is composed of three parts. The coxæ are so close to the middle of the body that they are invisible from above. The other segments are very freely jointed to each other so that the leg has a wide range of movement and in this respect shows several close resemblances to the legs of Spiders. In the Tarantulidæ the tarsi bear pulvilli between the paired claws which enable the animal to climb vertical surfaces: in the other groups there are three claws.



(i) *STEGOPHRYNUS*



(ii) *PHRYNUS*

The Pedipalpi possess a **buccal cavity** in front of the true mouth or opening into the pharynx. In the Uropygi the sides and floor of this chamber are formed by the palpal coxæ and the roof by a small upper lip and the cheliceræ. In the Amblypygi the coxæ of the palpi are farther apart and the floor is formed by the forward prolongation of the first sternal plate.

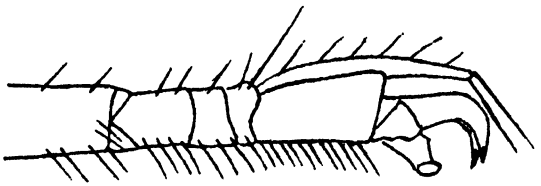


FIG. 26.—Tarsus of Pedipalpi. [Species, *Charon grayi*.] After Kraepelin.

The **sternum** is composed of three pieces. In the Thelyphonidæ the first and third of these are large and sub-triangular, and the second is a very small plate between the third coxæ. In the Tarantulidæ the elements are more equal in size and the first is produced forwards to form a spear-shaped labial process between the palpal coxæ.

A narrow pedicle joins the prosoma to the opisthosoma in all the families of this Order. The **opisthosoma** is oval or elongated in shape and always retains its segmentation. In the Thelyphonidæ there are nine broad somites followed by a post-abdomen of three narrow somites. The last of these is cylindrical in shape and bears a many-jointed telson to which the common name of Whip-Scorpion is due. In the Schizonotidæ the narrowing of the last three somites persists, but the telson is short and is either unjointed or ended by a small knob (Fig. 27). In the Tarantulidæ the

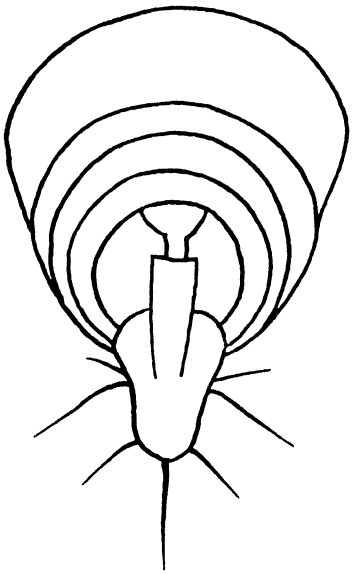


FIG. 27.—Telson of Nyctalops. After O. Pickard-Cambridge.

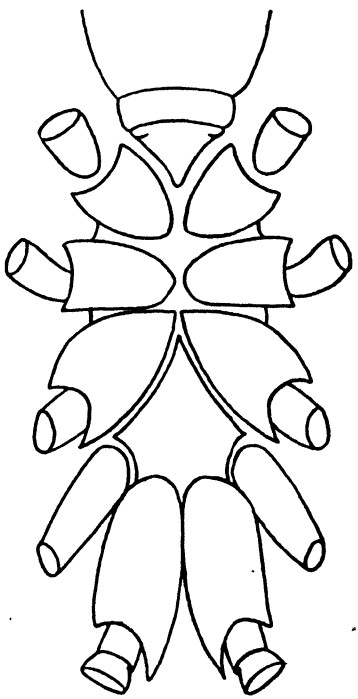


FIG. 28.—Schizonotidæ—Ventral Aspect. [Species, *Nyctalops crassicaudata*.] After O. Pickard-Cambridge.

opisthosoma has nine tergites only. The posterior margin is rounded and there is no telson.

The lower surface of the opisthosoma is also segmented and is protected by separate sternites. The first of these is large and consists of the first two joined together. The genital orifice is situated just behind it and it bears two pulmonary stigmata leading to the lung-books. Two more lung-books open behind the second sternite. The last somite bears two or four white patches to which the name ommatoids has been given, based on a belief that they may be sensitive to light, but their true nature and function is really unknown. In the opisthosoma are two glands which open at orifices near the anus. When the animal is irritated they emit a secretion which smells of acetic and formic acids.

Distribution

The Pedipalpi are purely tropical Arachnida, whose range is much the same as that of the Scorpiones. No Pedipalpi, however, are found in Europe or even in North Africa. The two sub-Orders are very differently distributed. The Uropygi are found in two separate areas in America, namely the southern States of North America and the north-eastern portion of South America (Fig. 29). They are absent from Africa, but appear again in India and in the extreme eastern parts of Asia, as well as in Japan and Malaya. This sub-Order includes the largest species. The Amblypygi on the contrary occupy a continuous area in America (Fig. 30), the bulk of which is in South

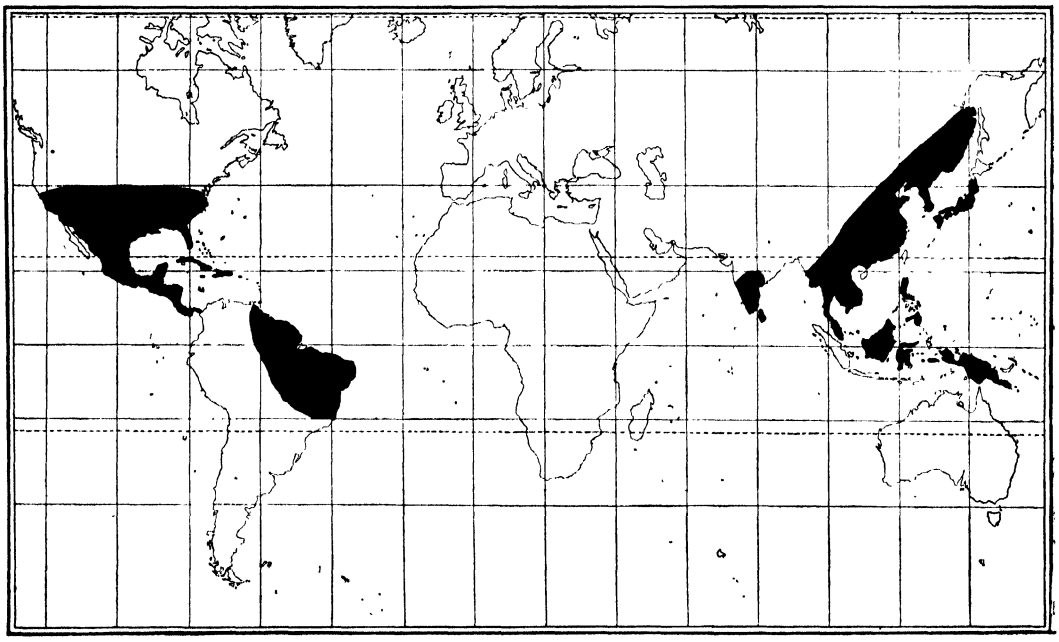


Fig. 29.—Map showing Distribution of the Uropygi.

America, are widespread in South Africa and are found in India, Borneo and New Guinea. They do not, however, accompany the Uropygi to the eastern Asiatic coast. They live on rocks and in caves, and often enter houses. The small family Schizonotidæ is found in Venezuela, tropical Africa and Asia, especially in Ceylon. They are small species, four to eight millimetres long, and live among stones and vegetable matter.

Pedipalpi, like Spiders, are liable to accidental dispersal and a few examples of these erratics have been recorded. They do not, however, appear to have been able to establish themselves in Europe. Simon once found a Tartarid, *Schizomus crassi-*

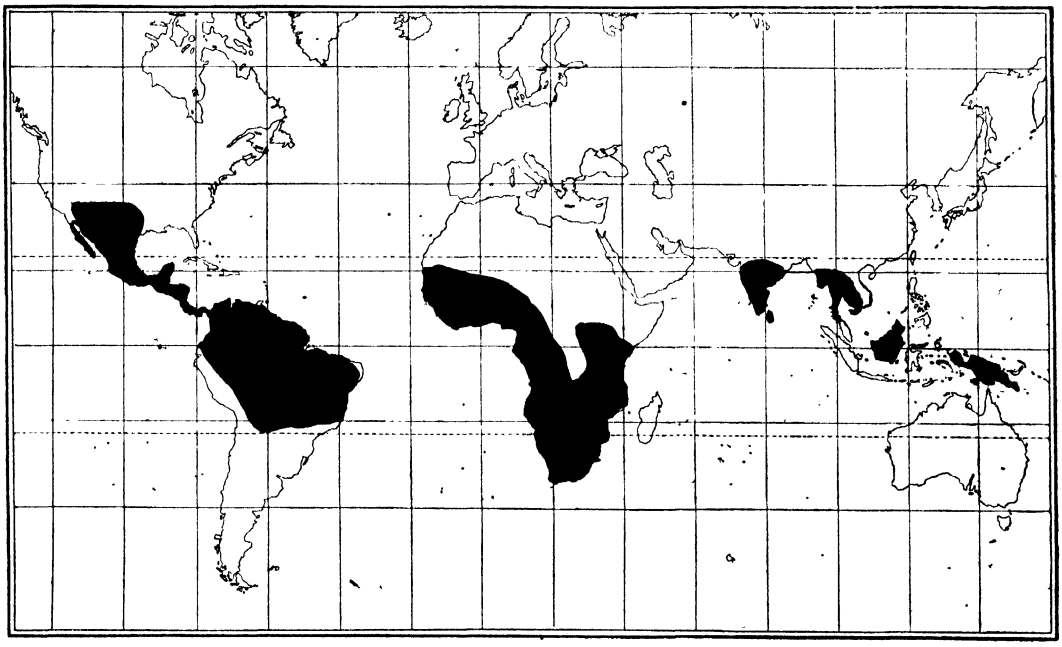


Fig. 30.—Map showing Distribution of the Amblypygi.

caudatus, a native of Ceylon, living in the Paris Museum. In 1909 Jackson [48] figured a new species of the same group, *Trithyreus bagnallii*, several females of which had been found in Kew Gardens.

Classification

The Pedipalpi are divided into three families, frequently grouped into two very distinct sub-Orders. The classification, like that of the Scorpiones, has been accepted without modification by all zoologists for the past forty years, save that occasionally the sub-Orders have been disregarded. The differences between the families are so pronounced that their separation is comparatively simple.

TABLE XII

SEPARATION OF THE PEDIPALPI INTO FAMILIES

1 (4).	Prosoma longer than broad with parallel sides; last three opisthosomatic somites modified into a cylindrical tube bearing a telson	UROPYGI (2)
2 (3).	Prosoma unequally divided into one large and two small plates, telson of one to three joints, with or without terminal knot .	SCHIZONOTIDÆ
3 (2).	Prosoma uniform, telson, long and many-jointed . . .	THELYPHONIDÆ
4 (1).	Prosoma broader than long with curved sides; posterior opisthosomatic somites rounded; telson absent; tarsi of many segments, very long and thin	AMBLYPYGI (5)
5.	Only one family	TARANTULIDÆ

Before leaving the subject of classification, it may be of interest to quote the slightly more elaborate division which has recently been used by Kästner [50*b*].

ORDER PEDIPALPI

SUB-ORDER UROPYGI

Tribe Schizopeltidia = Tartarides
Family Schizomidæ (2 genera)
Tribe Holopeltidia = Oxypœi
Family Thelyphonidæ (10 genera)

SUB-ORDER AMBLYPYGI

Family Tarantulidæ = Phrynidæ
Sub-family *Phrynichinæ* (2 genera)
Sub-family *Tarantulinæ* (4 genera)
Sub-family *Charontinæ* (8 genera)

TABLE XIIA

SUB-FAMILIES OF THE TARANTULIDÆ

1 (2).	Spear-shaped labial process of prosternum broadening at base into a flat plate; meso- and metasternum broader than long Sub-family	PHRYNICHINÆ
2 (1).	Labial process only slightly thicker at base; meso- and metasternum small, quadrate or longer than broad	3
3 (4).	Tarsi without pulvilli; American . . . . Sub-family	TARANTULINÆ
4 (3).	Tarsi with pulvilli; Asiatic . . . . . Sub-family	CHARONTINÆ

EXCURSUS V

Limb-Segments in the Arachnida

A certain degree of confusion exists in the names applied to the segments or joints of the legs in the Orders Pedipalpi, Scorpiones and Palpigradi. The problem

is a dual one. In some instances it is merely the use of a different word to describe the same thing, as for example the alternative of prætarsus or transtarsus to describe the extreme terminal portion of a limb. This is quite immaterial and not worth comment—indeed, an opinion of the place of logomachy in Science has already (p. 41) been expressed.

In other instances there is a divergence of opinion as to the category to which a segment really belongs. For example, the fourth segment of the Scorpion's leg is named the "tibia" by Kraepelin [52] and the "patella" by Petrunkevitch [66]. This is a more serious problem. A solution could be reached only by a rather lengthy discussion of the exact meaning of each of the words applied to leg-segments, and would involve a discussion of the internal musculature and also a comparison with other Classes of the Arthropoda. This extremely interesting piece of work is, it must be admitted, disproportionate to the design and scope of this book. The solution seems to be that the most useful purpose will be served if the existing nomenclature be tabulated so that divergences are made evident. This may help to reduce the confusion that otherwise is likely to arise.

TABLE XIII

LEG-SEGMENTS IN THE ARACHNIDA

	1	2	3	4	5	6	7	
SCORPIONES	Coxa Coxa Coxa	Trochanter Trochanter Trochanter	Femur Femur Femur	Tibia Tibia Patella	Tarsus i Metatarsus Tibia	Tarsus ii Protarsus Metatarsus	Tarsus iii Tarsus Tarsus	Kraepelin Birula Petrunkevitch
PEDIPALPI Legs 2–4	Coxa Præcoxa	Trochanter Transcoxa	Femur Femur	Patella Patella	Tibia Tibia	Basitarsus Co-tibia	*Tarsus* *Tarsus*	Börner Hansen
UROPYGI . Leg 1	Coxa Præcoxa	Trochanter Transcoxa	Femur Femur	Patello-tibia Patella		Basitarsus Tibia	*Tarsus* *Co-tibia* *Tarsus*	Börner Hansen
AMBLYPYGI Leg 1	Coxa Præcoxa	Trochanter Transcoxa	Femur Femur	Patella Patella	*Tibia* *Tibia*	*Basitarsus Tarsus* *Tarsus*		Börner Hansen
PALPIGRADI Legs 2–4	Coxa Præcoxa	Trochanter Præfemur	Femur Femur	Patella Patella	Tibia Tibia	Basitarsus Co-tibia	Tarsus Tarsus	Börner Hansen
PALPIGRADI Leg 1	Coxa Præcoxa	Trochanter Præfemur	Femur Femur	Patella Patella	Tibia Tibia	*Basitarsus* *Co-tibia*	*Tarsus* *Tarsus*	Börner Hansen

Segments in italics consist of two or more portions.

VII

THE ORDER ARANEÆ

Spiders

" Post ea, discedens, succis Hecateïdos herbæ
Spargit, et extemplo tristi medicamine tactæ
Defluxere comæ, cumque his et naris, et auris ;
Fitque caput minimum, totoque in corpore parva est ;
In latere exiles digiti pro cruribus hærent ;
Cetera venter habet : de quo tamen illa remittit
Stamen, et antiquas exercet aranea telas."

Ovid.

Arachnida in which the prosoma is uniform, bears not more than eight eyes and is joined by a pedicle to the opisthosoma. Opisthosoma usually unsegmented, bearing not more than four, usually three pairs of spinnerets. No telson. Chelicerœ of two segments, moderately large and unchelate, containing a poison-gland. Pedipalpi of six segments, leg-like, tactile in function. Sternum present, usually ovoid. Legs of seven segments, tarsi with two or three claws. Respiration by lung-books or tracheœ or, normally, both. Pedipalp of male modified as intromittent organ.

The **prosoma** of the Araneæ is protected by a uniform shield without much trace of segmentation beyond a groove, not always present, which separates a cephalic from a thoracic region. Upon the thoracic portions are usually indentations, a median fovea and eight radial striæ, pointing towards the legs. These depressions mark the internal attachments of the muscles of the " sucking stomach " and of the legs. The ocular region is sometimes darker than the rest, and the separate name of clypeus is usually given to that part of the prosoma between its anterior edge and the first row of eyes. The clypeus of Spiders is never distinctly separated, but it corresponds to the cucullus of the Ricinulei. Occasionally an elevation of the ocular region carries the eyes, or some of them, in a prominent position, sometimes exaggerated into a remarkable form.

The **eyes** are simple ocelli, the cornea of which is but a portion of the cuticle shaped to form a lens and free from setæ and pigment. The majority of Spiders have eight eyes but a number have six only. The genus Tetrablemma has four eyes and the genera Nops and Matta but two. Cave-dwelling Spiders of the genus Anthrobia have no eyes. In many Spiders it is obvious that the eyes are of different types, for some appear black and others pearly-white or yellow.

The **cheliceræ** consist invariably of two segments. The first, or paturon, is normally a stout conical part, which in a few families carries a smooth condyle articulated on the outer edge of its proximal end. This is something of a mystery ; it might be a vestigial exopodite (but see p. 34). The outside of the lower edge is provided with a rake or rastellus of stout teeth in those families which dig burrows. The inner

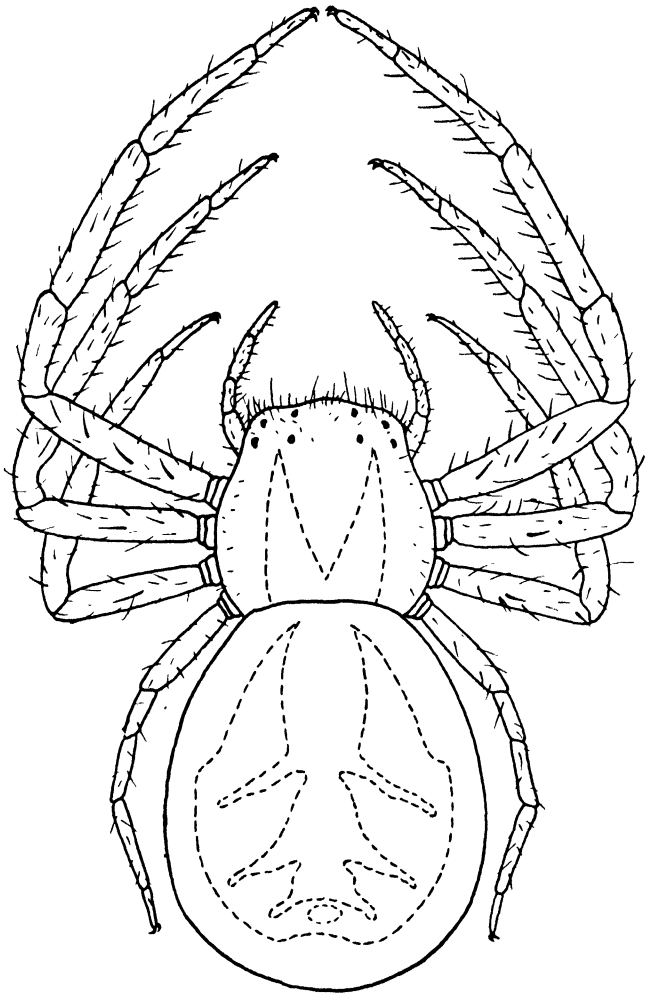


FIG. 31.—A Spider—Dorsal Aspect. [Species *Xysticus cristatus* ; a Malvern specimen, 24.vii.34.]

edge of the paturon sometimes bears a small nipple-like tuber, called the mastidion, of unknown significance. The outer edge is sometimes corrugated with a series of ridges, which form a stridulating organ.

The second segment, or unguis, is a pointed piece of very hard chitin, slightly curved. Its concave edge is grooved and finely toothed on the inside. Near the tip is the orifice of the duct of the poison gland.

The **pedipalpi** consist of six segments. The coxa carries a maxillary lobe, except in the most primitive sub-Orders, which has a compressing, masticatory function. The femur is sometimes used in stridulation. The remaining segments are used by young and female spiders as tactile organs, but in the mature male the tarsus is

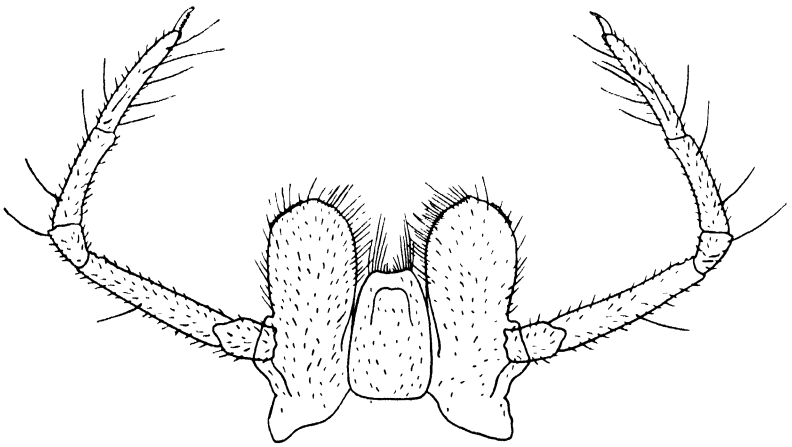


FIG. 32.—Lip, Maxillæ and Pedipalpi of Female Spider. [Species, *Tegenaria atrica*, a Malvern specimen, 1923.]

modified to form an intromittent organ. The male palpal tibia is usually shorter than that of the female, and it often carries on its outer side a short process or apophysis, which, in mating, is fitted into a groove in the female epigynum.

The **male palpal organ** lies near the tip of the tarsus in a cavity, the alveolus. In its simplest form it consists of a coiled tube, or receptaculum seminis, of three

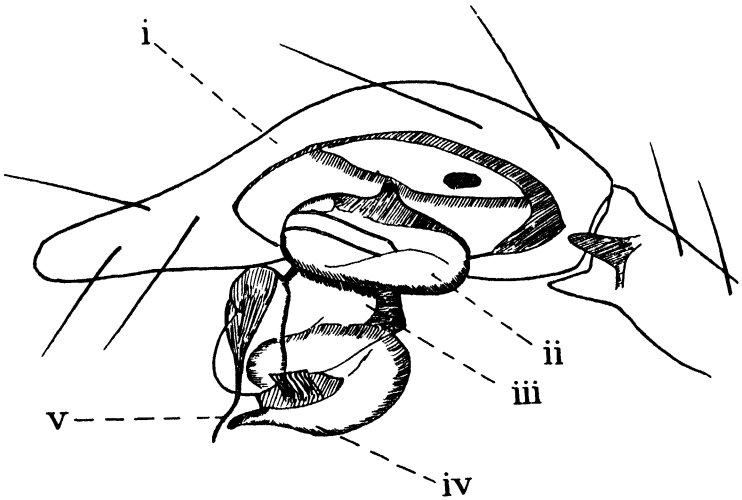


FIG. 33.—Pedipalpal tarsus of Male Spider, showing Palpal Organ expanded by boiling in Caustic Potash. [*Tegenaria atrica*: a Cornish specimen, 8.viii.1912.]
i. Cymbium; ii. Fundus; iii. Reservoir; iv. Embolus; v. Conductor.

parts. These are a basal or proximal swollen bulb, the fundus, an intermediate reservoir, and, distally, a dark elongated ejaculatory duct.

The first advance from this simple condition is the migration of the whole genital bulb to the lower side of the tarsus and an increase in the size of the alveolus. The tarsus thus becomes more or less cup-like and is often renamed the cymbium. At the same time the palpal organ becomes divisible externally into three regions, containing the fundus, reservoir, and duct respectively. The apical division is usually called the embolus.

In the next stage the embolus becomes divided into two. One of these is the ejaculatory duct or embolus proper, the other, called the conductor, protects it when the organ is at rest (Fig. 33). The tarsus, too, is sometimes divided into two parts, the smaller of which is called the paracymbium.

In the most complicated type of palpus there are elaborations of these parts consisting chiefly in the addition of blood-cavities or hæmatodochas, protecting rings of chitin and extra apophyses. Its numerous variations form a valuable means of characterising the males of every species.

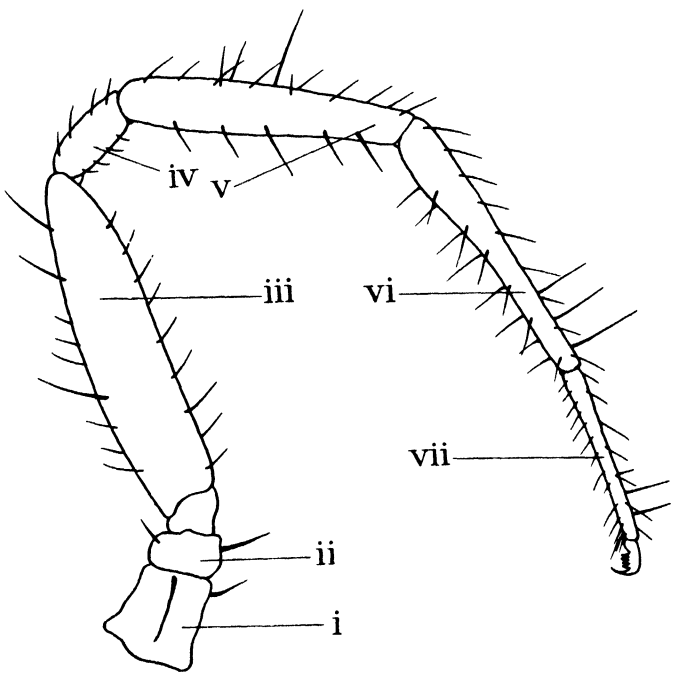


FIG. 34.—Leg of a Spider (Xysticus).
i. Coxa; ii. Trochanter; iii. Femur; iv. Patella; v. Tibia; vi. Metatarsus; vii. Tarsus.

The legs are always composed of seven segments (Fig. 34). The coxæ lie round the sternum and never exercise a masticatory function. The femora of some male trap-door Spiders have small hooks on their inner surfaces. These are a protective device used in mating, when the male spider thrusts them against the cheliceræ of

the female, gagging her temporarily and reducing the risks to himself. The tarsi carry the paired claws which terminate the legs of all Spiders. Sometimes an extension of the tarsus, the empodium, extends between the paired claws, either as a pad or as a bearer of adhesive hairs or as a third, median, claw.

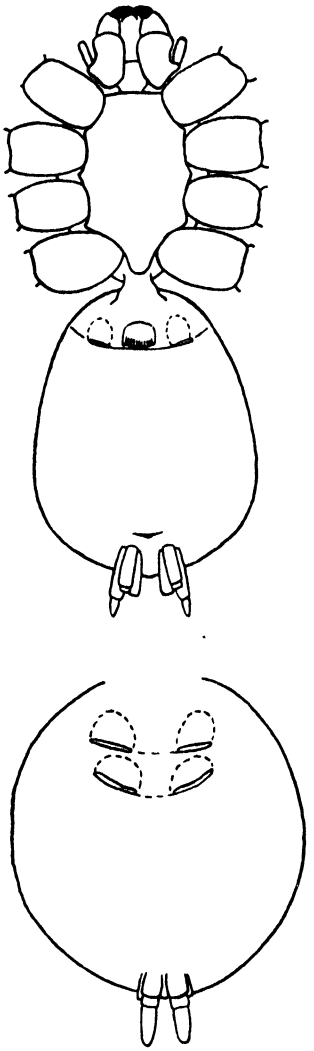


FIG. 35.—A Spider—Ventral Aspect. [Species i. *Dysdera cambridgii*; ii. *Atypus affinis*, with 4 lungs.]

The claws, whether two or three in number, are very hard and sharply pointed, curved and set with a row of teeth on the inside of the curve. Nielsen [6] has recently described his observations of the action of the claws and claw-tufts on the threads of the web. He finds that the set of the claws gives a twist to the thread and that the claw-tuft forms a springy pad which releases the claw as the Spider runs. In this unexpectedly elaborate way the Spider escapes entanglement. The first leg is often but not always the longest, but only rarely is it held outstretched in front of the Spider. In many male Spiders it is decorated with tufts of hair and with black or coloured patches, which are displayed before the female during courtship.

The underside of the prosoma is formed by two unequal plates of chitin, the **sternum** and the **labium.** The latter lies between the maxillary lobes of the palpal coxæ and is of various shapes, square or elongated, semicircular or oval. Directly above it is a flattened cone of tissue, the rostrum. Below the rostrum is a chitinous plate, the epipharynx, and above the labium is a similar, corresponding plate, the hypopharynx. The epipharynx is marked with a longitudinal groove, the stomodæum, up which the liquid food rises into the œsophagus, partly by surface tension, partly by the sucking action of the stomach within.

The **sternum** is oval or heart-shaped, slightly convex and generally marked on each side by four bays or acetabula, which receive the coxæ of the legs. Like the carapace, the sternum represents a number of fused segments, and Giltay [38] has reported the existence in certain young specimens suitably fixed of three transverse striations dividing it into four sternites. But this appearance cannot be seen in any adult.

The **opisthosoma** of the Araneæ is normally a more or less elongated cylindrical sac, with no trace of segmentation. Sometimes it has no pattern, but often there is a longitudinal dorsal mark lying above the heart, as well as small depressed points due to internal muscle attachments. Sometimes there is an elaborate and even a beautiful

pattern, and sometimes the shape is strangely modified into bizarre and fantastic forms. Segmentation persists in the small sub-Order Liphistiomorphæ, where a number of chitinous tergites and sternites protect the abdomen above and below. In some families an unsegmented dorsal plate is also found.

The under-side of the opisthosoma shows more features than the upper. The region near the pedicle is more convex than the rest and is called the epigastrium : it is separated by the epigastric furrow. Two lung-books or the two anterior lung-books in four-lunged spiders lie in the epigastrium and are conspicuous as pale patches.

The **genital orifice** lies in the middle of the epigastric furrow. In the male the vas deferens has a very small aperture, difficult to discern, and unprotected by any epiandrium. The oviduct of the female has a larger aperture, in close association

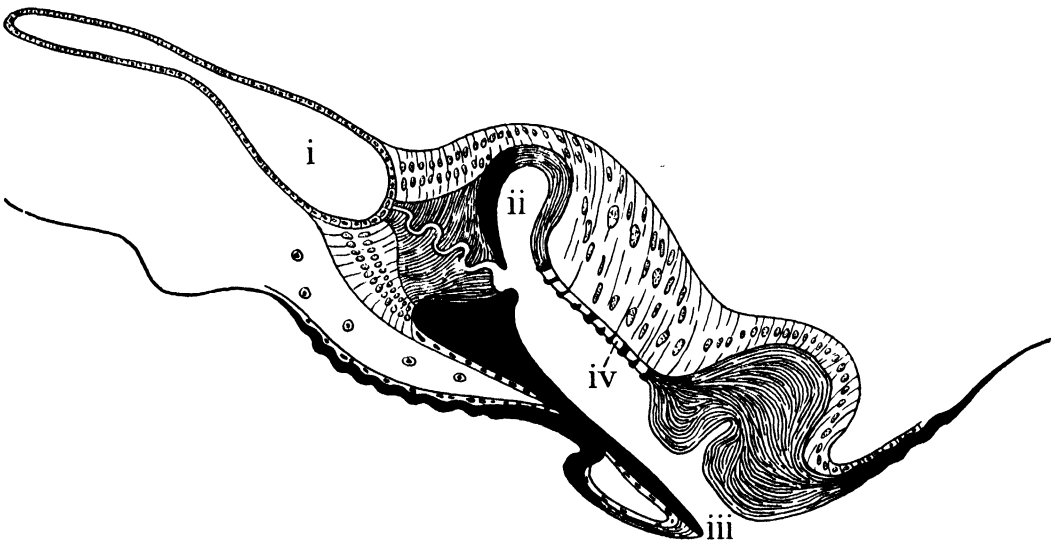


FIG. 36.—Section through the Genital Orifice of a Spider. [Species *Holocnemus hispanicus*.] After Wiehle.
i. Uterus internus ; ii. Receptaculum seminis ; iii. Vagina ; iv. Perforated plate of chitin.

with the single or paired openings of the spermathecæ, the whole surrounded by a complex epigynum (Fig. 36). In this, the actual vulva is protected by an operculum, the scape, and in the most elaborate forms there is a downward projection from the anterior side of the scape, called the crochet or clavus. This is occasionally accompanied by a second, posterior, process, the parmula : the two together act as a short ovipositor.

In many Spiders, but not in the Mygalomorphæ, nor in those possessing a cribellum, there is a small pointed appendage just in front of the spinnerets. This is the **colulus.** It is probably without function, being merely derived from the spinnerets by degeneration.

Behind the spinnerets a small tubercle, not always very obvious, carries the anus at its tip. This is sometimes called the **anal tubercle,** sometimes the post-abdomen.

It is a vestigial structure, representing the remains of the last seven of the twelve opisthosomatic somites.

The only opisthosomatic appendages persistent in the adult Spider are those of the fourth and fifth somites, where they function as the spinning organs, namely,

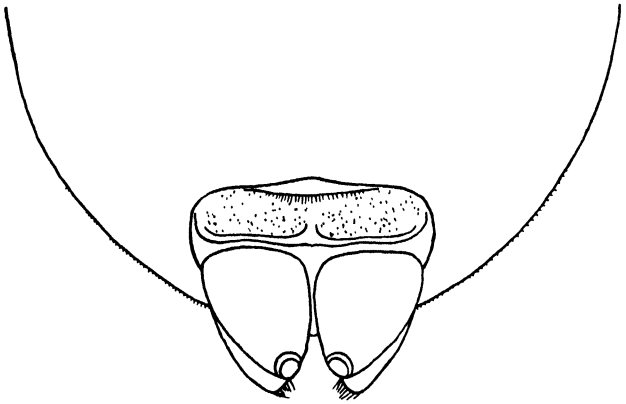


FIG. 37.—Cribellum and Spinnerets of the Spider, Amaurobius. [Species, *A. ferox*, a Malvern specimen. 21.xii.27.]

the **cribellum**, when this is present, and the six **spinnerets** (Fig. 37). The cribellum represents the endopodites of the fourth somite, the exopodites of which are the anterior or superior spinnerets. The small middle spinnerets are the endopodites of the fifth, and the exopodites of this somite are the posterior or inferior spinnerets.

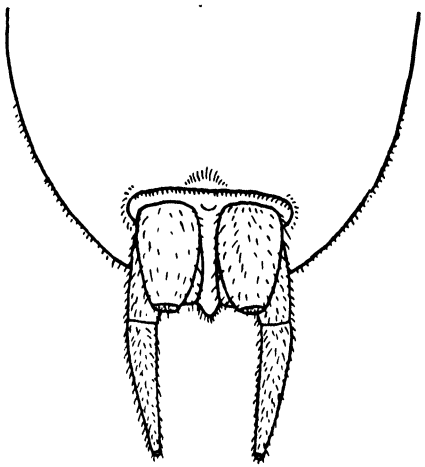
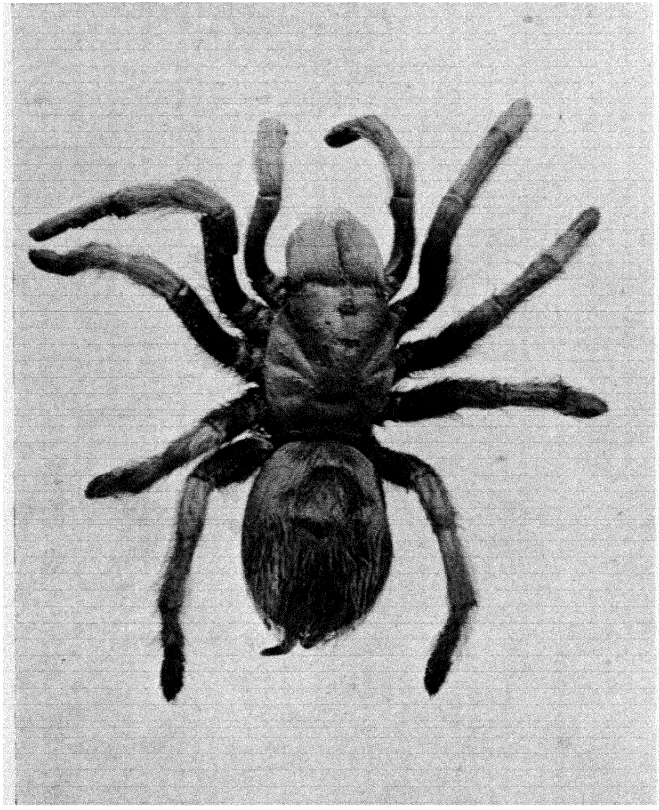


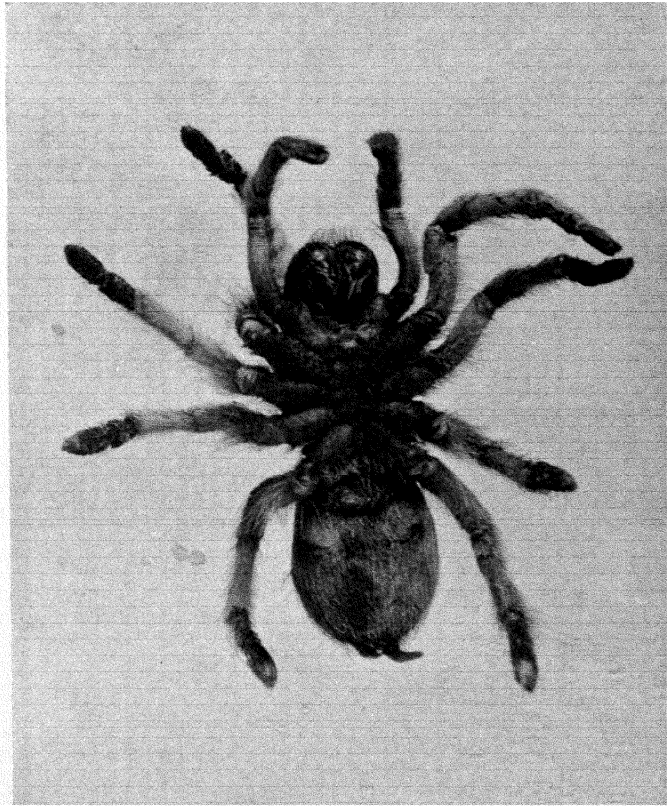
FIG. 38.—Spinnerets of *Agelena labyrinthica*. [A Hampshire specimen, viii. 28.]

The number of spinnerets is not constant. In the Liphistiomorphæ the primitive number, eight, is found, occupying the middle of the ventral surface, but only the four exopodites are said to be active. In most Mygalomorphæ there are two pairs and in exceptional instances only one pair. The relative lengths of the spinnerets in different families are also variable, and seem to be related to the method by which the silk is distributed. Where a sheet-web is made and the opisthosoma is swayed from side to side, the anterior spinnerets are very long (Fig. 38).

The spinnerets are not the actual tubes through which the silk is secreted. The tip of a spinneret is covered with a number of minute tubes, through which the fluid silk passes. The smallest of these are called spools and are numerous. Those on the anterior spinnerets produce the attachment disc or transverse sweep of short threads which anchor a Spider's line to the ground and those on the posterior spinnerets



(i) Dorsal View



(ii) Ventral View

EURYPELMA HENTZII

PLATE V

produce the broad ribbon or swathing band which is wrapped round a victim. The larger tubes or spigots produce the drag lines and foundation lines of the web ; also the soft wadding found in egg cocoons and the viscid fluid which makes the spiral thread of a web adhesive.

The cribellum is an oval plate found just in front of the anterior spinnerets in certain families. It is perforated with a large number of minute pores, each of which

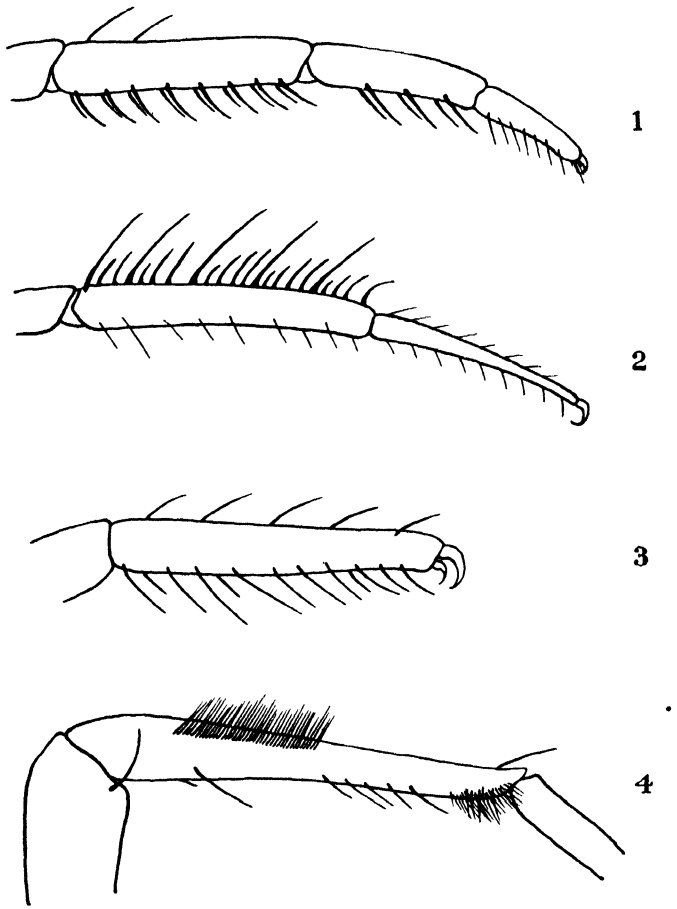


Fig. 39.—Leg Spines of Spiders.

1. Zora spinimana ; 2. Ero furcata ; 3. Tarsal comb of Theridion ; 4. Calamistrum of Amaurobius.

is the orifice of the duct from a gland. The cribellum produces a broad strip of silk composed of some hundreds of threads. This is combed out of the cribellum by the calamistrum (Fig. 39 (4)) on the fourth metatarsus and laid upon the plain silk strand which the spinnerets are simultaneously producing. The effect is to render the threads more adhesive ; it also gives them a characteristic bluish appearance.

The **sense organs** of Spiders include the spines or setæ with which their bodies and legs are covered, and the lyriform organs. Probably all the **setæ** on a Spider are

more or less developed as sense organs, but some of those on the legs are useful accessories to the spinning organs. On examination it is easy to distinguish at least three different kinds. The most conspicuous are the stout sharp spines on the legs and pedipalpi, generally described as tactile. The most difficult to distinguish, even under the microscope, are the long delicate acoustic setæ, believed to be receptors of sound waves. Intermediate between these extremes are many others, vaguely termed protective, and found in different forms, some club-shaped, some spatulate, some branched and some like smaller spines. In many cases Spiders of a particular family are characterised by a special arrangement of leg-spines (Fig. 39). The so-called acoustic setæ are situated on the upper surface of the leg segments, either alone or in a series (Fig. 34).

The **lyriform organs** are found on the legs, palpi, cheliceræ and elsewhere on the body of Spiders as well as on other Arachnida, but not on Acari, Solifugæ or Scorpions. They present the appearance of patches composed of ridges of chitin supplied internally with a branching nerve. It has been contended that these are scent organs and the work of McIndoo [61] supports this. If they are not scent organs they must be considered as a mystery.

Many spiders are also provided with **stridulating organs** in different parts of the body. These consist in general of a tooth (or teeth) which rubs against a series of hard ridges and the relatively moving parts may be found on the prosoma and opisthosoma, on the cheliceræ and pedipalpal femur, on the legs and pedipalpi or on the legs and pulmonary opercula. In many species these stridulating organs are confined to the male, being absent from or rudimentary in the female. Usually they do not produce a note audible to human ears, but there are exceptions to this and some spiders buzz like bees or purr like cats. The use of the organs is unknown.

Distribution

The **Liphistiomorphæ** are composed of two extinct families and one recent one. This includes but nine species, interesting because they are the most primitive

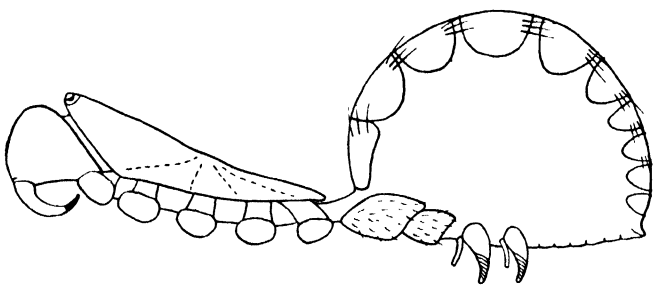


Fig. 40.—*Liphistius batuensis*. [Specimen from Batu Caves, Selangor, Malaya, 1922.]

living Spiders (Fig. 40). Spiders of this sub-Order were dominant in Palæozoic times, but their surviving descendants are limited to a relatively small area in

Eastern Asia (Fig. 41), where they live some in caves, some on hills and some in the jungle. They make silk-lined burrows, closed with a trap-door. Our knowledge of this important group has lately been summarised and increased in an excellent monograph by Dr. Bristowe [24*c*].

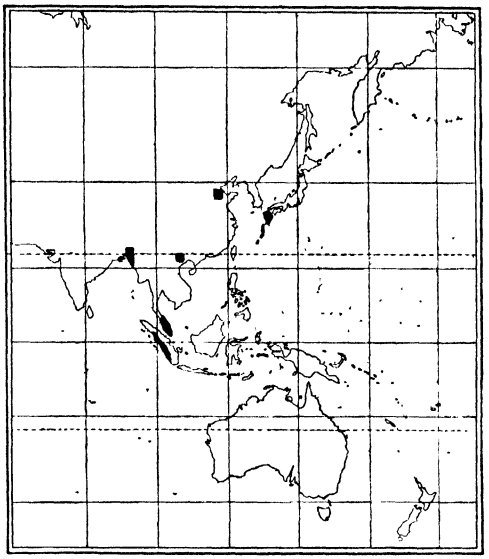


FIG. 41.—Map showing Distribution of the Liphistiomorphæ.

The **Mygalomorphæ** include the "Trap-Door Spiders" or "tarantulas" of America. They are generally large Spiders with a squarish prosoma and eyes on a small ocular prominence. Their cheliceræ, like those of the Liphistiidæ, are so articulated that they strike vertically downwards, piercing their prey in two parallel directions from above. The proximal segment is in many species provided with a rake or rastellus used in excavating the burrow. The pedipalpi are long and leg-like, and there are two pairs of lungs. In most genera there are four spinnerets. The Mygalomorphæ include wandering species which hunt their prey, others which dig holes in the ground and close them with

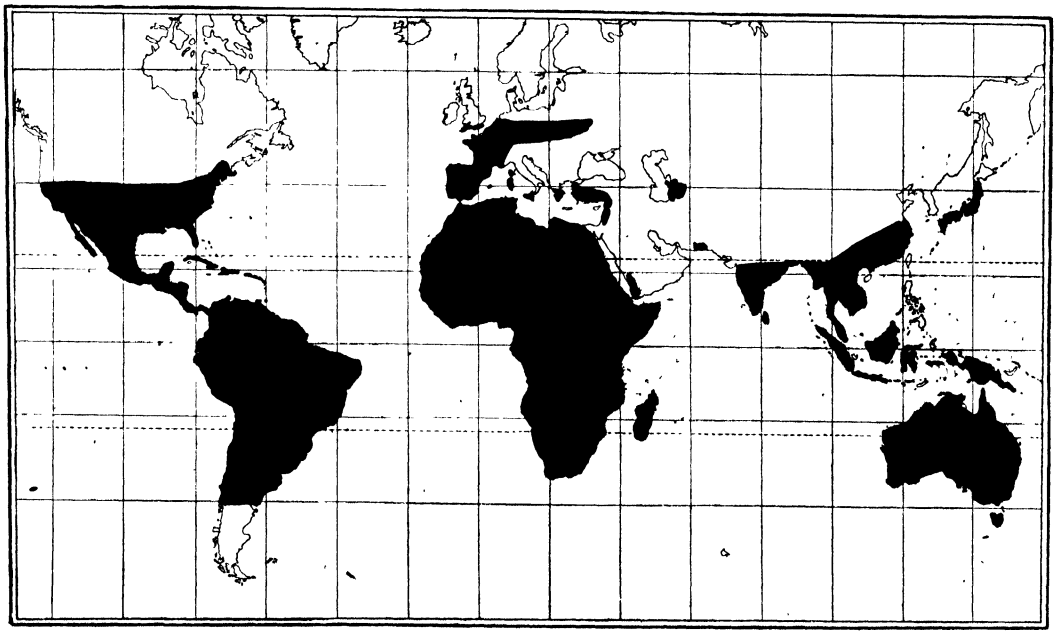


FIG. 42.—Map showing Distribution of Mygalomorphæ.

trap-doors, and others which spin silk tubes above the ground or make a web similar to that of the Agelenidæ.

The family Atypidæ, which includes the British *Atypus affinis*, is the only one found in temperate regions. The Paratropididæ from the Amazon and the Pycnothelidæ from Brazil are also small families. The rest are of wider range. The Migidæ are found in South Africa, Madagascar and New Zealand. They do not burrow, but make perfectly concealed silk tubes on tree-trunks. The Theraphosidæ are the " bird-eating Spiders," the typical hunters of the sub-Order, and include the largest known species in the genera Theraphosa from New Guinea, Eurypelma and Avicularia from America.

The **Hypochilomorphæ** contain only the family Hypochilidæ, with but two species, *Hypochilus thorelli* from North Carolina and Tennessee, and *Ectatosticta davidi* from China. Their systematic position has been a matter of some doubt, for they possess two pairs of lung-books, a characteristic of the Mygalomorphæ, but in no other way are they related to this sub-Order. They possess six spinnerets and a cribellum, and in many ways their structure shows primitive features. It seems to be undoubtedly best to put them in a sub-Order of their own.

The **Apneumonomorphæ** include three somewhat aberrant families, the Telemidæ, Caponiidæ and Symphytognathidæ. The Telemidæ are small cavernicolous spiders. The genus Telema includes the blind species *Telema tenella* from the Pyrenees ; the other genus, Apneumonella, has eyes, and lives in East Africa.

The Caponiidæ include barely a dozen species. The genus Caponia is found in South Africa and Caponina in South America. From South America and some of the adjacent islands comes the genus Nops, peculiar in the possession of two eyes. The Symphytognathidæ include the remarkable Spider *Symphytognatha globosa*, described by Hickman, from Tasmania, in 1931. In this Spider the pedipalp of the female consists solely of the coxal segment with its gnathobase, a reduced condition almost without parallel in the Arachnida.

The **Dipneumonomorphæ** include the bulk of the world's Spiders in all regions and in Petrunkevitch's latest system is divided into forty-nine families in three branches.

The ten families of the *Quadrostiatæ* include three which have six eyes, the Dysderidæ, Segestriidæ and Oonopidæ. These are relatively primitive families, whose web, if they make a web, is a bell-mouthed tubular retreat. The Dysderidæ have a peculiar sternum, which overlaps the coxæ of the legs, and the Oonopidæ often have a hard plate or scutum covering the dorsal surface of the opisthosoma. The Argyronetidæ include but one species, the Water-Spider, *Argyroneta aquatica*, familiar in Europe and northern Asia. The Hahniidæ are characterised by the peculiar arrangement of their spinnerets which form a transverse line across the hind edge of the opisthosoma. The Anyphænidæ are a large family ; the others are all small and of local or very discontinuous distribution.

The thirteen families of the *Dionychæ* are in general Spiders which wander in search of their food. The Zoropsidæ and Acanthoctenidæ are, however, small families of chiefly African and American localities, and possess a cribellum and a short calamistrum. Five families are large and of cosmopolitan distribution. Of these the Drassidæ and Clubionidæ represent the wandering mainly nocturnal species, the Thomisidæ and Sparassidæ are flattened " Crab-Spiders " which lurk hidden in crevices or, concealed by protective coloration, lie in flowers waiting for visiting insects, and the Attidæ are large-eyed Jumping-Spiders, particularly numerous in the Tropics, which can see and leap upon their victims at a distance of several inches. The other families are only small groups.

The *Trionychæ* include nine cribellate families, of which the Amaurobiidæ and Dictynidæ are the most widespread representatives in temperate regions. The Eresidæ have a quadrangular prosoma very similar in shape to that of the Attidæ, and the Uloboridæ are of great interest since they spin orb-webs, similar to those of the well-known Garden-Spider. The Aracheidæ are most peculiar: the caput is much raised in front and the cheliceræ articulate far above the pedipalpi. Living forms are rare but exactly similar curiosities have been found " fossilised " in Baltic amber.

The Mimetidæ are well-characterised by the spinal armature of their legs, the Hersiliidæ by their long tail-like spinnerets and the Pholcidæ by their elongated narrow bodies and very long legs.

Three families of this group are huntsmen, the Oxyopidæ, Pisauridæ and Lycosidæ, which pursue their prey and trust to speed to catch it. The last two are numerous and very widely distributed.

The Agelenidæ are a large family, spinning the ordinary cob-web, a tubular resting-place the lower edge of which is continued into a wide hammock, held by threads above and below.

Finally there are the three largest families, the Theridiidæ, characterised by a comb of setæ on the tarsi of their fourth legs, small Spiders spinning an irregular maze of threads among leaves, the Linyphiidæ, including an enormous number of tiny Spiders, often without pattern, which spin a sheet of web and live upside-down, hanging from its lower surface, and the Epeiridæ or Argiopidæ, whose web is the familiar orb-web. All these Spiders are spread throughout the world.

The number of species of Spiders is very great—Berland estimates it at 50,000 —and many times greater than that of any other Order of the Arachnida.

Classification

The early methods of classifying Spiders, which have now only an historical interest, were first superseded by the amazing industry and genius of Eugene Simon [12], who, recognised for many years as the supreme authority on this matter, pro-

duced the system to which all modern methods must acknowledge their debt. In outline this system was as follows:

Sub-Order Araneæ theraphosæ	3 families
Sub-Order Araneæ veræ	
Section Cribellatæ	8 families
Section Ecribellatæ	
Sub-section Haplogynæ	6 families
Sub-section Entelegynæ	24 families

The first alternative system, due to Friedrich Dahl [31] in 1906, was based on the arrangement of leg-spines, and has not established itself. During recent years seven systems have been proposed, as follows:

1. A. Petrunkevitch in *Ann. N.Y. Acad. Sci.* 1923.
2. L. Giltay in *Bull. Soc. Ent. Belg.* LXVI. 1926.
3. T. H. Savory in *A.M.N.H.* XVIII. 1926.
4. A. Petrunkevitch in *Systema Aranearum.* Conn. 1928.
5. K. Kishida in *Lansania.* Tokyo. 1930.
6. L. Berland in *Les Arachnides.* Paris. 1932.
7. A. Petrunkevitch in *Trans. Conn. Acad. Arts. Sci.* 1933.

The first of Petrunkevitch's papers was widely recognised as a conspicuous advance in taxonomy; it divided the Order into three sub-Orders with fifty-six families. The methods of Giltay and myself were attempts to carry Petrunkevitch's work a step farther, and to bring the classification into closer agreement with the probable phylogeny by introducing named divisions between the sub-Order and the family. This was, in fact, adopted by Petrunkevitch in his later work.

Kishida's system gave new names to the sub-Orders and increased the size of the Liphistiidæ. Berland's was a return to Simon's method of grouping together all the Spiders which possess a cribellum.

In Petrunkevitch's notable work *Systema Aranearum*, all the 2,144 genera then established were for the first time brought together, arranged in the same sub-Orders as before, the families being grouped together in branches. His most recent system was noteworthy because it was based on a study of internal structure and not merely on external form. The revelations of the microtome included important variations in the number of cardiac ostia and in the form and number of the tracheal tubes, so that as a result the Order is now split into five sub-Orders, the families of which are grouped in intermediate branches. These branches especially depend on internal structures only determined by dissection, so that they cannot conveniently be used in the ordinary dichotomic tables intended for identification.

The classification is as follows:

ORDER ARANEÆ

Sub-Order Liphistiomorphæ	1 family
Sub-Order Mygalomorphæ	
Branch Octostiatæ	4 families
Branch Sexostiatæ	4 families
Sub-Order Hypochilomorphæ	1 family
Sub-Order Dipneumonomorphæ	
Branch Trionychæ	26 families
Branch Dionychæ	13 families
Branch Quadrostiatæ	10 families
Sub-Order Apneumonomorphæ	
Branch Proterotracheatæ	2 families
Branch Deuterotracheatæ	1 family

These may be distinguished by the following table:

TABLE XIV

SEPARATION OF THE ARANEÆ INTO SUB-ORDERS

1 (2).	Abdomen segmented; spinnerets not terminal	LIPHISTIOMORPHÆ
2 (1).	Abdomen not segmented; spinnerets terminal	3
3 (8).	Abdomen with two pairs of lung-books	4
4 (7).	Cheliceræ move so that fangs move up and down	MYGALOMORPHÆ (5)
5 (6).	With four pairs of cardiac ostia	*Octostiatæ*
6 (5).	With three pairs of cardiac ostia	*Sexostiatæ*
7 (4).	Cheliceræ move so that fangs move transversely	HYPOCHILOMORPHÆ
8 (3).	Abdomen with one pair of lung-books or none	9
9 (12).	Abdomen with no lung-books	APNEUMONOMORPHÆ (10)
10 (11).	Cephalothorax receives tracheal tubes from first tracheæ	*Proterotracheatæ*
11 (10).	Cephalothorax receives tracheal tubes from second tracheæ	*Deuterotracheatæ*
12 (9).	Abdomen with one pair of lung-books	DIPNEUMONOMORPHÆ (13)
13 (16).	With three pairs of cardiac ostia	14
14 (15).	With three tarsal claws	*Trionychæ*
15 (14).	With two tarsal claws	*Dionychæ*
16 (13).	With two pairs of cardiac ostia	*Quadrostiatæ*

TABLE XIVA

Separation of the Mygalomorphæ into Families

1 (4).	Claw tufts present	2
2 (3).	Last segment of posterior spinnerets very short	Barychelidæ
3 (2).	Last segment of posterior spinnerets at least as long as, often longer than, preceding segment	Theraphosidæ
4 (1).	Claw tufts absent	5
5 (6).	All tarsi with a scopula	Pycnothelidæ
6 (5).	Posterior tarsi at least without scopula	7
7 (8).	Cheliceræ with a rastellus	Ctenizidæ
8 (7).	Cheliceræ without a rastellus	9
9 (10).	Labium mobile; posterior spinnerets very long	Dipluridæ
10 (9).	Labium fixed.	11
11 (12).	Six spinnerets	Atypidæ
12 (11).	Two or four spinnerets	13
13 (14).	Three tarsal claws	Migidæ
14 (13).	Two tarsal claws	Paratropididæ

TABLE XIVB

Separation of the Trionychæ into Families

1 (4).	Anal tubercle large, of two segments and hirsute	2
2 (3).	Cribellum and calamistrum present	Œcobiidæ
3 (2).	Cribellum and calamistrum absent	Urocteidæ
4 (1).	Anal tubercle normal	5
5 (6).	Cribellum and calamistrum present, at least in the females	7
6 (5).	Cribellum and calamistrum absent	21
7 (8).	Opisthosoma with two posterior spiracles connected by a groove	Filistatidæ
8 (7).	Opisthosoma with a single median posterior spiracle.	9
9 (10).	Tarsi with claw tufts	Psechridæ
10 (9).	Tarsi without claw tufts	11
11 (12).	First and second metatarsi with scopula	Tengellidæ
12 (11).	None of the metatarsi with scopula	13
13 (14).	Eyes homogeneous and diurnal	15
14 (13).	Eyes heterogeneous; anterior median eyes alone diurnal	19
15 (16).	Cribellum divided; posterior spinnerets largest.	Eresidæ
16 (15).	Cribellum undivided	17
17 (18).	Femora with trichobothria; maxillæ parallel	Uloboridæ
18 (17).	Femora without trichobothria maxillæ divergent	Dinopidæ
19 (20).	Cribellum divided; tarsi with trichobothria.	Amaurobiidæ
20 (19).	Cribellum entire; tarsi without trichobothria	Dictynidæ
21 (22).	Caput elevated; cheliceræ long, inserted far above mouth	Aracheidæ

22 (21).	Caput and cheliceræ normal	23
23 (24).	Two spinnerets only	PALPIMANIDÆ
24 (23).	Six spinnerets	25
25 (26).	Anterior tibiæ and metatarsi with spines as in Fig. 39 (2)	MIMETIDÆ
26 (25).	No such spinal arrangement	27
27 (28).	Fourth tarsi with a ventral comb of serrated bristles	THERIDIIDÆ
28 (27).	No such tarsal comb	29
29 (30).	Cheliceræ fused together at base	31
30 (29).	Cheliceræ freely movable	33
31 (32).	Tarsi long and flexible with false articulations	PHOLCIDÆ
32 (31).	Tarsi normal	SICARIIDÆ
33 (34).	Tarsi with serrated bristles, forming spurious claws	35
34 (33).	Tarsi without such bristles	39
25 (31).	Six eyes	LEPTONETIDÆ
36 (35).	Eight eyes	37
37 (38).	External surfaces of cheliceræ with stridulating ridges, cheliceræ without boss	LINYPHIIDÆ
38 (37).	No stridulating ridges; cheliceræ with boss	ARGIOPIDÆ
39 (40).	Cheliceræ without boss	41
40 (39).	Cheliceræ with boss	43
41 (42).	Colulus present; posterior spinnerets very long	HERSILIIDÆ
42 (41).	Colulus absent; posterior spinnerets not long	ZODARIIDÆ
43 (44).	Tarsal trichobothria in a regular row	AGELENIDÆ
44 (43).	Tarsal trichobothria in two rows or irregular	45
45 (46).	Fourth trochanters only with a notch	OXYOPIDÆ
46 (45).	All trochanters notched	47
47 (48).	Superior claws with many teeth; inferior with two or three teeth	PISAURIDÆ
48 (47).	Superior claws with few teeth; inferior with one tooth or none	LYCOSIDÆ

TABLE XIVc

SEPARATION OF THE DIONYCHÆ INTO FAMILIES

1 (2).	With a cribellum and calamistrum	3
2 (1).	Without a cribellum and calamistrum	5
3 (4).	First and second tarsi and metatarsi with a scopula	ZOROPSIDÆ
4 (3).	All tarsi and metatarsi without a scopula	ACANTHOCTENIDÆ
5 (8).	Eyes in three rows, 4, 2, 2, or in four rows, 2, 2, 2, 2	6
6 (7).	Eyes in three rows	ATTIDÆ
7 (6).	Eyes in four rows	LYSSOMANIDÆ
8 (5).	Eyes in two rows, or in three rows, 2, 4, 2	9
9 (10).	Sternum broader than long	PLATORIDÆ
10 (9).	Sternum normal	11
11 (12).	Eyes in two rows, 6, 2	SELENOPIDÆ
12 (11).	First row of eyes not composed of six eyes	13
13 (14).	Anterior spinnerets wide apart	DRASSIDÆ
14 (13).	Anterior spinnerets contiguous or nearly so	15

15 (16).	Sternum wide, pointed posteriorly; fourth coxæ wide apart	HOMALONYCHIDÆ
16 (15).	Sternum oval or long; fourth coxæ near together	17
17 (18).	All tarsi without scopula; colulus present	19
18 (17).	First and second tarsi at least with scopula; no colulus	21
19 (20).	Lip and sternum normal; second metatarsi longer than fourth	THOMISIDÆ
20 (19).	Lip long and narrow; sternum narrow, pointed behind; fourth metatarsi longer than second	APHANTOCHILIDÆ
21 (22).	Legs laterigrade	SPARASSIDÆ
22 (21).	Legs prograde	23
23 (24).	Eyes in two rows, 4, 4	CLUBIONIDÆ
24 (23).	Eyes in three rows, 2, 4, 2	CTENIDÆ

TABLE XIVD

SEPARATION OF THE QUADROSTIATÆ INTO FAMILIES

1 (2).	Opisthosoma with lung-books and a pair of spiracles	3
2 (1).	Opisthosoma with lung-books and a single-median spiracle	9
3 (6).	Tarsi with two or three claws, pectinate in a single row	4
4 (5).	Eyes in a transverse oval	DYSDERIDÆ
5 (4).	Eyes in three groups of two	SEGESTRIIDÆ
6 (3).	Tarsi with two claws pectinate in a double row	7
7 (8).	Eyes six (or none)	OONOPIDÆ
8 (7).	Eyes eight	HADROTARSIDÆ
9 (10).	Tarsi with three claws	11
10 (9).	Tarsi with two claws	15
11 (12).	Anterior median eyes small and far in front of others	SENOCULIDÆ
12 (11).	Anterior median eyes not far from the rest	13
13 (14).	All spinnerets in a transverse row	HAHNIIDÆ
14 (13).	Spinnerets arranged normally	ARGYRONETIDÆ
15 (16).	Cheliceræ fused at base, with boss; lip immobile	AMMOXENIDÆ
16 (15).	Cheliceræ and lip free	17
17 (18).	Anterior pair of spinnerets wide apart	PRODIDOMIDÆ
18 (17).	Anterior pair of spinnerets contiguous or nearly so	ANYPHÆNIDÆ

The Spider is the dominant Arachnid; it surpasses all others in the number and variety of its species, in the complexity of its habits, and in the breadth of its range across the world. So well is it advertised by the beauty of the orb-web that all men know the Spider, and for many it represents the whole Class of Arachnida. The Spider may be encountered in mythology, in history, in art, in literature: its reputation is not unspotted and its merits are seldom recognised. But if goddesses, saints and kings have found cause to be thankful for its existence, humbler mortals may well find in the study of Spiders some help in bearing those trials which are the common lot.

Excursus VI

The Spinning of Arachnida

Among the Arachnida silk is produced by all the Araneæ and Chelonethi, by some of the Acari and by a few of the Opiliones.

The **silk** is a secretion of special glands and its chemical nature is that of a complex albuminoid protein. Fischer [35] has published the following analysis of its composition :

Glycol	$CH_2(OH).CH_2(OH)$	35·13%
d-Alanine	$CH_3.CH(NH_2).COOH$	23·4
l-Leucine	$(CH_3)_2CH.CH_2.CH(NH_2).COOH$	1·76
Pyrroline	$(CH.CH_2)_2.NH$	3·68
Tyrosine	$C_6H_4(OH).CH_2.CH(NH_2)COOH$	8·2
Glutamic acid	$COOH.CH(NH_2).CH_2.CH_2COOH$	6·1
Diamino acids		5·24
Ammonia		1·16
Fatty acids		·66

The most striking physical property of the silk is its great tensile strength and its elasticity. A thread ·01 cm. in diameter has been found to carry more than 80 grams before breaking and to have stretched by 20 per cent. of its original length.

The **uses** which a Spider makes of its silk are many, for unlike the silk of insect larvæ it is used throughout life. Silk provides the gossamer threads on which young Spiders migrate, webs are made of silk and captured insects are bound in silk fetters. Wanderers leave a silk dragline behind them, sedentary Spiders live in a silk home or in a silk-lined burrow, and eggs are laid in a silk cocoon. The silk products of spider industry may be classified as follows :

I. *Linear Structures.*
   1. The dragline.
   2. The gossamer thread.
   3. The webs of Miagrammopes and Cladomelea.

II. *Plane Structures.*
   4. The attachment discs which anchor threads.
   5. The swathing bands wrapped about insects.
   6. The similar sheets of the Theridiidæ.
   7. The hackled band of cribellate spiders.
   8. The sperm web made by males.

III. *Solid Structures.*

9. The webs of most spiders.
10. The egg-cocoon.
11. The nest or retreat.
12. The moulting chamber.
13. The mating chamber.
14. The hibernating chamber.

The **silk glands** of Spiders are situated in the posterior part of the opisthosoma and open by ducts at the spinnerets which are terminal except in the Liphistiidæ. These glands were first investigated by Apstein [15] and by Warburton [82], working chiefly with Epeiridæ, and were classified into seven types, according to their apparent functions and shapes. This classification, which has been widely quoted, was as follows:

i. Aciniform glands to median and posterior spinnerets.
ii. Pyriform glands to anterior spinnerets: these and the above produce the swathing bands and attachment discs.
iii. Ampullaceal glands to anterior spinnerets, produce all long threads.
iv. Cylindrical glands, peculiar to the female, produce the cocoon-silk.
v. Aggregate glands to posterior spinnerets, produce the spiral thread of orb-webs and its viscid coating.
vi. Lobed glands, peculiar to the Theridiidæ.
vii. Cribellum glands which feed the cribellum.

A more recent investigation of these glands has been made by Millot [62*a–c*]. He finds it impossible to retain the older classification, for the silk glands are of many kinds and the types represented in one family are only rarely similar to those found in others. There is indeed a close similarity between all silk glands in histological structure and produce, but the form and the disposition of the glands have been evolved independently in each group. As a result there is no standard arrangement which can be legitimately described as the general type.

The nature of the silk glands and their relation to the poison glands is first suggested from the fact that the two kinds of gland occupy the same position in Scorpions and Spiders. Their homology is proved by Millot's [62*c*] work on the Spider Scytodes. Here the cephalothoracic gland is found not to be homogeneous throughout its length, but to consist of two kinds of cell. The cells in the posterior lobe produce a silk-like glutinous substance which the spider spits out at its insect prey, a method of attack which is unique among the Arachnida, although it is well known in several other animals.

The cells in the anterior part are typical poison-producing cells such as occur in the venom glands of all Spiders. Individuals differ from one another in the proportions of the two kinds of cell present, with the result that the bites of some are incapable of killing their normal prey, while the bites of others are quickly fatal.

This homology between silk and venom is maintained when we turn to the silk glands of the Chelonethi. In this Order the silk glands lie in the forepart of the prosoma, their ducts pass along the chelicerae and open at the so-called galea at the tip of the movable finger. Thus gland, duct and orifice of the silk-secreting apparatus of the Chelonethi are completely homologous with the gland, duct and orifice of the poison-producing apparatus of the Araneæ.

The Chelonethi use their silk solely for their own protection. They close the entrance to their hiding-places with a curtain and they build small nests of solid particles such as grains of sand, brushed over with layers of silk. In this nest they moult, incubate their eggs and hibernate.

The spinning activities of the Acari have been summarised by André [14]. The chief spinners are the Tetranychidæ, which often live in colonies on trees and plants, and sometimes smother both sides of the leaves with layers of silk. Under this silk sheet they find shelter for themselves, their eggs and larvæ. Many species are known from all parts of the world, and a single species does not habitually spin on the same kind of tree, but may be found on different species.

The silk of Mites is so fine that a single thread is invisible to the naked eye. It is secreted by prosomatic glands, comparable to the silk glands of the Chelonethi and the mixed silk and venom glands of the Sicariid Spiders. The ducts of the silk glands open inside the mouth, and by observation from beneath the liquid silk can be seen issuing therefrom. It is drawn out by the chelicerae, whose stylets or movable fingers manipulate it, sometimes assisted by the pedipalpi. The silk is never viscid.

In other families, a number of isolated examples of silk production have been reported, some of them with doubtful accuracy. Almost always the structure produced is a sheet-like shelter under which the Mite moults or deposits its eggs. As examples there may be mentioned the species *Analges passerinus*, which spins nests on the bodies of birds under the feathers, where the nests may be found containing eggs and young; and *Oribata castanea*, which spins colonial tents under stones, sheltering forty or more individuals.

VIII

THE ORDER PALPIGRADI

MICRO-WHIP-SCORPIONS

" Tendit iter noctu, lapides frondesque pererrans
Arentes." K.

Arachnida of small size, in which the prosoma has the last two somites free and the opisthosoma is wholly segmented. Eyes absent. Telson in the form of a long jointed flagellum. Chelicerœ of three joints, chelate. Pedipalpi of six joints, leg-like, with small tarsal claw. Legs of 12, 7, 7 *and* 8 *segments respectively, tarsi with two claws. No gnathobases on any coxœ, mouth on a projecting rostrum. Sternum of four segments. Respiration cutaneous or by three pairs of lung-books on fourth, fifth and sixth opisthosomatic somites.*

The **prosoma** of the Palpigradi is protected by three chitinous shields. The foremost of these is the largest, an oval plate which covers four segments and extends from the chelicerœ to the second pair of legs. It is followed by two free somites, bearing the third and fourth pairs of legs. In this respect it will be seen that the Palpigradi closely agree with Hansen's conception (*vide* p. 34) of the primitive Arachnid, possessing a " head " of four segments and a thorax of two, and show relations to the Solifugæ, in which three fused somites are followed by three free ones.

There are no **eyes** on the carapace, but two seta-like structures exist near its anterior margin and are usually described as sensory patches.

The **chelicerœ** superficially resemble those of the Opiliones. They are composed of three segments. The first is a straight rounded piece, projecting forwards from beneath the anterior end of the cephalic shield. The second is at right angles to the first and therefore points downwards ; it has a pointed and toothed process extending downwards on its inner edge. Against this works the third segment, which is also pointed and toothed and joins the second outside its process. Thus the chelicerœ are chelate, the pincers working laterally. They are the only chelate limbs of the Palpigradi and their only weapons ; they are consequently capable of very free movement, and, with their long proximal segments, have a comparatively wide range.

The **pedipalpi** are simple pedal structures, not specialised for any particular

function and used in so leg-like a manner that, apart from analogy, it would be accurate to describe this Order as possessing five pairs of legs. They consist of nine segments, coxa, trochanter, femur, tibia and five tarsal joints. The last tarsal segment bears a pair of small claws.

The first pair of true **legs** are by far the longest of the limbs, and possess, owing to multiplication of the tarsal joints, twelve segments each. The last six of these carry long sensory setæ. The limb is not used for walking, but is carried stretched out ahead of the animal, in the same way as are the forelegs of some of the Spiders and Mites. It is clear that these legs are the chief sense organs of the animal. The second and third legs have the normal complement of seven segments each, but the fourth, owing to the possession of a divided tarsus, number eight segments. All the legs have two claws on the tarsi.

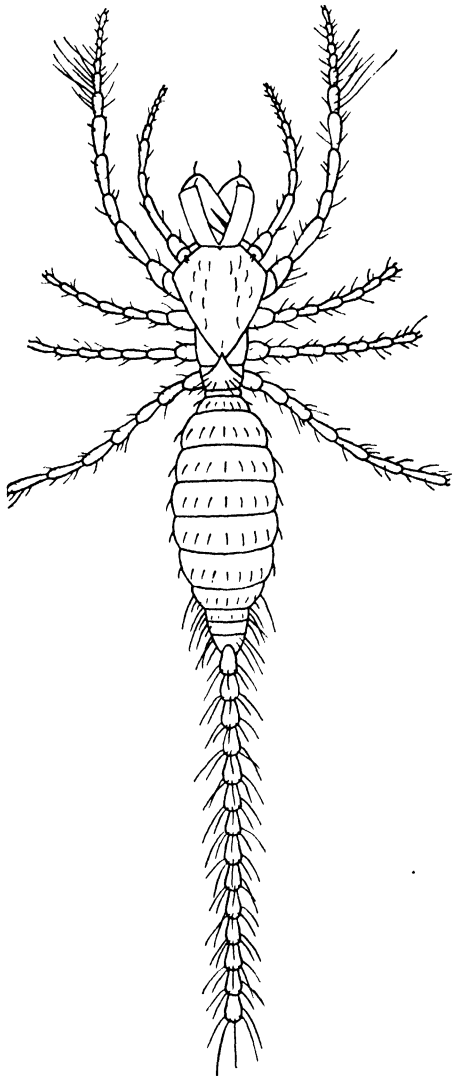


Fig. 43.—Palpigradi—Dorsal Aspect. [Species, *Kœnenia mirabilis*.] After Kraepelin.

The **mouth** of the Palpigradi is unique. Below the proximal end of the cheliceræ is a soft egg-shaped prominence, pointing forwards and composed of epistome and hypostome. The mouth appears as a transverse slit at the end of this oral process, lying as it were between the two lips. There is no other Arachnid in which the mouth is so far forward as to lie between the basal joints of the cheliceræ, and it may be that this is a primitive position, from which the mouth has not migrated as far back as it has in the allied Orders.

The **sternum** is also very remarkable, differing from that of all other Arachnida and probably representing a much more primitive stage. There are four prosomatic sternites. The anterior of these is the largest and consists of the fused sternites of the segments carrying the pedipalpi and the first pair of legs; the three succeeding ones are smaller and lie directly between their corresponding conical coxæ. Thus if the hypostome be taken as representing sternite i, the large anterior plate represents sternites ii and iii, and the remainder sternites iv, v and vi. This is a full complement

and there is no other Arachnid prosoma with so well defined a segmentation on its ventral surface.

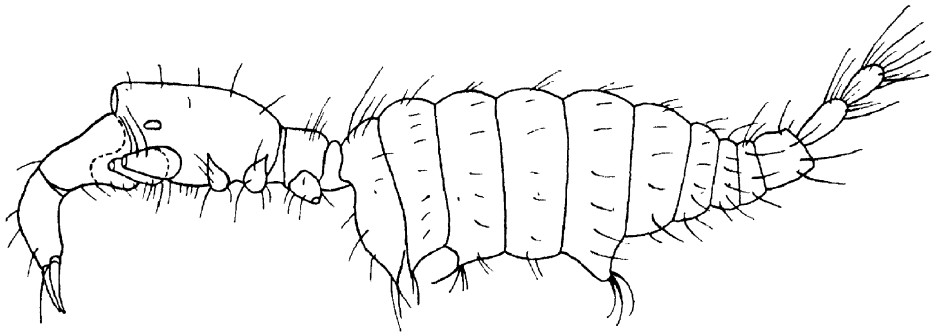


FIG. 44.—*Kœnenia mirabilis*—Lateral Aspect. After Kraepelin.

A soft weakly-chitinised **pedicle** unites the two parts of the animal's body, and is followed by ten clearly defined opisthosomatic somites. The **opisthosoma** is soft, no distinct tergites or sternites being recognisable in the covering membrane. The genital orifice lies on the ventral side of the first and second somites, and is of quite complicated appearance.

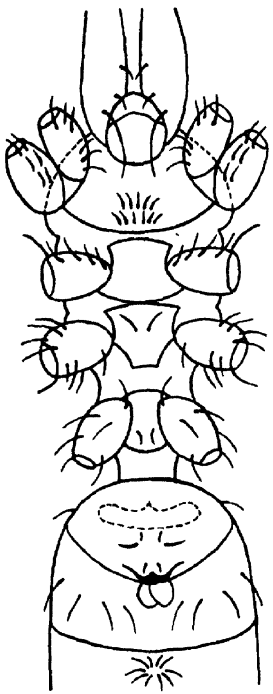


FIG. 45.—*Kœnenia mirabilis*—Ventral Aspect. After Kraepelin.

The second, third and fifth somites are characterised by single or paired nipple-like humps on the ventral surface, set with strong sensory setæ. The last three somites are abruptly narrowed into a " tail," similar to that of the Uropygi and Ricinulei. The last carries a very characteristic post-abdomen, composed of fourteen or fifteen apparent segments, most of which carry long setæ. In life this curious organ is borne erect at right angles to the body.

The first Palpigradi discovered were described as being without **respiratory organs.** It was supposed that in such a small, soft animal cutaneous interchange of gases would suffice. In the American species belonging to the genus Prokœnenia paired lung-sacs have however been reported in the fourth, fifth and sixth opisthosomatic sternites. These sacs can apparently be evaginated by internal pressure and invaginated by muscles, a pair of dorso-ventral muscles being attached to each pair of lung-sacs.

The Palpigradi seldom exceed 2 millimetres in length and are of a translucent whitish appearance.

Distribution

First discovered at Catania in Sicily by P. Grassi [39] in 1885, the Palpigradi have since been found in several parts of Italy, notably among the olive-groves of Palmi in Calabria, in northern Africa and in France, where they are not rare at Banyuls-sur-Mer (Fig. 46). Probably they could be found at many places on the Mediterranean. In the East they have been recorded from Siam and in America from Chile, Texas and Paraguay, as well as from some of the northern states. Although

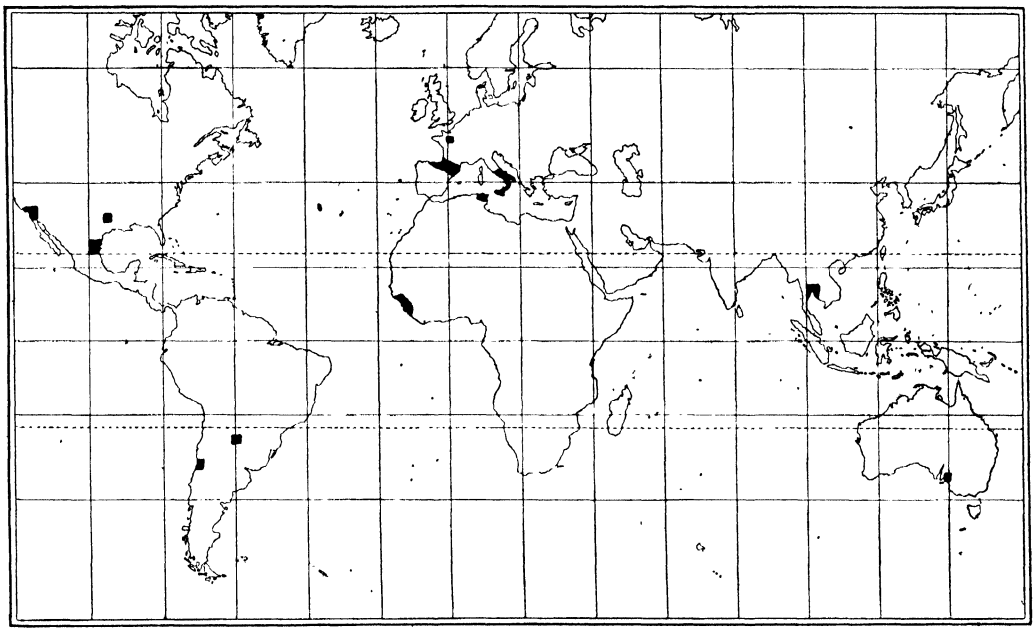


Fig. 46.—Map showing Distribution of the Palpigradi.

apparently feeble and defenceless, they seem to have powers of resistance which enable them to secure dispersal by the chance means provided by man. In 1914 Berland [18] described a species which seemed to have become acclimatised in the Museum de Paris, and in 1933 *Kœnenia mirabilis* was found on the lower slopes of Mount Osmond, Adelaide, whither it had most probably been imported. These Arachnida are generally found under stones, often in company with the insect Thysanura.

Classification

Since 1885, when *Kœnenia mirabilis* was discovered, the Order Palpigradi has been held to consist of but a single family, the Kœneniidæ. The discovery of other species, which now number about twenty, has necessitated the establishment of four genera.

In 1901 Miss Rucker [71] separated the species with abdominal lung-sacs from

those without, placing the former in a new genus Prokœnenia and the latter, the original Kœnenia, in a genus Eukœnenia. The generic name Kœnenia cannot, however, be abandoned in this way.

In 1913 Silvestri [75] added two more genera to receive the new species discovered in French Guinea. These were Allokœnenia and Kœnenioides.

The classification is therefore as follows :

ORDER PALPIGRADI

Family Kœneniidæ

Genus Kœnenia Grassi.	Type *K. mirabilis* Grassi.	1885
Genus Prokœnenia Rucker.	Type *P. Wheeleri* Rucker.	1901
Genus Allokœnenia Silvestri.	Type *A. afra* Silvestri.	1913
Genus Kœnenioides Silvestri.	Type *K. notabilis* Silvestri.	1913

Excursus VII

The Tail and Telson in Arachnida

The termination of the opisthosoma of the Arachnida provides a rather interesting study in comparative arachnology.

Hansen and Sørensen pointed out that the last three somites of the opisthosoma show a tendency to form a narrower and semi-independent portion in the Pedipalpi, Palpigradi, Ricinulei and Araneæ. In fact, they suggested the inclusive term Arachnida micrura for these four Orders.

In the Uropygi the relative mobility of the tenth to the twelfth opisthosomatic somites may well enable the animal to direct the secretion of its acid-producing glands. In the Amblypygi there are no such glands and the tail is less obvious. In the Palpigradi the mobility of this part is probably a help in the use of the flagellum, whatever this may be. In the Araneæ it is supposed that the value of the tail is that it separates the anus from the spinnerets and so prevents the latter from being soiled. The habits of the Ricinulei are so little known that no purpose can be suggested for the tail in this order. Nevertheless it is undeniable that these four Orders do very definitely resemble each other in having a kind of tail, typically formed from the last three somites of the body.

Similar comparisons may be made when the presence of a post-anal telson is considered. In the Arachnida post-anal structures are very different in form and function. The Xiphosura have a long pointed lance, evolved from the much shorter one of the Eurypterida and used as a support in progression and in digging. The Scorpions have a short sharp perforate sting with a swollen base enclosing a poison sac. The Uropygi and the Palpigradi have long whip-like structures whose function

is unknown. In the Uropygi the telson trails behind, but in the Palpigradi it is arched and carried over the abdomen, like the metasoma of a Scorpion.

In striking contrast to this there is no trace whatever of either a three-somite tail or a post-anal telson of any sort in the Solifugæ, Opiliones or Chelonethi. This shows that the latter structure has evidently been developed independently by the groups which possess it. Its origin may be sought in the pointed termination to the body of certain of the Eurypterida, but its existence does not necessarily point to a closer relationship between the telson-bearing Orders.

IX

THE ORDER RICINULEI

"Rarior apparet, caput ipsum tecta cucullo."

K.

Arachnida in which the prosoma is uniform and bears anteriorly a jointed cucullus. Eyes absent. Opisthosoma of nine somites, united to the prosoma by a pedicle which is normally hidden within a coupling device. No telson. Chelicerœ of two segments, small, chelate. Pedipalpi of six segments, chelate, their coxœ fused in the middle-line. Sternum small, hidden by pedal coxœ. Legs of seven, eleven or twelve segments, without spines ; tarsi with two smooth claws. Respiration by tracheœ, with apertures on prosoma. Metatarsus and tarsus of third leg of male modified as sexual organ.

The **prosoma** of the Ricinulei is protected by a uniform carapace, roughly square shaped and unusually thick and hard. It is covered, as is the rest of the body, by characteristic granulations, interspersed with setæ. Some of these setæ are spatulate or club-shaped, with a longitudinal groove and roughened surface : they are probably sense organs of a special kind. The carapace has a central transverse groove of varying length and often a number of other markings, probably indications of some of the original somites. One of the chief characteristics of the Order is the cucullus, a wide, oval, slightly convex plate, articulating with the anterior edge of the prosoma. This cucullus is readily movable and when bent downwards it completely covers and protects the mouth and the chelicerœ. A similar cucullus is found in some of the Pedipalpi and bears the median eyes : the cucullus is therefore regarded as being the first somite of the body, one which is not as a rule separated from those behind it and to which the direct eyes belong.

The Ricinulei have no **eyes.** From this it follows that the interpretation of the cucullus cannot be directly confirmed, save perhaps by a study of the embryonic development.

Posteriorly the prosoma seems to end in a transverse ridge, but actually the end is below this ridge. This appearance is due to a second characteristic of the Ricinulei, the remarkable way in which the prosoma and opisthosoma are linked or clasped together. On the dorsal surface of the opisthosoma there is a deep transverse groove between the second and third tergites, into which the prosomatic ridge fits. Ventrally the third sternite projects forwards and forms a pair of pocket-like spaces into which fit processes from the posterior borders of the fourth coxæ. The conse-

quence of this curious arrangement is that the animal does not appear to be pediculate, the prosoma and opisthosoma are securely locked together, and the first two opisthosomatic somites are hidden. Coupling and uncoupling must be possible to the living animal, for the genital aperture lies within the enclosed space ; hence during copulation and during egg-laying the attachment must be undone in order to expose the orifice.

The **opisthosoma** presents the appearance of four well-defined somites, but actually nine can with certainty be distinguished. The first of these which may,

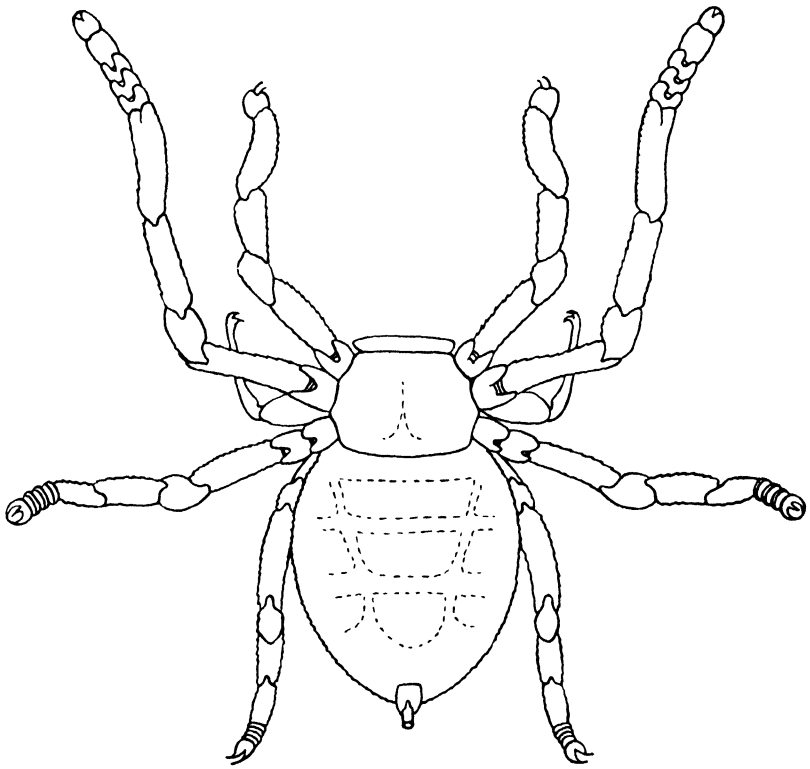


FIG. 47.—Ricinulei—Dorsal Aspect. [Species, *Ricinoides crassipalpe*.] After Hansen and Sørensen.

strictly speaking, be regarded as the last somite of the prosoma, is the pedicle. This pedicle has a short narrow tergite, comparatively feebly chitinised, and surrounded by quite soft and flexible membrane. Its sternite is crescent-shaped, its concave margin facing backwards. The second somite is about three times as wide as the pedicle. Its tergite is a narrow strip, its sternite also crescentic, but with its concavity forwards. Thus there is between the first two sternites an oval area of membrane in which is the genital orifice, a broad transverse slit. It will be noticed that this places the genital orifice in front of the second opisthosomatic somite, whereas in those

Arachnida most closely allied to the Ricinulei it lies behind the second somite or on its posterior margin. It may be, therefore, that an undetected somite exists or existed in front of the pedicle, or, alternatively, that the pedicle of the Ricinulei is not homologous with that of the Araneæ or the Pedipalpi.

The third somite is short and wide, being a strip of chitin across the opisthosoma where this is coupled to the prosoma. Its tergite is generally divided into a central and two lateral pieces; its sternite is plainly seen on the lower surface.

The fourth, fifth and sixth somites are the largest of the series and constitute the bulk of the opisthosoma. The tergite of each is divided into a large median and smaller lateral areas, separated by softer, lighter-coloured membrane of great

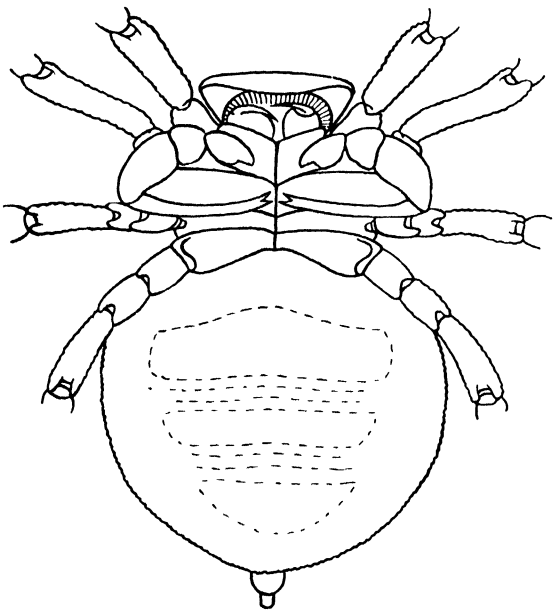


FIG. 48.—Ventral Aspect of *Ricinoides crassipalpe*. After Hansen and Sørensen.

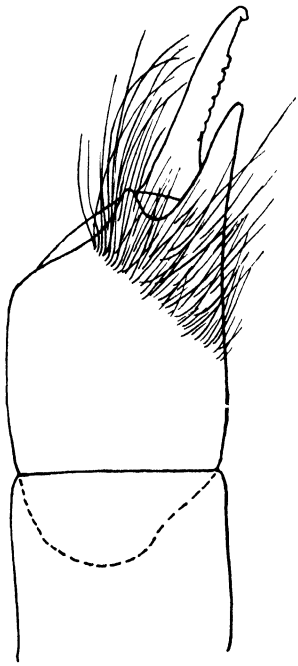


FIG. 49.—Chilicera of *Ricinoides crassipalpe*. After Hansen and Sørensen.

thickness. As the animals grow older these passages between the tergal elements tend to narrow and disappear. The sternites of these three somites are not divided longitudinally (Fig. 48), and, as the spaces between them narrow, they come to form almost a continuous shield on the ventral side of the body. Both tergites and sternites of this region are marked each with a pair of depressions, similar to those often seen on the backs of Spiders, and like them due to the insertion of muscles within.

The seventh, eighth and ninth somites are much reduced in size. Their exoskeletal supports are complete rings of chitin and the segments can be drawn together like a telescope, making them even more inconspicuous. In this condition, which is probably their normal one, the eighth and ninth somites can only be seen inside the seventh,

their posterior edges forming concentric circles. The anus is a transverse slit on the last somite : no glands, like those of the Uropygi, open beside it.

The **sternum** is not normally visible from the outside, since it is covered by the pedal coxæ. If these are removed it is seen as a small plate, lying longitudinally.

The **cheliceræ** are composed of two segments, and are chelate. The first, basal, segment is short and stout and provided with a transverse belt of close setæ on the ventral surface and a similar smaller belt on its dorsal surface (Fig. 49). One or two strong processes, with sharp edges and teeth, rise from the distal end of this segment, and against them works the second segment. This is a sickle-shaped point, often with a serrated edge, and closely resembles the corresponding organ in the Araneæ.

The **pedipalpi** are of six segments. They are remarkable in that their coxal segments are fused together in the middle line instead of acting independently as

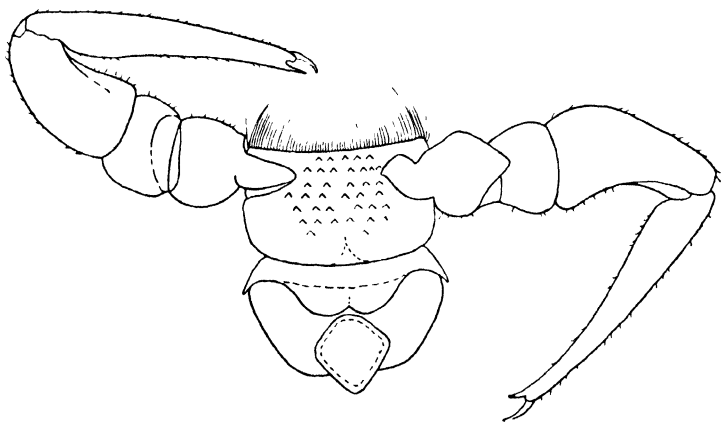


FIG. 50.—Pedipalpi of *Ricinoides westermannii* showing Range of Rotation. After Hansen and Sørensen.

gnathites. In this the Ricinulei resemble the Uropygi. This common maxillary plate bears the ordinary pair of palpi, consisting of two trochanters, femur, tibia and tarsus. The first trochanter moves slightly up and down, but the second is capable of a complete rotation (Fig. 50), turning through 180° and directing the remaining segments in the opposite way from that in which they usually lie. The femora are stout, the tibias long. The joint between these two allows them to touch each other when fully flexed and, on account of this mobility, the tip of the limb can reach the mouth from either direction. The distal end of the tibia carries a small serrate process against which the tarsus moves and so makes the pedipalpi also chelate on a small scale.

The **legs** of these curious Arachnida also have peculiar characteristics. The first three pairs of coxæ are immovably coalesced and the fourth pair which is concerned with the linkage of the prosoma and opisthosoma is freely movable. The legs are not all similarly constituted. The first has one trochanter and one tarsal segment, the second one trochanter and five tarsals, the third two trochanters and four tarsals, and the fourth two trochanters and five tarsals. The other segments are as usual, and hence the total number of segments on the four legs are seven, eleven, eleven and

twelve. The second pair of legs is always the longest, then the fourth and the first is always the shortest. All the legs are devoid of ordinary spines and all end in two simple claws without teeth, situated in a small excavation at the end of the tarsus.

The **male organs** of the Ricinulei are to be found in a unique situation, on the metatarsus and tarsus of the third pair of legs. The metatarsus and first two segments of the tarsus are strangely modified by cavities and by fixed and movable processes. When the tarsus is bent upwards, it nearly touches the metatarsus and a closed or almost closed space is formed by the interlocking of their processes and cavities. It is assumed that this complex organ, which does not seem to be adapted for containing a seminal fluid, is used to convey spermatophores, but this has not yet been confirmed by direct observation.

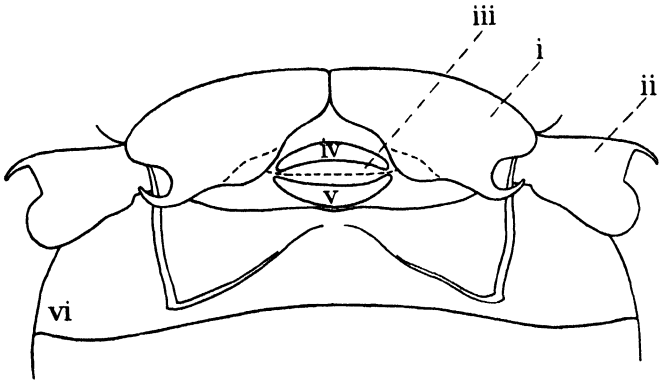


FIG. 51.—*Ricinoides afzelii*—Female genitalia.
i. Fourth coxa; ii. Fourth trochanter; iii. Vulva; iv–vi. First, Second and Third sternites.

In addition to having no eyes, the Ricinulei seem to be poorly supplied with **sense-organs.** In the only specimen dissected by Hansen and Sørensen, an immature *Ricinoides crassipalpe*, no lyriform organs were found on pedipalpi, legs or opisthosoma. Nor do the Ricinulei possess the long thin spines often described as acoustic setæ such as are found on the legs of the Araneæ. Their spatulate setæ are possibly organs of touch, and a very curious seta is found standing in a small depression on the last tarsal joint of each of the three posterior legs. It is short, slightly broader at its upper than at its lower end and carries delicate scattered branches all over its upper portion. The actual tip is, however, bare.

The **tracheal tubes** by which the Ricinulei breathe open on the prosoma, at two apertures near its apparent posterior margin, above the third coxæ. The apertures are very small and are not visible in the intact animal.

DISTRIBUTION

The Ricinulei are of strictly limited distribution and have so far been found only in two regions in the Tropics (Fig. 52). These are the central west coast of Africa and the Amazon basin. The two hemispheres contain different genera, Cryptocellus from the Old World and Ricinoides (Cryptostemma) from the New.

CLASSIFICATION

The Order has at all times been limited to a single family, at first called the Cryptostemmatoidæ or Poliocheridæ. The name Cryptostemma Guérin, 1838, for

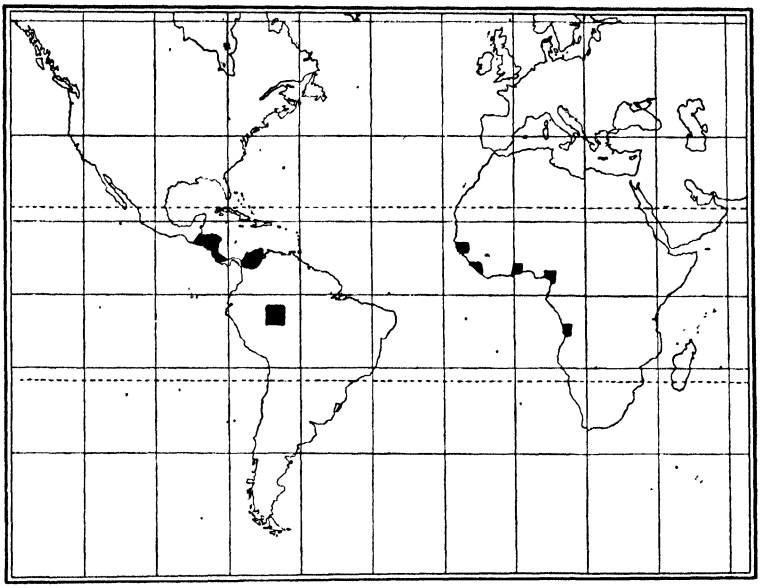


FIG. 52.—Map showing Distribution of the Ricinulei.

the type genus is, however, preoccupied by Cryptostemma Herrich Schäffer, 1835, for the Hemiptera, and for this reason Ewing [33*a*] proposed the name Ricinoides for the genus and Ricinoididæ for the family. Ewing gives the following table for the Classification.

TABLE XV

CLASSIFICATION OF THE RICINULEI

1 (2).	Second coxæ subtriangular and not meeting on middle line	3
2 (1).	Second coxæ broad, platelike and meeting on middle line	5
3 (4).	Opisthosoma divided into tergites : palæozoic . .	Polyochera Scudder
4 (3).	Opisthosoma uniform : palæozoic	Curculioides Buckland
5 (6).	Last segment of cheliceræ opposed by two processes on penultimate segment : fourth segment of tarsus ii longer than fifth	Ricinoides Ewing
6 (5).	Last segment of cheliceræ opposed by one process on penultimate segment : fourth segment of tarsus ii shorter than fifth	Cryptocellus Westwood

Here is indeed an unusual phenomen—a whole Order of zoology devoted to thirteen species and known to all the world by thirty examples caught in two continents in ninety-seven years. And yet these animals cannot be as rare as they appear to be, or their survival from the Carboniferous era until to-day would not have been possible. Here, too, is a challenge to those collectors fortunate enough to find themselves in the right neighbourhood ; for each specimen seen by man is something of an historical event. The future of this group may well hold surprises in store—

if those who have studied Horse-Shoe Crabs, exotic Spiders and Harvestmen are still capable of feeling surprise at anything.

Excursus VIII

The Known Specimens of the Ricinulei

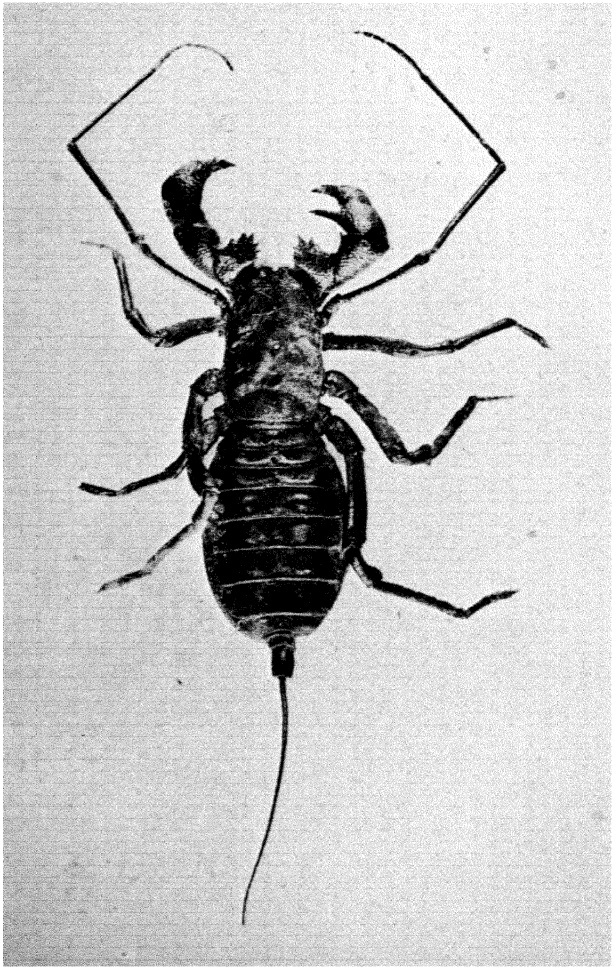
There can be very few Orders of animals or of plants which have been known for almost a century and yet whose rarity is such that it is an easy matter to trace not only every species but actually every specimen captured during that time. Yet this is true of the Ricinulei. This fact so greatly increases the interest of an otherwise sufficiently fascinating group, that I append a tabular synopsis of its history. In this table I have taken the thirteen species in chronological order and temporarily reverted to the old historic name of Cryptostemma.

TABLE XVI

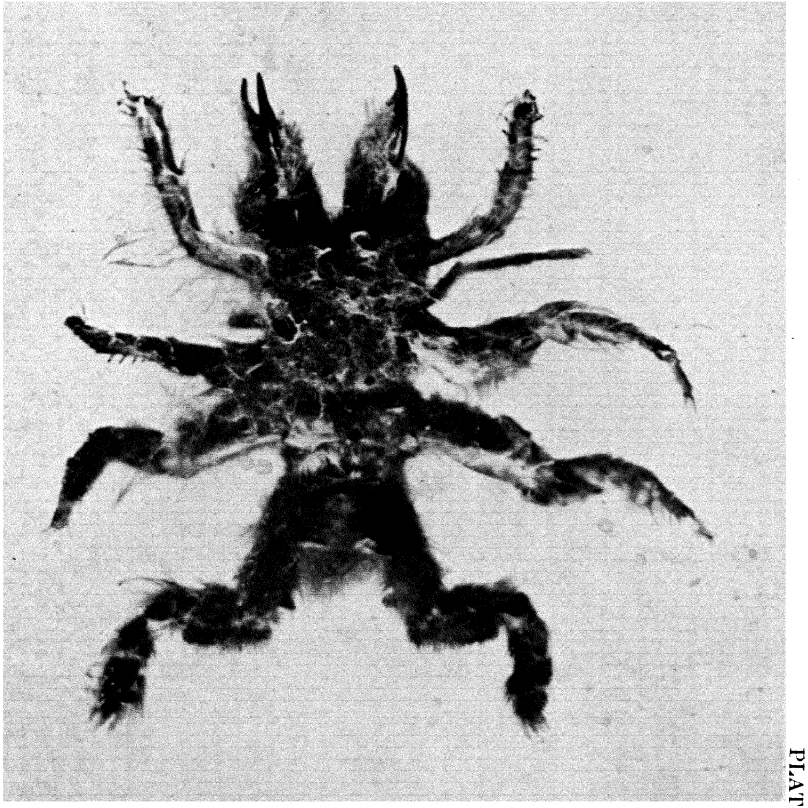
History of the Ricinulei

Date.	*Name.*	*Author.*	*Captor.*	*Locality.*	*Numbers.*
1838	*Cryptostemma westermannii*	Guérin	Westerman	Guinea	1 ?
			R. Buttner	Togo	1 ♂, 1 j.
1874	*Cryptocellus fœdus*	Westwood	Bates in '61	Brazil	1 ♀
1892	*Cryptostemma afzelii*	Thorell	Afzelio		1 ♀
			E. E. Austen	Sierra Leone	1 ♀
1892	*Cryptostemma westermannii*	Karsch		Kamerun	1 ♂, 1 ♀
1904	*Cryptostemma karschii*	Hansen and Sørensen	G. L. Bates	Congo	1 ♂, 1 ♀
1904	*Cryptostemma crassipalpe*	,,	Y. Sjöstedt	Kamerun	2 j.
1904	*Cryptostemma plebejum*	,,	E. Baumann	Togo	1 j.
1904	*Cryptostemma sjöstedtii*	,,	Y. Sjöstedt		1 ♂, 1 ♀?, 1 j.
			L. Conradt	Kamerun	1 ♂, 1 ♀, 1 j.
1904	*Cryptocellus simonis*	,,		Brazil	1 ♂
1921	*Cryptocellus centralis*	Fage	P. Serre	Costa Rica	1 ♂
1929	*Cryptocellus magnus*	Ewing	W. M. Mann in '24	Columbia	1 ♀
1929	*Cryptocellus manni*	,,	W. M. Mann in '24	Columbia	1 ♀
1929	*Cryptocellus emarginatus*	,,	W. M. Mann in '24	Costa Rica	1 ♀ ?
1929	*Cryptocellus barberi*	,,	W. M. Mann in '24	Honduras	1 ♀
			H. S. Barber in '06	Guatemala	6 ♀ s and j.

Summary :— 2 genera.
13 species (6 Cryptostemma and 7 Cryptocellus).
32 specimens (18 Cryptostemma and 14 Cryptocellus).



(i) *THELYPHONUS CAUDATUS*



(ii) *CHELYPUS, A SOLIFUGE*

PLATE VI

X

THE ORDER SOLIFUGÆ

" Quis calcare tuas timeat, Solpuga, latebras."

LUCAN.

Arachnida in which the prosoma has the last three somites free and in which the opisthosoma consists of ten somites, each with a dorsal and ventral sclerite. No pedicle ; no telson. Chelicerœ of two segments, chelate, very large and powerful. Pedipalpi of six segments, tactile, the tarsus ending in a suctorial sac. Legs of first pair tactile, with one claw, the rest with two claws ; third and fourth pairs with divided femora ; fourth pair with five racquet-organs or malleoli on ventral surface. Respiration by tracheœ. Male usually with flagellum on chelicerœ.

The **prosoma** of the Solifugæ is more fully segmented than that of any other Arachnid, a fact which is in accordance with their generally primitive nature. The anterior part consists of a conspicuously swollen head or propeltidium, the large size of which is due to the muscles of the powerful cheliceræ within it. The pair of direct eyes are situated in the middle of its anterior margin on a small ocular prominence.

The forepart of the prosoma is characterised by the existence of several plates of chitin, each surrounded by softer epidermal tissue and thus more or less isolated. These have received various names from different authors in the past and have lately been most satisfactorily described by Roewer [70]. They are as follows :

(i) Lobus exterior : by the forward angles of the propeltidium.
(ii) Lamina exterior major : ventral to the above.
(iii) Lamina exterior minor : anterior to the lamina exterior major.
(iv) Arcus anterior : two hoop-like strips behind the propeltidium.
(v) Plagula mediana : between the above.
(vi) Arcus posterior : two strips behind and similar to the arcus anterior.

These plates are shown in Fig. 54. They are particularly clear in the genus Rhagodes, but are subject to considerable variation in other genera. As a result the precise morphological relations between these sclerites are difficult to determine and have been differently described.

Behind arcus posterior are the two transverse quadrate tergites of the segments which carry the third and fourth legs. These occupy their natural primitive positions

in the seventh and eighth somites. The ninth somite is suppressed in the adult and the prosoma is joined to the opisthosoma across its whole width. Nevertheless,

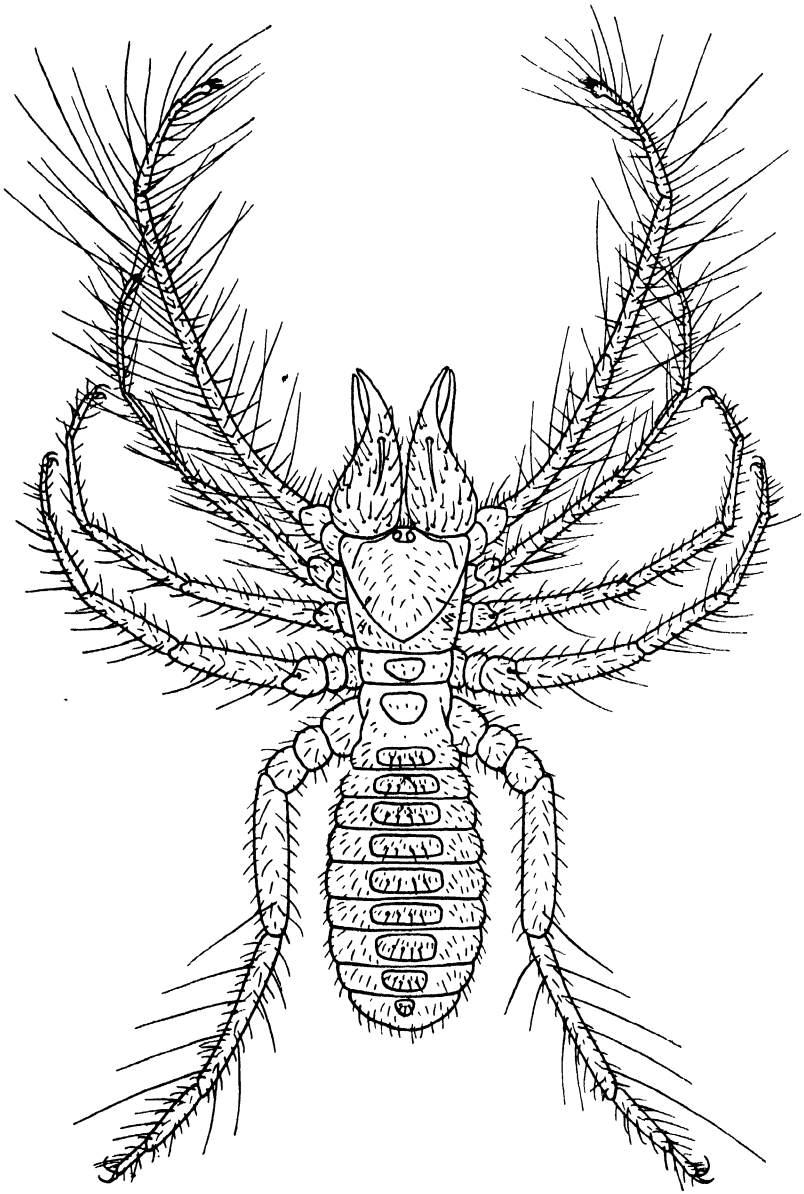


FIG. 53.—A Solifuge—Dorsal Aspect. [Species *Galeodes arabs*: a Libyan Desert specimen, 10.iv.28.]

there is great flexibility between the two parts of the body and the opisthosoma can readily be raised until it is almost perpendicular. This action is common in the active life of the Solifugæ, and it generally occurs posthumously so that Solifugæ

preserved in spirit usually lie in this flexed position. This peculiar freedom is emphasised because it is a probable factor in determining the positions of the prosomatic sclerites. As the abdomen is raised there is a tendency for the last two tergites to be pushed forwards so that the tergites of the somites directly behind the propeltidium are pushed to the side. With this as a guide, Roewer suggests that

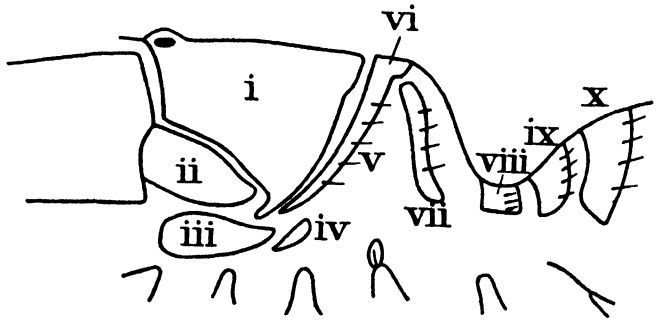


FIG. 54.—Prosoma of Rhagodes—Lateral Aspect. After Roewer.
i. Propeltidium; ii. Lobus exterior; iii. Lamina exterior major; iv. Lamina exterior minor; v. Arcus anterior; vi. Plaguoa mediana; vii. Arcus posterior; vii–x. Tergites.

the plagula mediana and arcus anterior belong with the first legs to the fifth somite and the arcus posterior with the second legs belongs to the sixth.

The **chelicerae** of the Solifugæ are large and powerful, so large that they are often as long as the prosoma and so powerful that it is probably true to say that the Solifugæ have the most formidable pair of jaws in the animal world (Fig. 55). The chelicerae

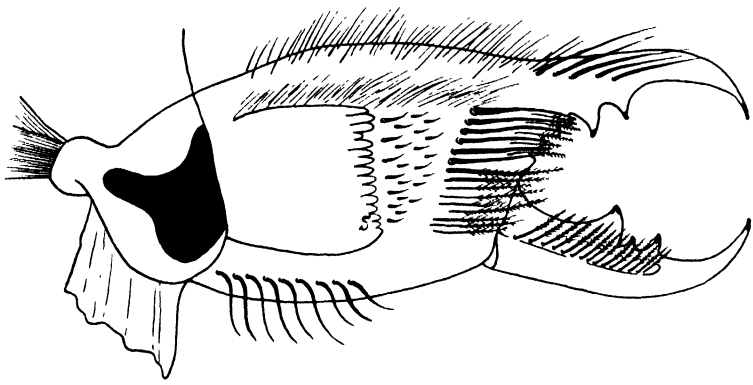


FIG. 55.—Chelicera of *Galeodes aranoides*, female. Seen from inside. S. Stridulating organ. After Roewer.

are of two segments and closely resemble the very much smaller chelicerae of the Chelonethi. The first segment has a broad base or palm continued into a fixed finger. The second segment or movable finger articulates below the base of this prolongation and works against it in a more or less vertical plane. The broad parts of the first segment are oval in section, so that there is a trough or channel-like space above

and below them. The former admits light to the ocular tubercle while the latter contains the rostrum. The interior of the base contains the powerful muscles which close the jaws and in well-fed specimens much fatty tissue as well. There are no internal poison-glands or ducts: the teeth are solid chitin and the bite of Solifugæ is not poisonous, but fatal only because of its severity. Both fingers are provided with teeth, the number and position of which is not only different in different genera (Fig. 56) but also differs in the two sexes of the same species. In the mature males the teeth are often reduced to a mere ridge, and it is doubtful whether cheliceræ so modified can act efficiently for their true purpose. But mature males die soon after copulation in any case.

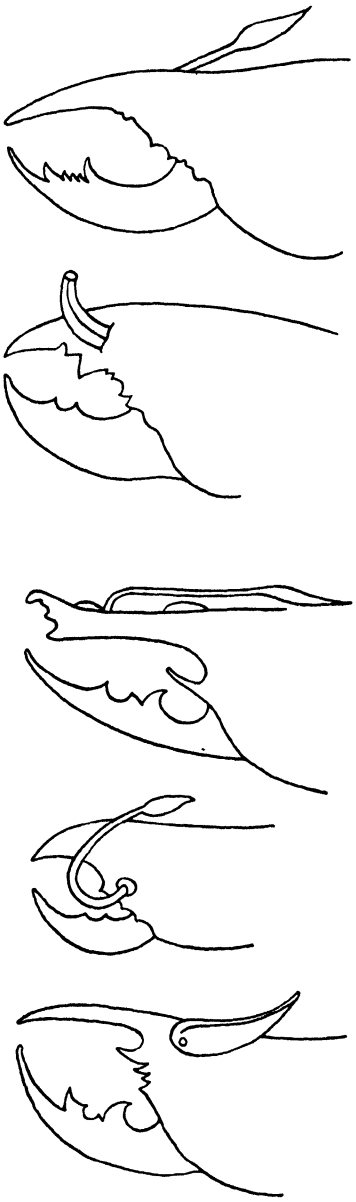


FIG. 56.—Cheliceræ of Male Solpugidæ, showing diverse forms of Flagella. After Kraepelin.

i. Galeodes; ii. Rhagodes; iii. Solpuga; iv. Hexisopus; v. Dæsia.

A copious provision of spines and setæ is also found on the surfaces of the cheliceræ. Between the two there is an important relation. When they are in use, biting a struggling captive, the basal segments move relatively to each other in a longitudinal direction, while the mandibles which work vertically, open and shut in alternation. This quickly reduces the prey to a fluid state and only the hardest parts are rejected.

They also possess **stridulating organs**. A smooth quadrangular surface is found on the inner side of each basal segment, where the two segments almost touch each other, and associated with this patch are spines of various stoutness. When the cheliceræ are rubbed together a kind of twittering sound is produced, similar to that produced by stridulating Spiders.

The **rostrum** of the Solifugæ is a very characteristic pointed beak, projecting from the ventral surface between the coxæ of the pedipalpi. It consists of a hard lower portion and a softer labrum above, the mouth being the space between them, and always carries a pair of sensory setæ.

The **pedipalpi** have the normal six segments. The coxæ are provided with large gnathobases, which triturate the food just below the rostrum. On the ventral surface of each is a small tubercle bearing the opening of the excretory coxal gland. The trochanter is a single short ring-like segment and the remaining segments are of normal form. The tarsus is very short. It ends not in a claw, but in a specialisation peculiar to the Solifugæ, a suctorial organ. All segments of the pedipalpi are thickly covered with hairs and spines of different length and strength. Sometimes the arrangement of the spines is of use in classification, but sometimes it differs in the two sexes of the same species, and is thus of little value.

The pedipalpi are most active organs. The suckers with which they terminate assist the animal in climbing vertical surfaces, and they are also used for picking up food particles. In drinking, their tips are brought together, thrust into the water and then lifted, like a pair of hands, raising the liquid to the mouth. In battle the pedipalpi are invaluable ; they determine the weak spots in the adversary's defence, and act as buffers to his attack. Provided as they are with long silky setæ they act as very delicate organs of touch, and when the animal is running they are held out in front like the antennæ of insects. The dependence of the Solifugæ on its pedipalpi is shown by the fact that if they are removed the first pair of legs make some attempt to act as substitutes, but the loss proves fatal within twenty-four hours.

The **legs** of the Solifugæ are very characteristic. The first pair are the feeblest of all the appendages, but they are longer than the other legs and are not used as

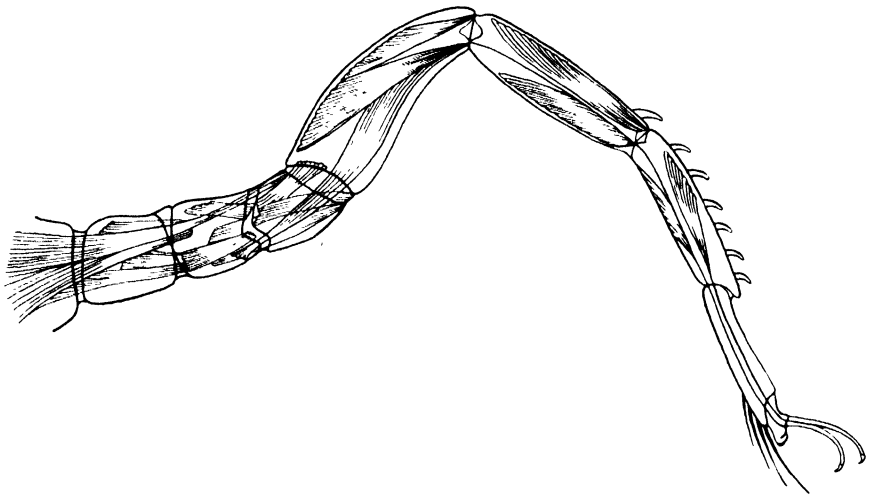


FIG. 57.—Leg of Solpugidæ, showing muscles. After Roewer.

ambulatory limbs. They are carried stretched out in front and used as additional tactile organs, a habit found also in the Pedipalpi. This leg consists of seven segments, and its femur is divided into two ; it ends in a tarsus of one segment. The second leg is a true ambulatory limb and ends in a tarsus of one to four segments. It has

two femora and its tibia and metatarsus bear double or single rows of dorsal or ventral spines, much used in classification. In some genera the tibia has very characteristic dorsal projections at its distal end.

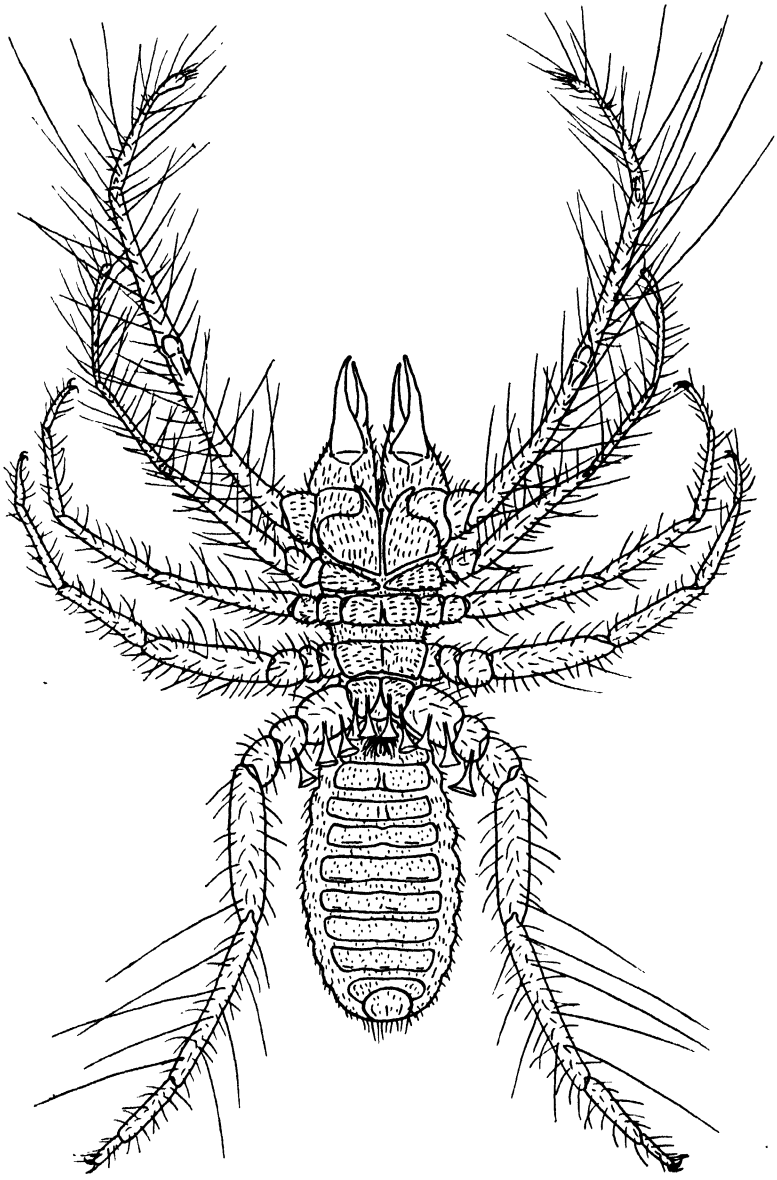


FIG. 58.—A Solifuge—Ventral Aspect. [Species *Galeodes arabs.*]

The third leg has two trochanters and two femora. In general the spines and setæ of the third leg resemble those of the second, but the spinal armature of the metatarsus is weaker than that of the second leg. The aberrant family Hexisopodidæ

is exceptional in this respect, as in many others. Between the second and third coxæ is a broad area of softer epidermis, in which lies the opening of the prosomatic tracheæ.

The fourth leg is the longest and strongest of all. It resembles the third in general, but the tarsus is often composed of more segments, and has a series of ventral spines. The coxæ of this pair are inclined towards each other, while those of the second and third lie in the same transverse line ; consequently, behind the fourth coxæ there is a triangular space in which the genital aperture lies. Each leg of this pair carries five characteristic appendages, known as malleoli or racquet-organs (Fig. 58). There are two of these on the coxa and first trochanter and one on the second trochanter. Some biologists believe these remarkable structures to be peculiar sense organs ; others believe that they have no function beyond providing support for the heavy opisthosoma, but their true nature is really unknown. Whatever they may be, they are peculiar to the Solifugæ and nothing like them is found in any other animal.

In the family Hexisopodidæ the form and arrangement of the legs differ from that of all others. The first pair of legs are much reduced and the fourth pair bear only three racquet-organs each. The legs in all the Solifugæ bear spines or setæ of every degree of stoutness from short sharp spikes to long hair-like setæ. German arachnologists divide these spines into five classes, Dornen, Borsten, Haare, Ctenidien and Papillen, according to their thickness. There is not much evidence for thinking that any of these have any other function than that of organs of touch, as in all the Orders of the Arachnida, but in the Solifugæ they seem to be more plentiful and more sensitive than in their allies. No other Arachnid is so " hairy " that to a casual glance it looks like a ball of fluff, and no other can show such proportions as those found, for example, in the fourth leg of the male *Solpuga monteiroi*, where a leg 2 mm. in diameter carries setæ 3 cm. long. It is said that if the tip of but a single seta be touched even with a hair, the animal responds instantaneously.

The **opisthosoma** of the Solifugæ is always a regular oval, the posterior margin being a smooth curve with no trace of post-anal structures. It is always conspicuously and completely segmented, and the somites carry both tergites and sternites. The number of somites appears to be ten, but eleven are present in the embryo and this number is really retained in the adult, though the first somite is much reduced. Its sternite is a small triangular plate between the fourth coxæ and its tergite is similar in shape and lies almost hidden between the prosoma and opisthosoma. The genital orifice is placed on the second sternite. It is a longitudinal slit-like aperture, peculiar among the Arachnida in being guarded by movable lips, so that it can open and close. The third, fourth and fifth sternites show just behind their posterior edges the orifices of the opisthosomatic tracheæ. There is a pair of these behind the third and fourth sternites and a median single one behind the fifth.

The epidermis separating the segmental plates is soft and elastic so that the length of the body of any specimen may vary according to circumstances. In this respect, as also in its general form, the body of the Solifugæ closely resembles that of the

Chelonethi. The opisthosoma contains many diverticula of the mesenteron so that the animal is visibly longer when well-fed and shorter when starved. During pregnancy the increase in the size of the opisthosoma is immense; the stretched epidermis seems to be almost at bursting point and the heavy mass is nearly beyond the animal's control.

Distribution

The Solifugæ are confined to tropical or sub-tropical regions (Fig. 59), and in Europe occur only in the south-east of Spain. In Africa they are found in the northern, eastern and southern parts, but are absent from the majority of the western coast and the land behind it. In Asia, Solifugæ are found in Arabia, Persia, Turkestan and India, coming west as far as the coast of Palestine and north as far as the Caspian Sea.

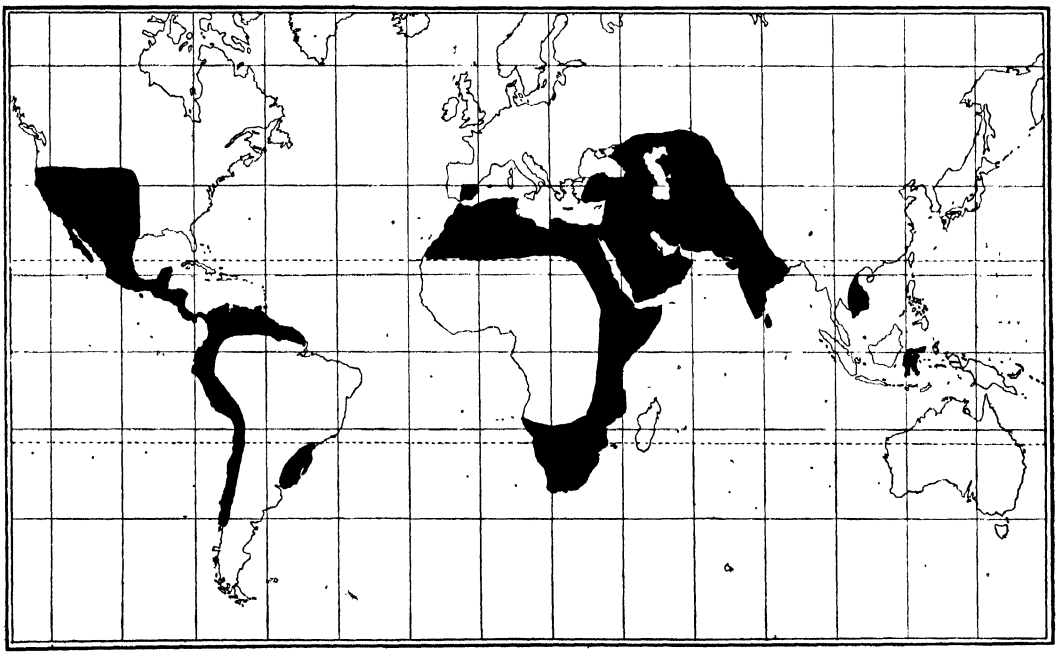


Fig. 59.—Map showing Distribution of the Solifugæ.

They also occur in Indo-China and Celebes. The American Solifugæ belong to the families Eremobatidæ and Ammotrechidæ, and are confined to a large area on the west of the States and a relatively narrow strip along the north and west coasts of South America. They are also found in Uruguay and the extreme south of Brazil.

In the north they have recently been found near the hot springs of Western Montana and in Nebraska.

Classification

The first, and for many years the generally accepted, reliable classification of the Solifugæ was that of Kraepelin [52*a*]. In this there were but three families—

1. Galeodidæ.
2. Solpugidæ.
   - i. Rhagodinæ.
   - ii. Solpuginæ.
   - iii. Dæsiinæ.
   - iv. Eremobatinæ.
3. Hexisopodidæ.

But in 1901 only 164 species were known, whereas in the recent work of Roewer [70] 595 species are distinguished. These have been arranged in 134 genera and 10 families: the following is a key to the latter.

TABLE XVII

Separation of the Solifugæ into Families

1 (2).	Anal somite of opisthosoma hemispherical; first metatarsus with many ventral spines; all tarsi of one segment. Old World	Rhagodidæ
2 (1).	Anal somite flattened; first metatarsus unarmed; second to fourth tarsi with one or more segments	3
3 (4).	All posterior legs adapted for digging; fourth tarsi without claws; prosoma without visible tergites. South Africa	Hexisopodidæ
4 (3).	Posterior legs not adapted for digging and with two claws; prosoma normally segmented	5
5 (6).	Second and third tarsi with dorsal spine above claws. New World	Eremobatidæ
6 (5).	Second and third tarsi without such spine	7
7 (8).	First tarsi with two inconspicuous claws. Old World	9
8 (7).	First tarsi without a trace of claws	13
9 (10).	Claws of second to fourth tarsi without hairs; tarsus of pedipalp immovable	11
10 (9).	Claws of second to fourth tarsi hairy; tarsus of pedipalp movable. Old World.	Galeodidæ
11 (12).	Second to fourth tarsi of one segment	Karschiidæ
12 (11).	Second to fourth tarsi of two segments; African	Ceromidæ
13 (14).	Second and third tarsi of one or two segments; fourth tarsus of not more than four	15
14 (13).	Second and third tarsi of one or two segments; fourth tarsus of six or seven. African	Solpugidæ
15 (16).	Male flagellum consisting of a group of spines; movable finger of female chelicera with many small teeth in front. Old World	Melanoblossidæ
16 (15).	Male flagellum like an ear of corn; female chelicerae without such teeth	17
17 (18).	Male flagellum immovable; New World	Ammotrechidæ
18 (17).	Male flagellum movable; Old World	Dæsiidæ

TABLE XVIIA

Separation of the Karschiidæ into Sub-Families

1 (2). Cheliceræ with many teeth . . . . . Karschiinæ
2 (1). Cheliceræ with few teeth, movable finger with three only. . Gylippinæ

TABLE XVIIB

Separation of the Melanoblossiidæ into Sub-Families

1 (2). Fourth tarsi of one segment. . . . . Dinorhaxinæ
2 (1). Fourth tarsi of two segments . . . . . Melanoblossiinæ

TABLE XVIIC

Separation of the Dæsiidæ into Sub-Families

1 (2). Fourth tarsi of one segment . . . . . Gnosippinæ
2 (1). Fourth tarsi of two, three or four segments . . . 3
3 (6). Fourth tarsi of two segments 4
4 (5). Third tarsi of one segment . . . . . Blossiinæ
5 (4). Third tarsi of two segments . . . . . Triditarsinæ
6 (3). Fourth tarsi of three or four segments 7
7 (10). Fourth tarsi of three segments 8
8 (9). Third tarsi of one segment . . . . . Gluviopsinæ
9 (8). Third tarsi of two segments . . . . . Gluviinæ
10 (7). Fourth tarsi of four segments . . . . . Dæsiinæ

TABLE XVIID

Separation of the Solpugidæ into Sub-Families

1 (2). Fourth tarsi of six segments . . . . . Ferrandiinæ
2 (1). Fourth tarsi of seven segments . . . . . Solpuginæ

TABLE XVIIE

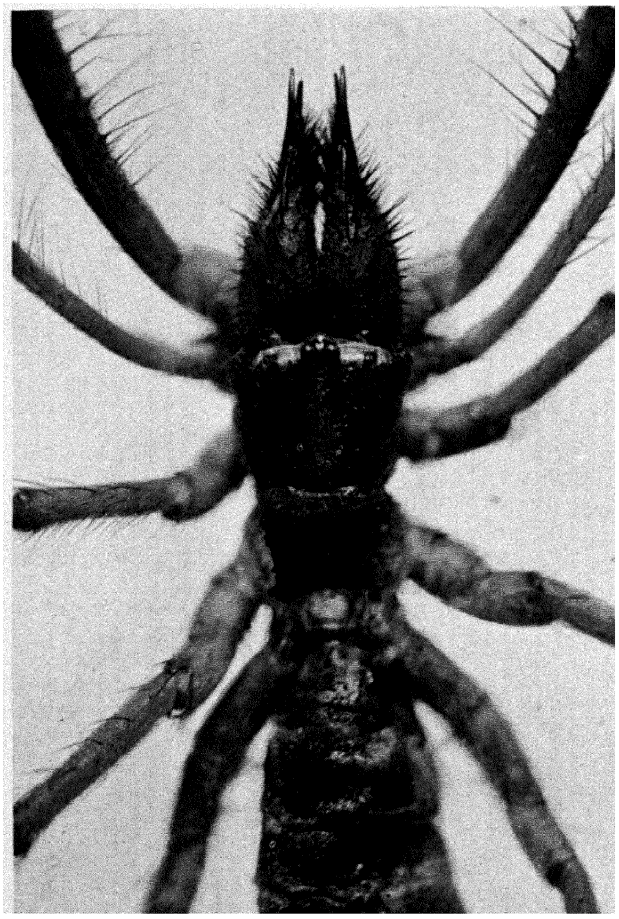
Separation of the Eremobatidæ into Sub-Families

1 (2). Fourth tarsi of one segment. . . . . Eremorhaxinæ
2 (1). Fourth tarsi of three segments . . . . . Eremobatinæ

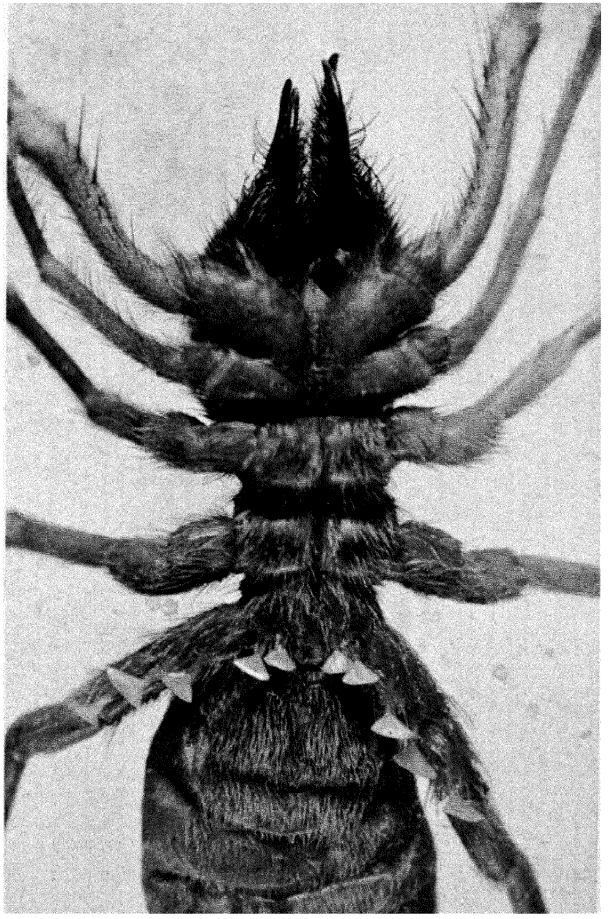
TABLE XVIIF

Separation of the Ammotrechidæ into Sub-Families

1. Fourth tarsi of one segment . . . . . Saronominæ
2. Fourth tarsi of two segments . . . . . Mummuciinæ
3. Fourth tarsi of three segments . . . . . Ammotrechinæ
4. Fourth tarsi of four segments . . . . . Oltacolinæ



(i) Dorsal View



(ii) Ventral View

GALEODES ARABS

PLATE VII

The fierce rays of the tropical sun have scorched the sands of the desert and night has fallen before the Wind-Scorpion ventures out upon the chase. Armed more powerfully than any other creature, he stands for speed, for fury, for sudden death, while the Sable Goddess so cloaks his crimes that men know not his ways nor tell of his deeds. Mysterious in life, and no less mysterious in death, we look upon his hairy body, wondering what messages these spines convey, and what kind of an existence is that in which every event is a vibration and every sensation is a touch.

Excursus IX

The Arachnida as Formidable Animals.

Many of the Arachnida have the reputation of inspiring fear; Scorpions are commonly avoided as if they were more dangerous than snakes, Solifugæ are shunned and countless people are terrified of Spiders. These facts are interesting because there is no logical justification for so disproportionate a dread. What is the reason and the origin of the fear?

What is fear? Fear is of two kinds. Subjective fear, or, in Spencer's words, "the revival on a given stimulus of past experience of pain," is the consciousness of the changes in blood-pressure and muscle-tone consequent upon the activity of the adrenal glands, and is therefore rightly described as "unfled flight." Objective fear is the secretion of adrenalin itself and is an unconditioned reflex normally elicited by an unexpected noise, a sudden fall or a loss of support threatening stability of posture.

The tonic reflexes which maintain equilibrium respond to tactile impulses from the soles of the feet, to impulses of pressure from the semicircular canals of the ear and to visual impulses from the retinas of the eyes. With the last of these alone are we concerned here. From it there arises a tendency to keep the images of moving bodies on the same place in the retina, a tendency well developed in the lower animals. It results in an orientation and movement of their bodies described as rheotropism. It is clear that if the body is moved or the eye is turned so as to keep the image of a moving object more or less stationary on the retina, the images of the background and surroundings must at the same time be passing across the retina. This is exactly what happens during an unexpected fall and the primitive response is a secretion of adrenalin to fit the body to meet the sudden change in circumstances. This is fear. Just as, according to the James-Lange theory of the emotions, "we feel sorry because we cry," so do we feel frightened because of the physical changes in blood-pressure and muscle tension.

The sudden running of a Spider across the floor, of a Scorpion across the tent-cloth or of a Solifuge across the desert sand attracts the eye, and as the attempt is automatically made to "keep the eye on" the moving animal, images of the back-

ground pass across the retina. The natural response follows and, since all motion is relative, the conscious mind has no difficulty in projecting the origin of the fear to the moving animal.

In complete proof of this explanation of the fear induced by the Arachnida, there is the fact that the sensation appears only in response to a certain speed and slowly moving images do not evoke it. Thus the moving animal to which the conscious mind transfers its emotions must itself run rapidly. Here is the explanation of the fact that fear of rapid animals is common all over the world. Actually it is not the Scorpion or the Spider which in the first place is responsible for our terror, but the rapidity of its motion. No one is afraid of a tortoise or of a snail.

XI

THE ORDER CHELONETHI

False-Scorpions

"Scorpiones terra vivunt; alia dentibus prædantur, alia unguibus, alia latitudine ruunt, alia retro."

Pliny.

Arachnida in which the prosoma is uniform and bears not more than two pairs of lateral eyes, and the opisthosoma consists of twelve visible segments, each provided with a distinct dorsal and ventral sclerite. No pedicle; no telson. Chelicerœ of two segments, small, chelate. Pedipalpi of six segments, large, chelate, provided with tactile setœ and containing poison-glands. Sternum usually absent. Legs of five to seven segments, all tarsi with two claws. Two pairs of respiratory spiracles on third and fourth opisthosomatic segments. Forelegs of male occasionally modified to assist fertilisation.

The **prosoma** of the Chelonethi is covered above by a carapace, quadrate or triangular in shape and almost certainly formed by a fusion of the primitive sclerites. It bears the eyes, two or four in number, when present, but some species are blind. Sometimes there are no transverse markings or furrows, but often these are present, and allow the carapace to be divided into four regions. The first of these is that portion anterior to the eyes, known as the cucullus. In some families the cucullus is not distinctly separate, but in the Garypidæ and Cheiridiidæ it is narrow and elongated. It is morphologically the same part as the usually perpendicular clypeus of spiders and is probably also homologous with the distinct jointed cucullus of the Ricinulei. The posterior, thoracic, portion of the prosoma consists of three parts, called by Chamberlin [2] the ocular disc, median disc and posterior disc. The furrows which separate these regions may be vestiges of the primitive segmentation, but this is not certain. They do not appear to be related to the insertions of the muscles within.

The primitive number of **eyes** is four. Many species, especially in the Monosphyronida, have two eyes, and many are blind, but these conditions have apparently been derived from the primitive possession of four eyes. The eyes themselves are always sessile and are situated close to the fore-edge of the carapace, except when the cucullus is elongated, and the two on each side are always close to each other. Structurally, the eyes are of the prebacillar type, familiar in the indirect eyes of Spiders.

They possess a tapetum and shine by reflected light. No False-Scorpion ever possesses median post-bacillar eyes like the direct eyes of Scorpions and Spiders, a fact which is a definite characteristic of the Order. In the two-eyed forms, the anterior pair of eyes are retained, the posterior pair lost. The anterior eyes in general are directed forwards in slightly divergent directions, the posterior pair backwards and somewhat

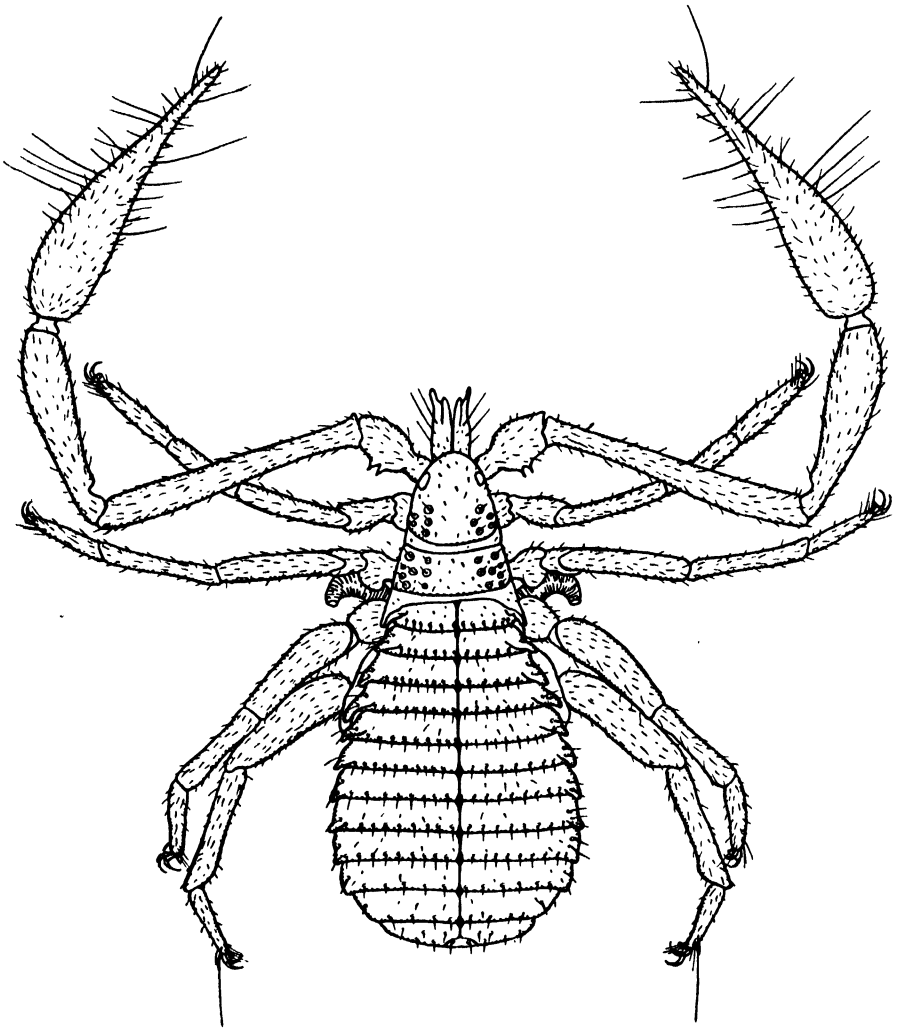


FIG. 60.—Chelonethi—Dorsal Aspect. [Species *Chelifer cancroides*.]

upwards. But False-Scorpions are not animals whose lives are much governed by the sense of sight; they are almost wholly dependent on touch.

In the front of the carapace the **cheliceræ** articulate. These are pre-oral appendages of two joints, specialised for four functions. Their most obvious use is comparable to that of the human hand—they hold the food which the animal is

eating, and they pick up and carry food particles and also the grains of sand used in nest-making. Further, they are spinning organs, bearing on the tip of the movable finger a galea or spinneret from which silk issues. It is to this presence of a silk gland in the chelicerae that the False-Scorpions owe the name of Chelonethi, given them by Thorell. Thirdly, like the corresponding organs of Spiders, the chelicerae are used for cleaning the pedipalpi so that the important sense-organs thereon retain their efficiency and are not clogged by dirt. Lastly, they are themselves sense organs, for they bear setæ and lyrifissures as well as a characteristic flagellum.

The chelicerae of Chelonethi are variable in size but constant in proportions throughout the Order.

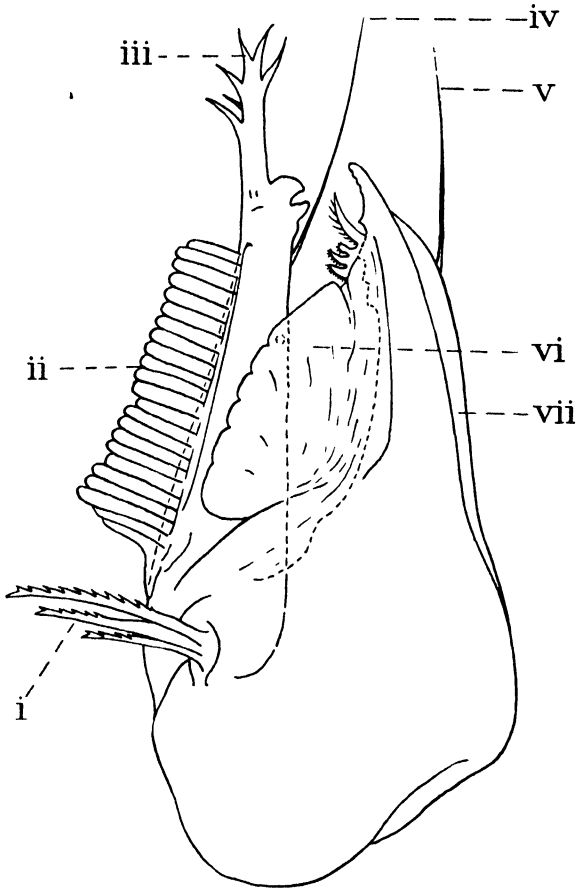


FIG. 61.—Chelicera of Chelonethid. After Chamberlin.
i. Flagellum; ii. Serrula exterior; iii. Galea; iv. Galeal seta; v. Laminal seta; vi. Lamina interior; vii. Lamina exterior.

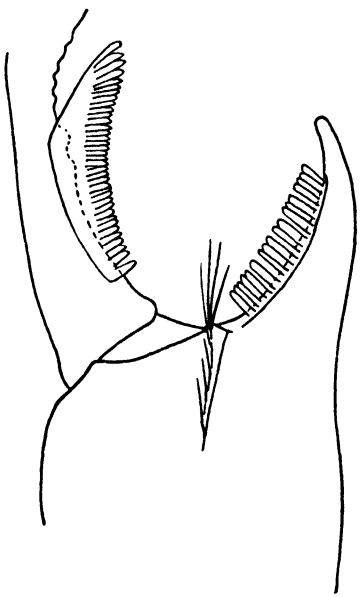


FIG. 62.—Chelicera of *Obisium simile*. After Schenkel.

They may, as in the Feællidæ, be so small as scarcely to project beyond the edge of the cucullus, or they may be almost as long as the cephalothorax, as in the Chthoniidæ. The first has a broad base or palm, prolonged into a pointed fixed finger. The second joint or movable finger articulates ventrally and moves up and down not quite vertically below the fixed finger. Upon the inner edge of each finger is a comb-like lamina or serrula. These are the active agents in the grooming of the pedipalpi, which are drawn through the " jaws " and so over the serrulæ. When the

cheliceræ are large their tips generally cross when the movable finger is closed, the serrulæ are attached to the fingers only for part of their lengths and the galea is usually small or absent. This condition essentially fits the cheliceræ to function as grasping organs. When the cheliceræ are small, they are not so efficient for grasping. The

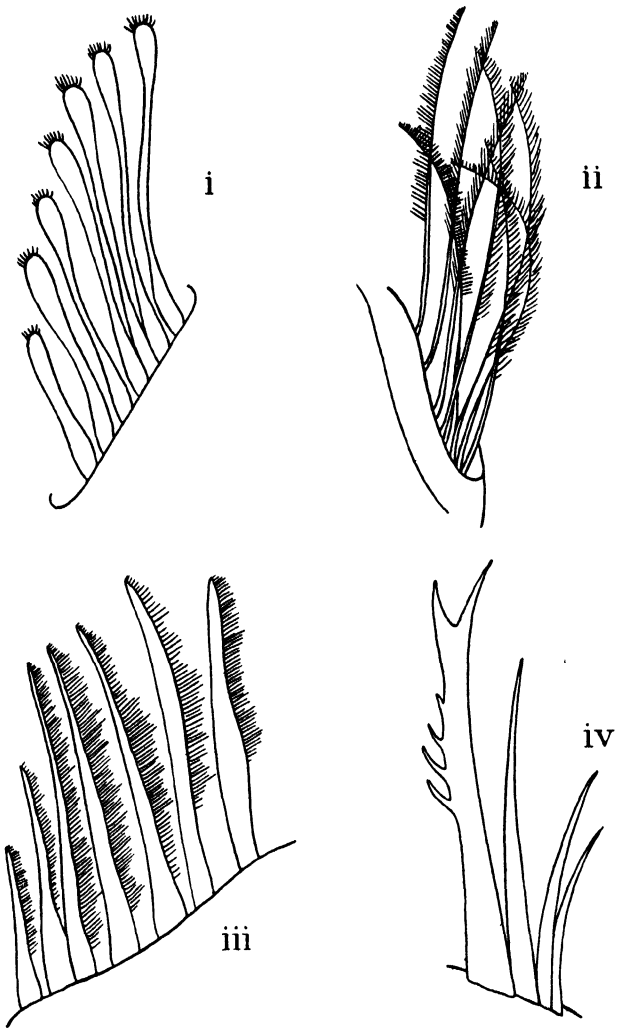


FIG. 63.—Cheliceral Flagella of Chelonethi. After Chamberlin.
i. *Hya heterodonta*; ii. *Chthonius ischnochelus*; iii. *Neobisium imperfectum*; iv. *Atemnus oswaldi*.

finger-tips do not cross, but their tips fit into each other, the serrulæ are attached throughout their whole length and the galea is usually well-developed. The earlier methods of classifying the Order of Chelonethi were based on these differences.

The **flagellum** of the cheliceræ consists of a group of one to twelve blade-like setæ (Fig. 63), arising on the inner side near the base of the movable finger. There

is a considerable diversity in the form and number of the setæ, which is of some value in taxonomic work. The flagellum is probably tactile, but its exact function is unknown. The spinneret or galea is always situated on the outer side of the tip of the movable finger. It is of two types, a short chitinous tubercle or a slender, translucent and often branched tube.

The **pedipalpi** are organs which are of the greatest importance, not only as the principal weapons but also as the bearers of many tactile setæ. They also function in some species as secondary sexual organs. They are invariably six-jointed and chelate (Fig. 64). The first segment or coxa is provided with a gnathobase or manducatory process and is often called the maxilla. It bears a pair of delicate lamellæ, essential components of the mouth-parts. The femur and tibia are the longest joints and can be bent to a very small angle on each other. The metatarsus and tarsus compose the chela. The latter forms the movable finger and is articulated

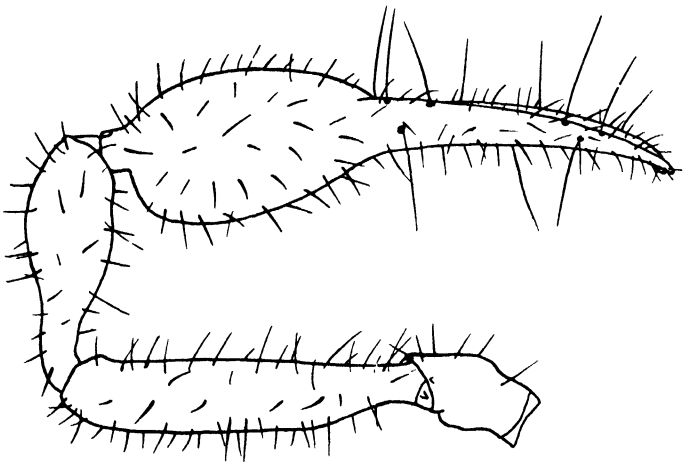


FIG. 64.—Pedipalp of Chthonius. After Beier.

ventrally so as to work against the fixed finger above. It is opened by blood-pressure and closed by a powerful adductor muscle which is spread within the swollen basal part of the metatarsus.

The form of the pedipalp is very diverse; so great indeed is the variation that it is scarcely an exaggeration to say that it is different for every different species. There is generally a slight sexual dimorphism, the limb of the female being stouter than that of the male. The pedipalpi normally contain poison-glands situated in the interior of the fingers with ducts opening at an orifice just below the tip of the last tooth. These glands may be present in both fingers or in either finger only or be absent altogether. Just posterior to the poison-tooth or venedens a blade-like modified seta, the lamina defensor, is found. Its function is unknown.

The metatarsus and tarsus together carry a number of tactile setæ. These are long, simple and slender structures, each inserted at the bottom of a small depression.

Ordinary " non-tactile " setæ have not this depressed insertion. Typically each chela has twelve setæ, though sometimes fewer and often more are present. The twelve are arranged in three series of four, one series on the exterior face of each finger and one on the inner face of the fixed finger.

The eight **legs** are naturally divided into four pairs, for throughout the Order the forwardly-directed first and second pairs are different from the backwardly-directed third and fourth pairs. Owing to this distinction, Kästner [50] has called the former Zugbeine and the latter Shubbeine, but as Chelonethi often run backwards the names are not altogether appropriate. The first leg always closely resembles the second, but the latter is slightly larger and the third is similar to but smaller than the fourth. The legs of the posterior pairs are usually the longest and stoutest.

The legs are typically composed of seven segments, two of which compose the femur. There is no patella. An additional prætarsus, regarded by some as an eighth segment, is usually present. Modifications of this number of segments are found. Frequently the metatarsus and tarsus (telotarsus) fuse, forming a compound miotarsus, and sometimes the two parts of the femur are united. In the Heterosphyronida the forelegs have miotarsi and the hind legs have separate metatarsi and tarsi. In the Diplosphyronida all the metatarsi and tarsi are separate and in the Monosphyronida all have miotarsi.

The prætarsus consists of two claws and a membranous arolium between them. The latter is a short sucking pad, which enables the False-Scorpion to climb perpendicularly and to walk or rest on the under-side of smooth horizontal surfaces. The tarsal claws are not toothed. In the forelegs of the males of most Cheliferidæ the anterior claw is distorted and is slenderer than its fellow. The tip of the miotarsus is often produced into a distinct spine, which is used in mating to open the female genital operculum and assist the entry of the spermatophore.

The **mouth-parts** of the Chelonethi lie between the maxillæ or gnathobases of the pedipalpi. The mouth itself is an aperture at the end of a tube or rostrum formed from dorsal and ventral projections. The latter, the labium or lophognath, is convex or crested dorsally and is immovable. The upper lip, epipharynx or taphrognath, fits over the lower. By a slight upward movement of the taphrognath, the tube which they form can be enlarged, thus exerting a slight sucking effect. The true mouth, however, does not directly touch the food. The coxæ of the pedipalpi enclose the rostrum in a trough-like chamber or camerostome. Within this the laminæ superiores and laminæ inferiores lie closely below the rostrum, forming a compound tube which touches the prey in feeding and conducts the juices to the mouth. In the rostrum is an internal expansion forming a pharyngeal pump similar to but not analogous with the sucking stomach of Spiders.

The ventral surface of the prosoma of the Chelonethi is never protected by a large **sternum**, though a vestige may be found in certain species. This region is generally composed of the coxæ of the legs and pedipalpi, which touch each other and meet in the middle line. However, in certain Chthonioidea a chitinous tubercle

or platelet bearing one or two setæ is found between the third and fourth coxæ. This is a vestige of the true sternum. A secondary sternum is found in the Garypidæ, a mere membranisation between the fourth coxæ, and there is a larger secondary sternum in the small family Sternophoridæ.

The **opisthosoma,** more or less oval in form, is always broadly attached to the

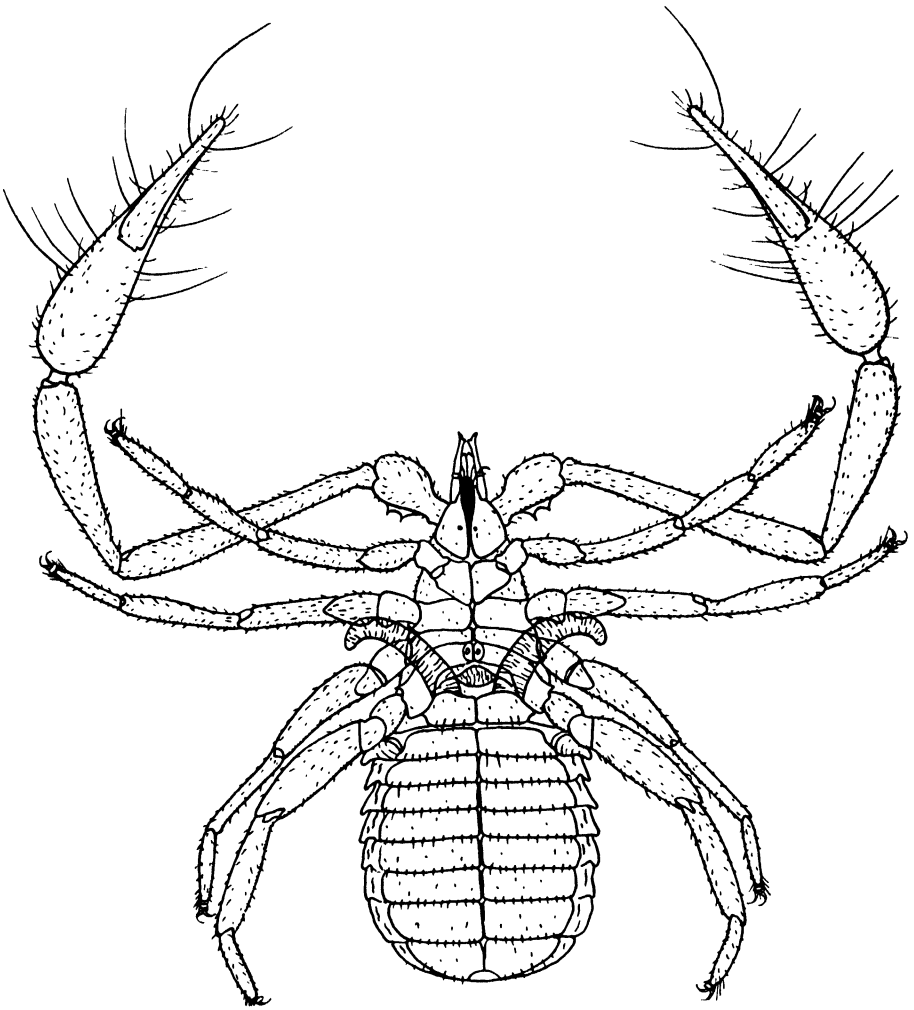


FIG. 65.—Chelonethi—Ventral Aspect. [Species *Chelifer cancroides.*]

prosoma and consists of twelve somites. Each somite has a tergite and a sternite, but in many species the existence of twelve somites is not easy to perceive. This is due to a downward movement of the small twelfth somite and a fusion of its tergite and sternite to form a circumanal ring not very distinct from the eleventh somite. The first sternite is often reduced and sometimes fuses with the second.

These hard plates of the opisthosoma are united by extensible membrane. Since the abdomen contains the digestive and reproductive organs whose bulk is liable to change the size of the opisthosoma is variable, according to seasons and circumstances. In many genera the tergites are medially divided into two halves, so that a suture runs along the centre of the opisthosoma.

The **genital aperture** of both sexes opens on the second sternite, where it appears as a procurved transverse slit near the posterior edge. The male organs within the second and third somites are an amazingly complex invagination of these two sternites. The slit leads to a uterus masculinus externus, and thence to a uterus masculinus internus. From the former arise three large extensible chambers, the median and lateral genital sacs. The lateral ones are the protrusible " ram's horn organs " of the Cheliferinæ, which apparently function in sexual display. The median sac may serve as a seminal receptacle or as a reservoir for the secretions of the accessory glands.

The female genitalia are much simpler. The uterus receives the oviduct, and a pair of spermathecæ also open into it. A median and a pair of lateral perforated plates known as the cribiform plates are found in association with the spermathecæ. Their function is doubtful.

The bodies and limbs of all Chelonethi carry sensory spines and setæ and are well provided with lyriform organs, to which an olfactory function is usually ascribed.

Distribution

False-Scorpions are found everywhere, except in the frigid regions of the Arctic and Antarctic. When the distribution of the separate families is considered, some degree of localisation is found, but several of them are cosmopolitan or practically so. The following summary of family distribution is taken from Chamberlin's work.

Family.	
Dithidæ	West Indies, South-East United States, Brazil.
Chthoniidæ	Cosmopolitan.
Syarinidæ	Rocky Mountains and Pacific Coasts of North America.
Neobisiidæ	Cosmopolitan.
Hyidæ	Philippine Islands.
Ideoroncidæ	Brazil, Paraguay, Mexico, West United States, Sumatra, Siam.
Menthidæ	Deserts of West Mexico and South-West United States.
Olpiidæ	Tropical.
Garypidæ	Tropical.
Feællidæ	Africa, India, Seychelles.
Pseudogarypidæ	Wyoming, Utah, Idaho, Oregon and California.
Cheiridiidæ	Cosmopolitan, except Australasia.
Sternophoridæ	Western Mexico and Australia.
Pseudocheiridiidæ	Nicobars, India, Burma and South Africa.
Myrmochernetidæ	Africa.
Chernetidæ	Cosmopolitan.
Atemnidæ	Chiefly Oriental and Ethiopian, rare in America.
Cheliferidæ	Cosmopolitan.

Classification

When Eugene Simon [11] produced his account of the French False-Scorpions in 1879 he grouped them all in a single family, the Cheliferidæ, with three sub-families and six genera. Simple as this system was, it was the foundation of all modern methods.

In 1891 there first appeared, in a work by L. Balzan [16], the division of the Order into two sub-Orders, Panctenodactyli and Hemictenodactyli, based on the complete or partial attachment of the serrula to the chelicera. In this scheme there were four families and thirteen genera, and it provided the foundation of all the systematic work on the group. It was greatly improved as a result of the labours of Hansen [41] and With [85], and in this modified form is adopted in the recent work of Berland [1].

In 1931 there appeared the striking monograph of J. C. Chamberlin [2]; the result of many years of intensive study, in which the whole Order is subjected to a thorough scrutiny, and a full and comparative account is given of the structure of these Arachnida. The concluding scheme of classification given by Chamberlin is much more elaborate than that of any of his predecessors, and his work is likely to be accepted as authoritative for many years.

Chamberlin's first division of the Order is into groups and three sub-Orders. These contain six super-families and eighteen families. A survey of his system is as follows :

Group	Heterosphyronida	Homosphyronida				
Sub-Order	Heterosphyronida	Diplosphyronida		Monosphyronida		
Super-family	Chthonioidea	Neobisioidea	Garypoidea	Feælloidea	Cheiridioidea	Cheliferoidea
Families	Dithidæ Chthoniidæ	Syarinidæ Neobisiidæ Hyidæ Ideoroncidæ	Menthidæ Olpiidæ Garypidæ	Feællidæ Pseudogarypidæ	Cheridiidæ Pseudocheiridiidæ Sternophoridæ	Myrmochernetidæ Chernetidæ Atemnidæ Cheliferidæ

The division into groups and sub-Orders depends on the possession of separate metatarsus and telotarsus or of a fused miotarsus. We append shortened Tables for the separation of False-Scorpions into families, but a specialist may be advised to consult Chamberlin's monograph, where much more detail can be found.

Note.—More recent than Chamberlin's work is that of Dr. Max Beier, who in *Das Tierreich*, Lieferung 57 and 58, 1933, has proposed a classification into three sub-Orders, Chthoniinea, Neobisiinea and Cheliferinea. These include 14 families with about 160 genera and 800 species.

TABLE XVIII

Separation of the Chelonethi into Super-Families

1 (2).	Heterotarsate, i.e. forelegs possess a fused miotarsus, hindlegs have meta- and telotarsus separate. (Heterosphyronida) .	Chthonioidea
2 (1).	Homotarsate, i.e. all tarsi of same structure. (Homosphyronida)	3
3 (6).	All legs have meta- and telotarsus separate. (Diplosphyronida, except Synsphyronus)	4
4 (5).	Movable finger of chelicera with several teeth . . .	Neobisioidea
5 (4).	Movable finger of chelicera with a single tooth . . .	Garypoidea
6 (3).	All legs have miotarsus. (Monosphyronida). . . .	7
7 (8).	With four eyes	Feælloidea
8 (7).	With two eyes or no eyes	9
9 (10).	Homofemorate	Cheiridioidea
10 (9).	Heterofemorate	Cheliferoidea

TABLE XVIIIa

Separation of the Chthonioidea into Families

1 (2).	Spiracles oblique; epigyne sclerotised	Dithidæ
2 (1).	Spiracles transverse, epigyne not sclerotised	Chthoniidæ

TABLE XVIIIb

Separation of the Neobisoidea into Families

1 (2).	Poison glands in fixed finger of pedipalp only . . .	3
2 (1).	Poison glands in both fingers of pedipalp	5
3 (4).	Pleural membrane smooth	Syarinidæ
4 (3).	Pleural membrane granulate	Neobisiidæ
5 (6).	Pleural membrane granulate	Hyidæ
6 (5).	Pleural membrane in longitudinal folds	Ideoroncidæ

TABLE XVIIIc

Separation of the Garypoidea into Families

1 (2).	Poison gland in fixed finger of pedipalp only	Menthidæ
2 (1).	Poison glands in both fingers	3
3 (4).	Opisthosoma scarcely broader than prosoma	Olpiidæ
4 (3).	Opisthosoma rounded and much broader than prosoma . .	Garypidæ

TABLE XVIIId

Separation of the Feælloidea into Families

1 (2).	Abdomen with two rows of pleural sclerites . . .	Feællidæ
2 (1).	Abdomen without sclerites; carapace with alæ . .	Pseudogarypidæ

TABLE XVIIIE

SEPARATION OF THE CHEIRIDIOIDEA INTO FAMILIES

1 (2).	Legs of five segments	CHEIRIDIIDÆ
2 (1).	Legs of six segments	3
3 (4).	With ovate pseudosternum	STERNOPHORIDÆ
4 (3).	With no pseudosternum.	PSEUDOCHEIRIDIIDÆ

TABLE XVIIIF

SEPARATION OF THE CHELIFEROIDEA INTO FAMILIES

1 (2).	Flagellum of a single blade	MYRMOCHERNETIDÆ
2 (1).	Flagellum of three or four blades	3
3 (4).	Poison gland in movable finger of pedipalp only	CHERNETIDÆ
4 (3).	Poison glands in fixed finger or in both fingers	5
5 (6).	Poison gland in fixed finger only	ATEMNIDÆ
6 (5).	Poison glands in both fingers.	CHELIFERIDÆ

EXCURSUS X

On the Cheliceral Flagellum of Certain Arachnida

A remarkable detail in the structure of the Arachnida is the existence in certain Orders of a "flagellum" on the proximal segment of the chelicerae. A cheliceral flagellum is found in all the Chelonethi on the medio-ventral side, near the base of the inner digital condyle, and consists in general of a group of specialised setæ. In more primitive families the number of setæ is greater than in the more specialised, and varies from twelve, in some of the Chthoniidæ, to one, in the Geogarypinæ. The individual setæ are blade-like structures, feathery or toothed in appearance.

In the Solifugæ the flagellum is limited to and is a mark of the male sex. It is generally but a single structure but it shows specific differences and is a valuable feature in classification (Figs. 56 and 66). In the Scorpions, whose chelicerae are composed of three segments, the second segment is coated with setæ on its inner surface. None of these is developed conspicuously into a flagellum, but their existence in this position is interesting, showing, perhaps, the primitive state from which the flagellum has been evolved.

In the Araneæ the proximal segment of the chelicerae is normally unarmed, but there are certain species in which it carries a spine or seta. The common British myrmecophile *Phrurolithus festivus* is the most familiar: a strong spine directed forwards rises from the anterior surface of the paturon, quite close to the inner edge. Recently Crosby [30] has described a new two-eyed Spider, *Matta hambletoni*, in which the chelicerae are armed in front with a narrow short and blunt tooth (Fig. 67).

What appears to be the same thing is again to be found among the Acari, where the chelicerae of Mites belonging to the genus Parasitus have a short spine at the base of the fixed finger (Fig. 68).

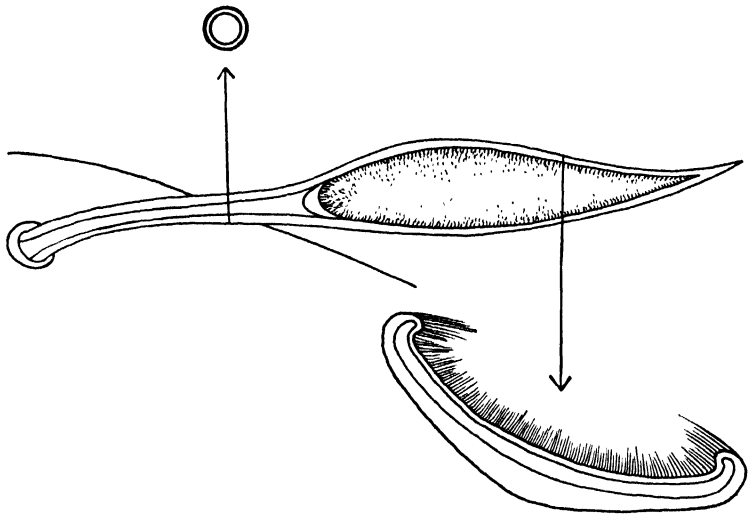


FIG. 66.—Flagellum of male *Galeodes arabs*. After Roewer.

It must be admitted that there is at present no justification for the assumption that all these cheliceral appendages are homologous, although from their situation it may well appear that they are. Nor can they really be described as analogous, for their function is quite unknown.

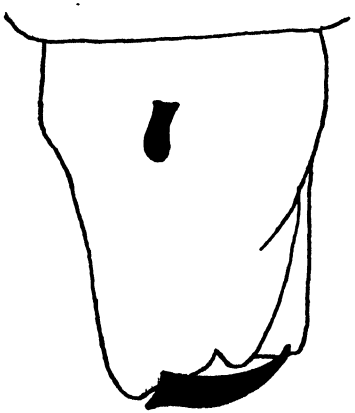


FIG. 67.—Left chelicera of *Matta hambletoni*, a Brazilian Spider. After Crosby, 1934.

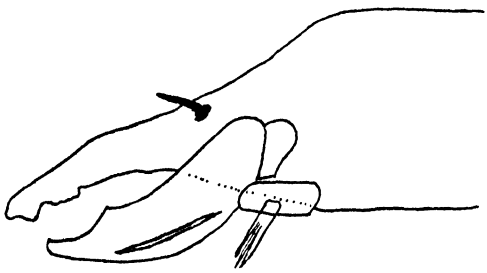


FIG. 68.—Chelicera of the Mite Parasitus, showing Flagellum.

In the Chelonethi an olfactory function has been attributed to the flagellum, with no foundation at all, and it is impossible to describe the organ as anything but tactile. In the Solifugæ the fact that the flagellum is confined to the male is suggestive of a sexual function, but this has not been observed on the rare occasions

when the mating of Solifugæ has been witnessed. On the contrary it has been found that males whose flagella have been removed are in no way handicapped.

It should not be forgotten that in dealing with the function of what is presumably some kind of sense organ we are always dealing not only with the unknown but with the unknowable. It is so impossible to realise what kind of impressions the outside world makes on an animal, especially an invertebrate whose psychic experiences must be very different from our own, that we must be content to regard at any rate some problems as presenting insoluble mysteries.

XII

THE ORDER OPILIONES

Harvestmen

"Iidem percussi a phalangio, quod est aranei genus, aut aliquo simili, cancros edendo sibi medentur."

Pliny.

Arachnida in which the prosoma is uniform and bears two eyes, usually on an ocularium. No pedicle; no telson. Opisthosoma with ten tergites and nine sternites, more or less united. Chelicerœ of three segments, small, chelate. Pedipalpi of six segments, usually small, with or without a terminal claw. Sternum small, lying between second and third coxœ. Legs of seven segments, generally long, the second or fourth pair the longest. Tarsi usually with many joints and provided with one, two or three claws. Respiration by tracheœ, a pair of spiracles on the second sternite. A pair of odoriferous glands in the prosoma.

The **prosoma** of the Opiliones is in general uniformly covered by the fused tergites, but in the sub-Order Laniatores the two posterior segments can be distinguished owing to transverse grooves. The carapace is usually smooth and is generally continuous with a dorsal shield over the opisthosoma.

Near the front edge are the **eyes.** Some genera of the sub-Order Cyphophthalmi are blind but all the other Opiliones possess two eyes. In the genus Stylocellus the eyes are small and round and are placed just above the coxæ of the second pair of legs. They are level with the exoskeleton and in this respect as in their distance apart they are characteristic. In the great majority of the Opiliones the eyes are situated on an ocularium. This is a prominent tubercle, placed farther forwards in the Laniatores than in most of the Palpatores and carrying an eye on each side. The top of the tubercle is often spiny and its shape and size are very different in different families. In the Trogulidæ, the anterior border of the prosoma is produced forwards into two curved processes covered with spines and carrying the eyes (Fig. 70). The under-surfaces of these projections are concave and form a hood over the cheliceræ and pedipalpi, known as the camerostome.

The prosoma also bears a feature characteristic of the Order, the orifices of a pair of **odoriferous glands.** In the Palpatores these orifices are above the coxæ of the first pair of legs and are clearly visible in many genera, although less conspicuous in others. In the Laniatores the orifices are above the second coxæ and are usually narrow oblique openings. In the Cyphophthalmi they are situated at the

ends of small conical processes, the coni fœtidi, between the second and third pairs of coxæ, just behind the eyes. In the past the apertures of these glands have been mistaken for spiracles and the glands themselves, which are often visible through the carapace, for eyes. Hence the Cyphophthalmi were originally described as having stalked eyes. The glands secrete a fluid when the animal is irritated. In many species the odour of the fluid is not intense, but some have been described as emitting a smell like walnuts and others like horseradish.

The **cheliceræ** are of three segments, the first projecting forwards and the second downwards at right angles to it. The second segment is produced on its inner edge and the third is articulated outside this process, forming a chela. These parts are pointed and finely toothed. In Palpatores the cheliceræ are not as a rule large, though they may be somewhat elaborated in males (Fig. 71), but in many genera they are conspicuously carried, stretched out in front and having sharp spines on their inner surfaces.

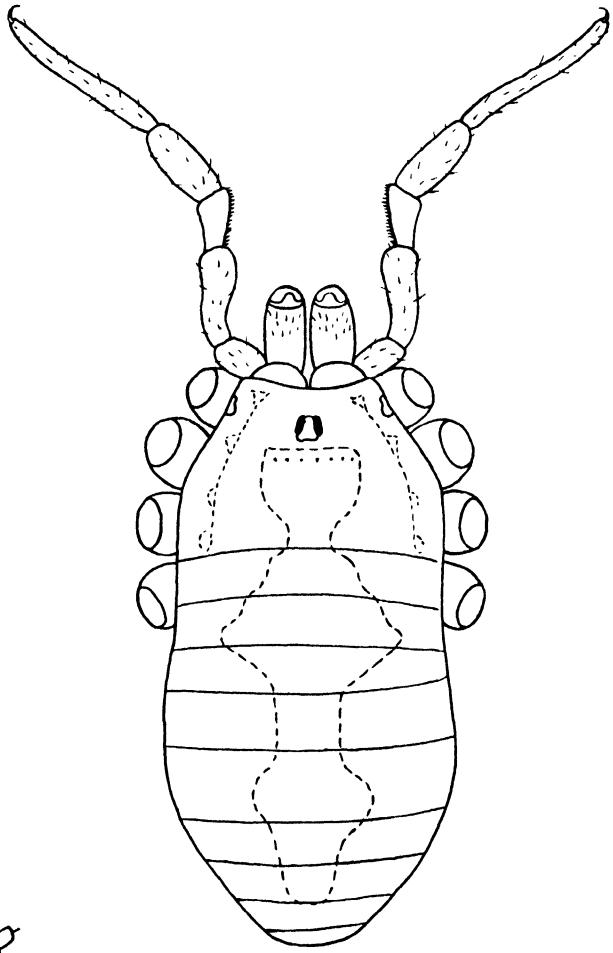


Fig. 69.—Opiliones—Dorsal Aspect. [Species, *Phalangium opilio*, from Happisburgh, Norfolk, 28.viii.33.]

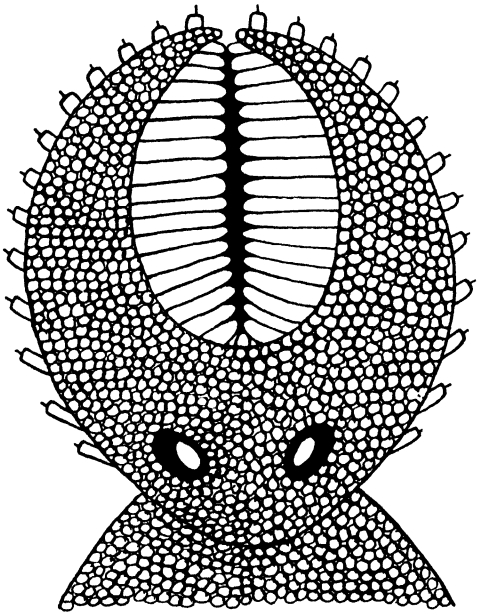


Fig. 70.—Hood of Trogulus. After Kästner.

The **pedipalpi** are of six segments

(Fig. 72). The coxæ bear gnathobases which form part of the rather complex mouth: the other segments are different in the three sub-Orders. In the Palpatores the

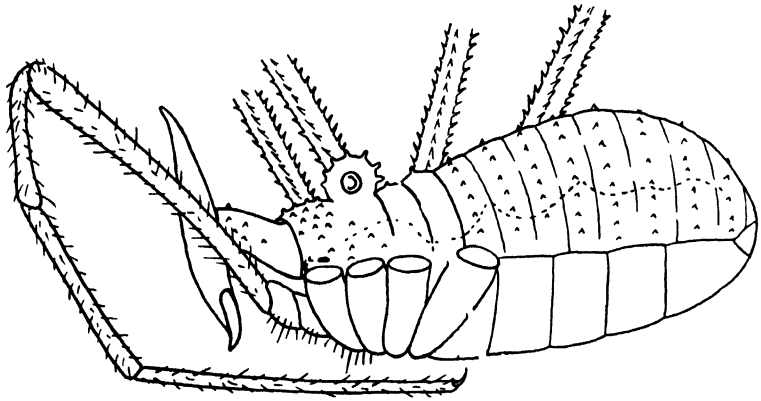


FIG. 71.—Lateral Aspect of male *Phalangium opilio*, showing characteristic cheliceræ. After Roewer.

appendage is relatively slender and almost always spineless. The tarsus usually carries a claw, which when present is almost immovable and is quite short, scarcely

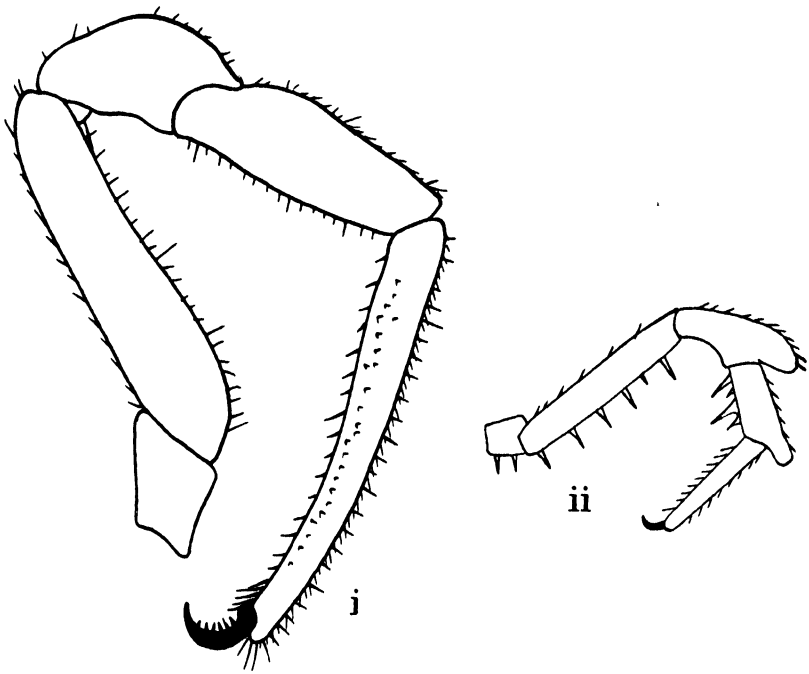


FIG. 72.—Palpi of Opiliones. [Malvern specimens, 1934.]
i. *Liobunum blackwallii*; ii. *Platybunus corniger* (male).

exceeding in length the width of the palp. The tarsus is longer than the tibia when it bears a claw and shorter when it does not. In the Laniatores the pedipalpi

are strong and armed with spines. The claws are large and can be closed against the tarsus so that they act almost like chelate organs. In the Cyphophthalmi the tarsi resemble those of the Palpatores and end in a plain straight claw.

The **legs** are of seven segments (Fig. 73). The first two pairs of coxæ generally carry gnathobases, but in some families these are borne by the first pair only. The

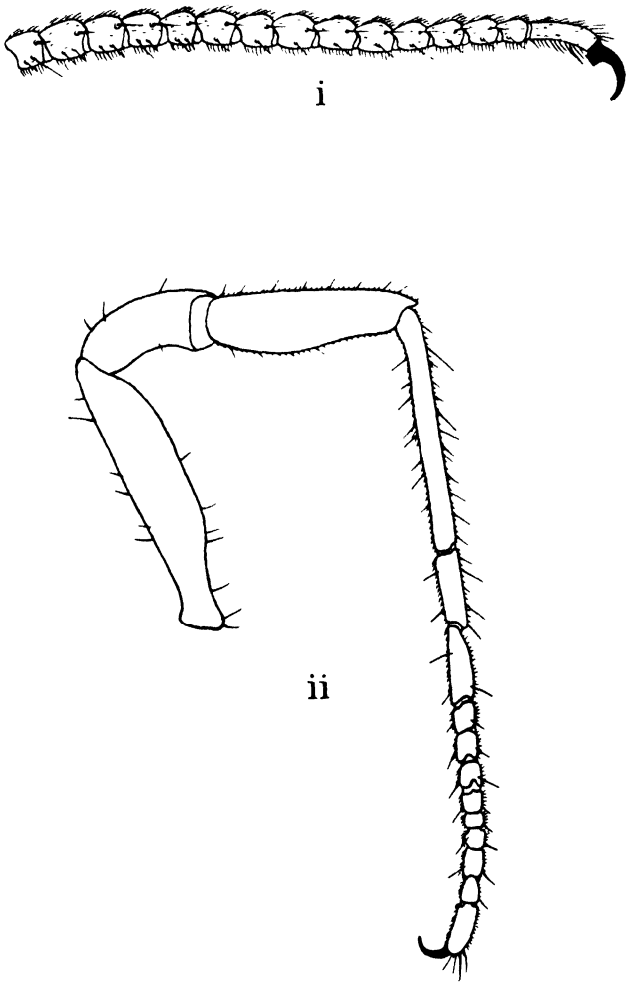


FIG. 73.—Legs of Opiliones. After Kästner.
i. Tarsus of *Opilio parietinus*; ii. Whole leg of *Nemastoma lugubre*.

remaining segments are in some families no longer than the legs of Spiders, but in the majority they are characterised by their extreme length, which indeed forms by far the most obvious feature of most of the familiar Opiliones. In the Cyphophthalmi and the family Trogulidæ the legs are short. In the Laniatores and Palpatores the legs of the first pair are the shortest and the longest are the second pair in Palpatores

and the fourth in most Laniatores. In this sub-Order these posterior legs are often remarkably strong and stout with sharp spines on the femora. The tarsal segments consist of one joint in the Cyphophthalmi but in the other sub-Orders are many-jointed, the number of joints ranging from a few to a hundred or more. In the latter case the tarsus becomes a delicate whip-like segment. In all the Cyphophthalmi and Palpatores the tarsi carry one claw ; in the Laniatores the two anterior pairs of legs have also one claw, while the two posterior pairs have two claws, sometimes pectinate. As a rule the tarsal claws in this Order are simple.

The **mouth** of the Opiliones lies between an epistome above and a labium below. The epistome projects from below the front edge of the carapace, and sometimes, as in the Nemastomatidæ and others, is preceded by an extra piece, the pre-epistome. The sides of the mouth are guarded by the maxillary gnathobases of the pedipalpi and first legs, with the second coxæ sometimes as accessories behind them.

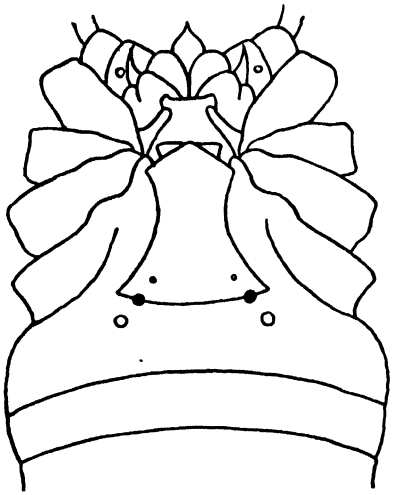
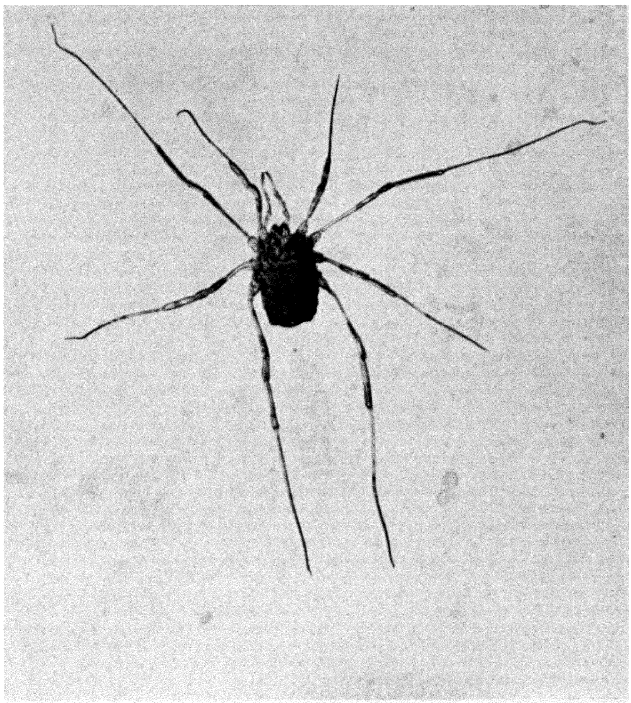


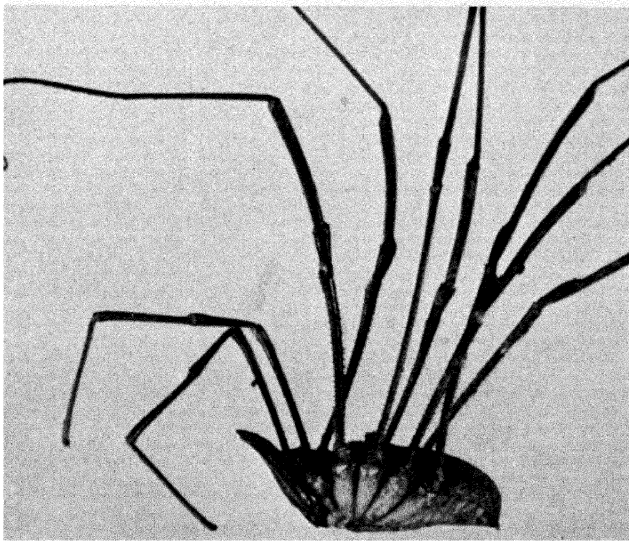
FIG. 74.—Phalangium—Ventral Aspect. From Roewer.

The lower surface of the prosoma is formed from the labium, **sternum** and the coxæ of the legs (Fig. 74). The labium, as mentioned above, may be regarded as one of the mouth-parts. It is probably homologous with the corresponding labium of the Araneæ and represents the sternite of one of the original somites. Behind it is the sternum proper, a single plate. In the Cyphophthalmi and the Laniatores it is long and narrow, reaching as far back as the fourth coxæ. In the Palpatores it is always short ; sometimes it is continuous with the labial portion and sometimes with the genital plates behind it, but it is often largely out of sight, hidden below the coxæ. The coxæ are sometimes all immovable and sometimes all movable in the Palpatores ; in the Laniatores the three posterior pairs are immovable, the fourth pair coalescing with the opisthosoma, while the first pair can be rotated, moving their maxillary lobes towards or away from the mandibles.

The **opisthosoma** is usually so closely united to the prosoma that the distinction between the two parts is not obvious. Its precise structure is not easily elucidated without the comparison of many forms, since segments are often fused together or are missing, and also because the tergites and sternites of the same segment are not always placed opposite each other in the lateral aspect of the adult. The shape of the opisthosoma is usually oval or globular, but it is flattened in the Trogulidæ (Fig. 75). It is covered with a fairly hard exoskeleton often decorated with spines. In European species these are small and usually amount to no more than rows of points indicating segments, but in many tropical forms, as in the Gonyleptidæ, there are more elaborate developments.



(i) *OLIGOLOPHUS SPINOSUS*



(ii) *PHALANGIUM OPILIO*

In the Cyphophthalmi and most of the Palpatores, nine tergites and nine sternites can be recognised, followed by the **operculum anale**, a small circular plate pierced by a transverse or round anus. This operculum is regarded as the tergite only of the tenth somite. Hence in these two sub-families there are ten opisthosomatic somites,

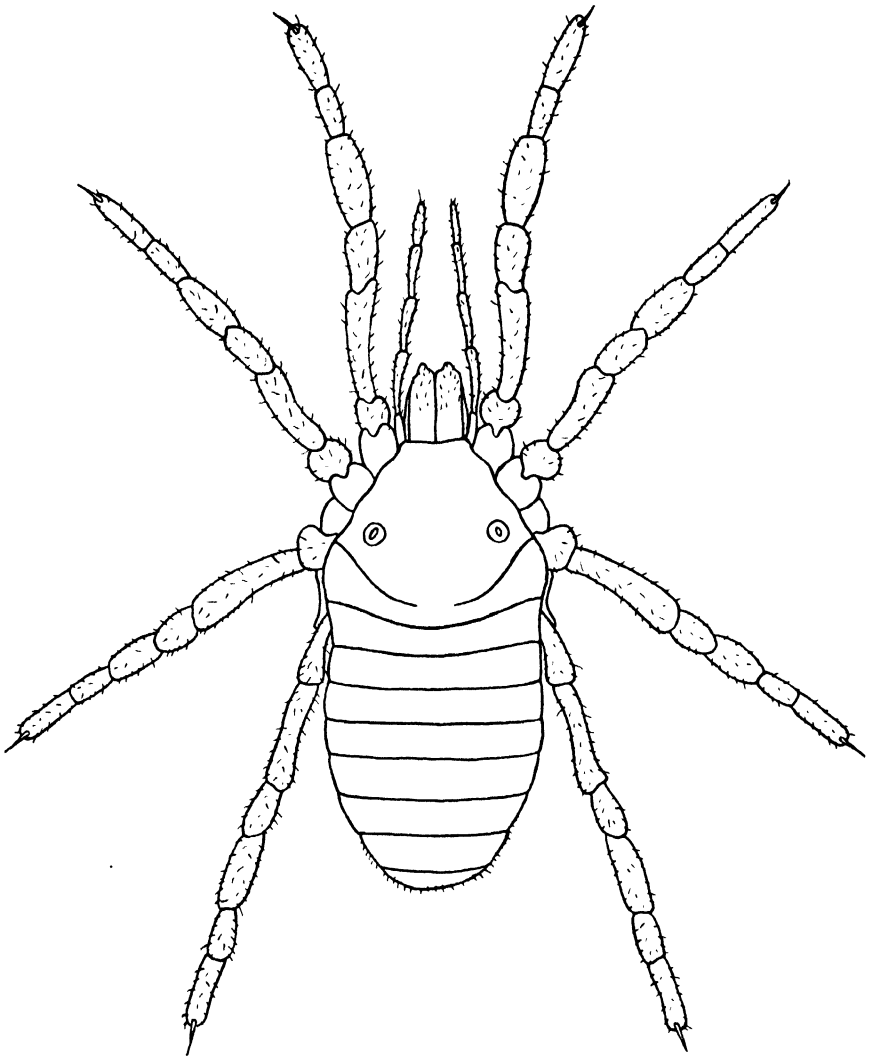


FIG. 75.—Dorsal Aspect of *Purcellia illustrans*, one of the Cyphophthalmi. After Hansen and Sørensen.

of which the last is incomplete, but in many Palpatores the ninth and sometimes also the eighth somites are much reduced or missing. In Laniatores there are generally nine sternites and eight tergites with the operculum anale.

In the Cyphophthalmi the first eight tergites are fused together but can be readily

distinguished; the first sternite bears the external genitalia, the second and third are united and the remainder are readily seen. In the other two sub-Orders the general arrangement is that the first five tergites are fused together into a single dorsal shield which is often also fused with the carapace. The last three somites with the anal operculum are free and are usually directed downwards. The first sternite surrounds the genital orifice and in general the second sternite is extended forwards forming a long plate which carries the genital orifice into a curious position not far behind the mouth.

Distribution

Although the Opiliones are one of the Orders whose distribution may be summarised in the word ubiquitous, there are several features which are of some interest.

The most primitive sub-Order, the **Cyphophthalmi,** has a rather discontinuous distribution (Fig. 70). This fact may of course be compared with the distribution of the primitive Araneæ, the Liphistiomorphæ (Fig. 41) as well as with that of many

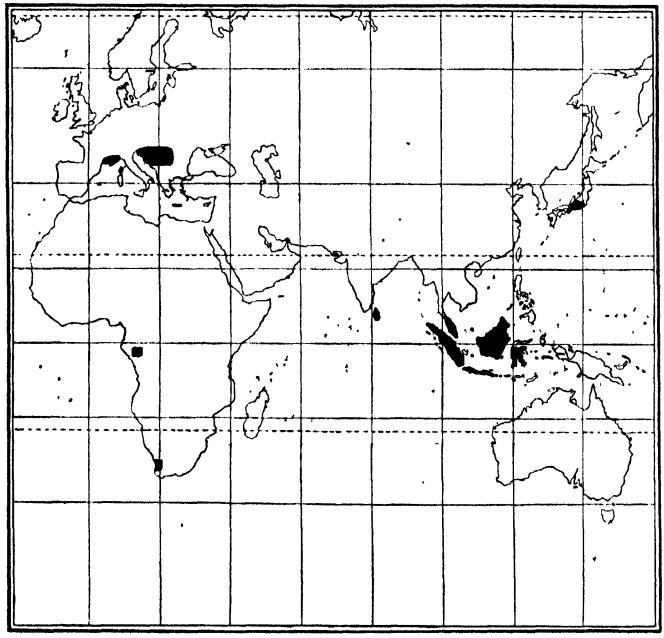


Fig. 76.—Map showing Distribution of the Cyphophthalmi.

other animals of primitive organisation, such as Peripatus. They are generally found in tropical regions, but a few species are Mediterranean and representatives of two genera, Siro and Parasiro, have been found in the south of France. A few have also been found in Oregon.

The **Laniatores** are the most highly specialised sub-Order. They number over

eight hundred species and are the dominant group in southern latitudes. Of the six families, the Oncopodidæ are a small group confined to south-east Asia, while the Cosmetidæ and Gonyleptidæ are found in South and Central America and include almost a quarter of the sub-Order. The Phalangodidæ are widespread and are also the only European family of the sub-Order. Most of the species are small and generally

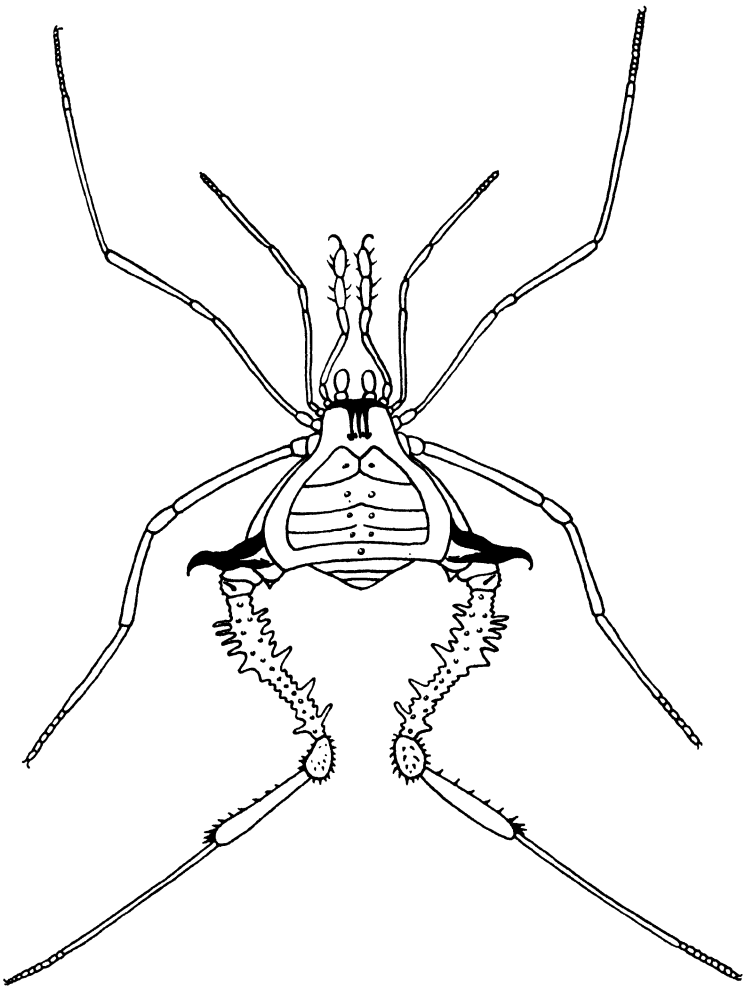


FIG. 77.—Dorsal Aspect of Laniatores. [Species *Gonyleptes janthinus*.] After Berland.

live in caves. The Triænonychidæ are found only in Australia and Africa, where it is the dominant family in the South African fauna.

The **Palpatores** are only slightly less numerous than the Laniatores and include all the familiar Opiliones of the north temperate regions. They extend across the tropics, but are less numerous in hot countries so that they are to this extent supplementary to the other sub-Orders.

The Trogulidæ are a family of slow-moving species, flattened in form and generally found among moss or grass in damp situations. The dorsal surface is covered with a long shield and the front edge of the prosoma is prolonged into the spinous hood or camerostome characteristic of the family. The Nemastomatidæ have a moderately hard epidermis and conspicuously long pedipalpi, usually without a claw. The Ischyropsalidæ are a small south European family, most generally found in caves and in mountainous districts. Their peculiar feature is the length of their cheliceræ, which in some species are as long as the body. The Acropsopilionidæ contains one genus of one species from Chile, and another also of one species from South Africa.

The Phalangiidæ include all the commonest Harvestmen of Europe and North America, and are of very wide distribution.

The relative distribution of the three sub-Orders, which is so characteristic of this group of Arachnida, can well be seen from the following table, part of which is due to Lawrence [55*a*].

	Cyphophthalmi.	Laniatores.	Palpatores.
Europe	3 species.	14 species.	215 species.
North America	1 ,,	31 ,,	69 ,,
Africa	3 ,,	88 ,,	81 ,,
South Africa *	2 ,,	67 ,,	21 ,,
Australia	0 ,,	33 ,,	5 ,,
South America	0 ,,	555 ,,	29 ,,
Eastern Asia	12 ,,	?	?

* South of latitude 17° S.

Classification

The foundations of systematic opilionology were laid by Sørensen, Thorell and Simon, and their methods have never needed revision, but only amplification.

Sørensen in 1873 was the first to divide the Order into two families, Gonyleptidæ and Opilionidæ, and three years later Thorell [77] raised these to the rank of sub-Orders, based on the character of the pedipalpi, under the names Laniatores and Palpares.

Simon [12] in 1879 altered the names of these sub-Orders to Mecostethi and Plagiostethi, because his division was based on the character of the sternum. He also added a third sub-Order, Cyphophthalmi, which is more closely allied to the Mecostethi than to the Plagiostethi, and which included the family Sironidæ, with the fabulous Gibbocellum. (See Excursus XI.)

Roewer's [9] great work, *Die Weberknechte der Erde*, appeared in 1923 and adopts the same sub-Orders, with descriptions of about sixteen hundred species in twelve families. The first divisions of the Order are given in the following Table.

TABLE XIX

Separation of the Opiliones into Sub-Orders

1 (2).	Odoriferous glands opening at the ends of lateral prosomatic tubercles; genitalia not covered by an operculum . .	Cyphophthalmi
2 (1).	Odoriferous glands without tubercles; genitalia covered by a movable operculum	3
3 (4).	Pedipalpi strong, tarsi with strong reflexed claw; anterior legs with single claw, posterior legs with two or three tarsal claws	Laniatores
4 (3).	Pedipalpi feeble, with small claw or with none; all legs with a single tarsal claw	Palpatores (5)
5 (6).	Palpal tarsus shorter than tibia, claw rudimentary or absent	Group Dyspnoi
6 (5).	Palpal tarsus longer than tibia, claw well-developed	Group Eupnoi

TABLE XIXa

Separation of the Laniatores into Families

1 (2).	Four posterior tergites free	3
2 (1).	Circum-anal tergite only separate, rest fused . . .	Oncodidæ
3 (4).	Posterior tarsi with three claws	Triænonychidæ
4 (3).	Posterior tarsi with two claws	5
5 (6).	Pedipalpi directed backwards from the patella . .	Assamidæ
6 (5).	Pedipalpi normally directed	7
7 (8).	Posterior tarsi without a pseudonychium . . .	Phalangodidæ
8 (7).	Posterior tarsi with a pseudonychium	9
9 (10).	Pedipalpi very powerful, tibia and tarsus rounded . .	Gonyleptidæ
10 (9).	Pedipalpi not so powerful, femur, tibia and tarsus long and thin	Cosmetidæ

TABLE XIXb

Separation of the Palpatores into Families

Dyspnoi

1 (2).	No ocular tubercle, two eyes widely separated . . .	Acropsopilionidæ
2 (1).	Eyes close together on an ocularium	3
3 (4).	Ocularium on fore-edge of prosoma, forming a hood which covers the mouth-parts	Trogulidæ
4 (3).	Ocularium remote from fore-edge of prosoma . . .	5
5 (6).	First and fourth femora with tubercles or spines . .	Nemastomatidæ
6 (5).	Femora without tubercles	Ischyropsalidæ

Eupnoi

1.	Only one family	Phalangidæ

Note.—In a recent work on the Laniatores, Henriksen [42] proposes five super-families and fourteen families to cover the species of the sub-Order, except the

Triænonychidæ, which are left as before. This work is based on the notes left by the late Dr. W. Sørensen, who intended to produce a monograph on the group. It is an interesting supplement to Roewer's great volume, but it remains to be seen which system will be found most convenient for general adoption.

The Harvestmen are, surely, the comedians among the Arachnida, animals with rotund bodies ornamented with little spikes, with two eyes perched atop, back to back, like two faces of a clock-tower, with ungainly legs insecurely attached, with feeble jaws and with an undying thirst—a queer assortment of characters, even among queer folk. Dr. Johnson's scornful comment on Gulliver was, " Once you have thought of big men and little men, the rest is easy." Perhaps the same principle applies here, " once you have thought of long legs and short bodies, the rest is easy." But easy or not, the result is sufficiently ludicrous to suggest that Evolution is not altogether unpossessed of a sense of humour.

Excursus XI

On Gibbocellum

The Order Opiliones was at one time believed to include in the sub-Order Cyphophthalmi the genus Gibbocellum, represented by twelve examples of a single species, *Gibbocellum sudeticum*. The story of Gibbocellum is now ancient history, but it will bear repetition, for events of this kind are rare in zoology, and, although regrettable enough, they are not without a humorous aspect.

The author of the species was Dr. A. Stecker [76], an Austro-German. In 1875 he published a paper of fifteen pages, describing an animal, discovered in the Riesengebirge (Sudeten mountains) in Bohemia. This paper was translated into English for our *Annals and Magazine of Natural History* in the following year, when a second paper by Stecker appeared, describing the structure, and especially the microscopic detail, of the animal. This paper was fifty-two pages long and had four plates.

Gibbocellum was manifestly a remarkable creature. It was 2·5 mm. long, and had two pairs of eyes both placed on oblique conical processes : one pair seemed to belong to the thoracic segments, but in the second paper an attempt was made to relate them to the head. It had also two pairs of spiracles and could produce silk from spinnerets at the base of the abdomen.

For some years the genus was bandied back and forth by systematists between the Opiliones and the Chelonethi. Stecker had elevated the Cyphophthalmi to the rank of an Order, but his contemporaries did not accept this. While most of them put Gibbocellum among the Opiliones, Thorell transferred it to the Chelonethi and was later supported in this by Croneberg. In 1884 Sørensen began to show that Stecker's study of Gibbocellum had been very imperfect and that his knowledge of either Opiliones or Chelonethi was not great. A paper of twenty-five pages which

he had written in 1875 on the latter group has been described by Wallis Kew [51*b*] as " worthless."

In 1892, four years after Stecker's death, Thorell agreed that the systematic position of the genus could not be settled without a more trustworthy description of its structure.

In 1904 Sørensen [5] finally disposed of Gibbocellum as a myth ! His arguments, as closely reasoned as those of an able detective, included the following. He pointed out that no other person had ever seen Gibbocellum or any preparation of it or been able either to catch a living specimen in spite of search or to trace one of Stecker's original dozen. Further, that Gibbocellum had the external form of *Cyphophthalmus duricorius* and an internal structure derived partly from Phalangium and partly from the Opiliones, including several mistakes and obscurities present in the early descriptions of these animals.

It only remains to add that Gibbocellum has not reappeared in the last thirty years. A zoologist of to-day, all but overwhelmed by new species that do exist, finds it hard to understand Stecker's motives, for creative fancy has but a small place in biological science.

XIII

THE ORDER ACARI

Mites

"Forsan convenient illi undique ; cum iisdem insectis, quae ex cute humana scabie ac pustulis correpta effodere non fastidivi, quaeve vulgo acari appellari solent."

Linné

Arachnida in which the prosoma is uniform and may bear simple eyes or not. No pedicle ; no telson. Opisthosoma with segmentation almost completely invisible. Chelicerœ and pedipalpi usually small and associated with mouth-parts, which are modified for biting, sawing, piercing and sucking functions. Legs of seven segments ; tarsi usually with two claws and a prœtarsus of varying form. Respiration by tracheœ or cutaneously. Generally a larval stage with six legs, and other stages with eight legs. Parthenogenesis not unknown.

In this Order the almost complete suppression of the segmentation and the many modifications of structure related to varying modes of life have made it inconvenient to retain the customary division of the body into prosoma and opisthosoma in its simplest form. The following notation for the different regions of the body has been suggested (see also Fig. 78) :

Segments of mouth and its appendages = Gnathosoma
Segments of first and second legs = Propodosoma
Segments of third and fourth legs = Metapodosoma
Segments posterior to fourth legs = Opisthosoma

Propodosoma + Metapodosoma = Podosoma
Gnathosoma + Podosoma = Prosoma
Prosoma + Opisthosoma = Idiosoma
Gnathosoma + Propodosoma = Proterosoma
Metapodosoma + Opisthosoma = Hysterosoma

Another complication arises from the various stages of development through which many Mites pass before reaching the adult state. Not only do the eggs of Mites generally hatch as larvæ with six legs, but other differences appear during their lives, so that in all six stages have been recognised. These are—

1. Ovum	3. Larva	5. Hypopus
2. Deutovum	4. Nymph	6. Adult

The ovum is the egg, laid by all Acari. The deutovum is a stage which may occur

either before or after the egg is laid. The outermost coat hardens and partly splits open; this allows more room for the developing embryo within, while at the same time it is protected by the hard case. Practically without exception the newly hatched

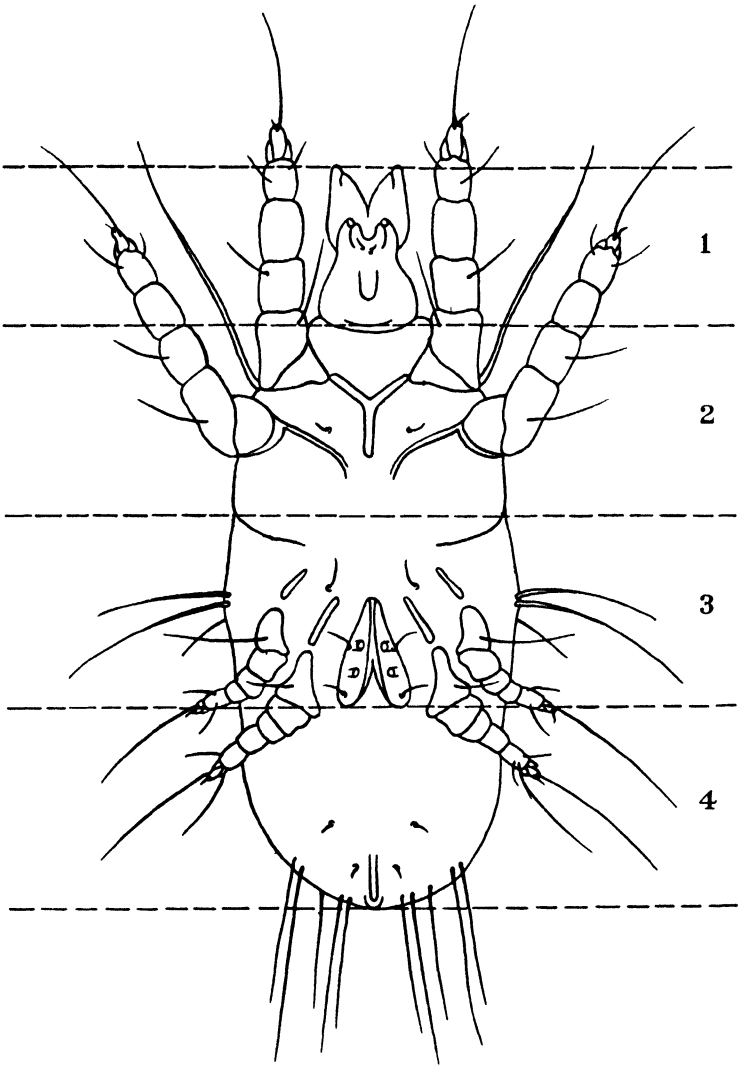


FIG. 78.—Acari—Divisions of Body. After von Vitzthum.

1. Gnathosoma; 2. Propodosoma; 3. Metapodosoma; 4. Opisthosoma.

Mite has but six legs until its first ecdysis, and this six-legged stage is known as the larva. When the fourth pair of legs appear, the animal is known as a nymph until it is sexually mature. In some species the nymph closely resembles the imago or adult; in others there is a considerable difference between them. The hypopus is

a peculiar stage of the Tyroglyphidæ—Cheese-Mites—and their allies, which appears when conditions are unfavourable. The hypopus is then responsible for dispersal of the species to a preferable environment.

In nearly all Mites the **mouth-parts** (Fig. 79) show an elaboration of the normal arachnid plan, forming a complex usually known as the rostrum. This contains in general:

i. The epistome, a forward projection of the gnathosoma, also called upper lip and labrum.

ii. The cheliceræ, sometimes chelate, sometimes unchelate, sometimes simple piercing organs.

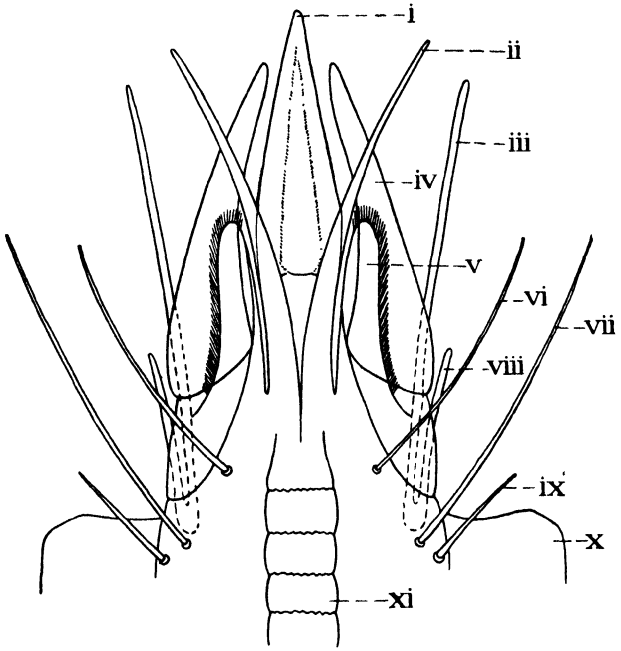


FIG. 79.—Gnathsoma of Macrocheles from below. After von Vitzthum.

i. Labrum; ii. Laciniae malarum internarum; iii. Styli; iv. Corniculi maxillares; v. Paralabra; vi. Setæ maxillares interiores anteriores; vii. Setæ max. int. posteriores; viii. Duplicationes stylorum; ix. Setæ maxillares exteriores; x. Coxæ maxillares; xi. Hypopharynx.

iii. The pedipalpi, typically of five segments, but sometimes acting as prehensile organs, sometimes as sensory organs like antennæ and sometimes modified for fixation.

iv. The pedipalpal coxæ are often fused to form a hypostome, or lower lip, which is especially conspicuous in Ticks.

v. The epipharynx, a forward projection of the anterior face of the pharynx.

These five parts are generally contained within a hollow opening of the fore part of the body, known as the camerostome.

The **legs** of most Acari have six segments, which in general resemble those of

other Arachnida, but the segment corresponding to the patella is so atypical, in musculature and other ways, that it is sometimes renamed genu. The leg-segments are therefore coxa, trochanter, femur, genu, tibia and tarsus. The femur is often divided into two parts, restoring the typical number of seven segments, and the tarsus exhibits much variation.

Because of the comparatively wide differences between the sub-Orders of Mites, it is much more convenient and satisfactory to deal with the characteristics of each sub-Order in turn. In Vitzthum's [81] system of classification which is followed in this book, the Order is divided into six sub-Orders based in the main on the number and position of the tracheal stigmata or spiracles. The distinctions between the sub-Orders is given in Table XX.

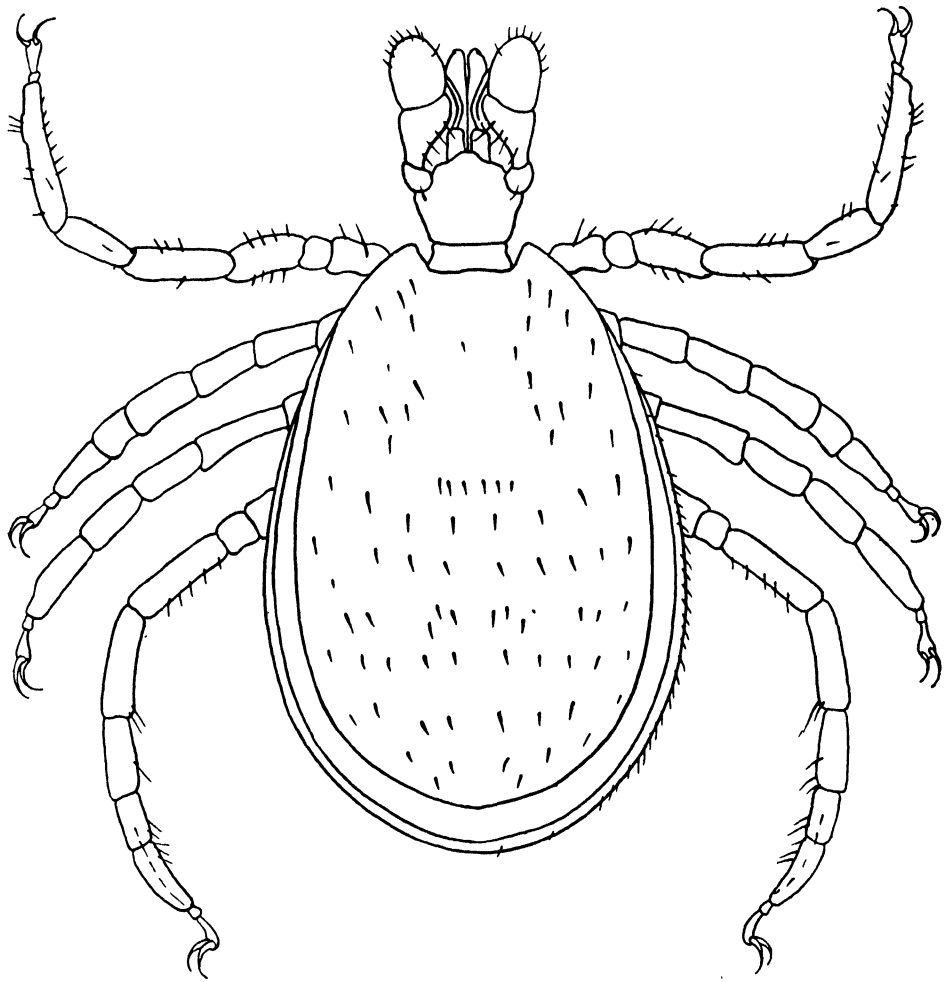


FIG. 80.—Parasitiformes—Dorsal Surface. After von Vitzthum. [Species *Ixodes ricinus*, male.]

NOTOSTIGMATA

In this small group of primitive Mites the segmentation of the body is manifest; the metapodosoma consists of two somites and the opisthosoma of nine. The legs have freely movable coxæ; the first pair function chiefly as sensory organs. The mouth-parts are characteristic, with a short epistome and pedipalpi of only four segments. The cheliceræ are chelate. The Mites of this group conspicuously resemble the Opiliones in general form, but they are brightly coloured, and exhibit a combination of gold, blue and violet hues unknown elsewhere in the Order.

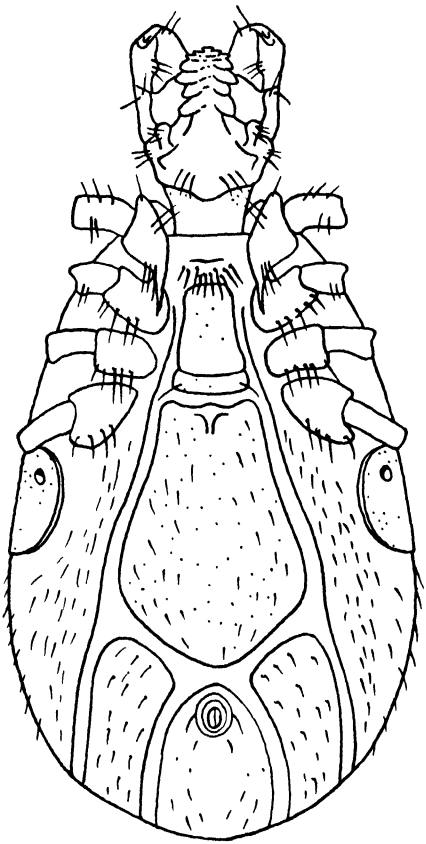


FIG. 81.—Parasitiformes—Ventral Surface. From von Vitzthum. [Species *Ixodes ricinus*, male.]

HOLOTHYROIDEA

This sub-Order consists only of the genus Holothyrus, with less than a dozen species, of interest chiefly because of their size, which reaches 7 mm. and makes them the largest of all the Acari. All segmentation is hidden by a strongly chitinised plate which covers the upper surface of the body. The two tracheal spiracles on each side lie on the third and fourth coxæ. The coxæ are freely movable. These Mites are found in Papua.

PARASITIFORMES

This large sub-Order contains the Mites which have but two prosomatic tracheal orifices, situated behind the second, third or fourth coxæ. The mouth-parts are in the form of a short tube, formed from epistome, hypopharynx and the maxillary lobes of the pedipalpal coxæ, and under the epistome are the cheliceræ, generally of

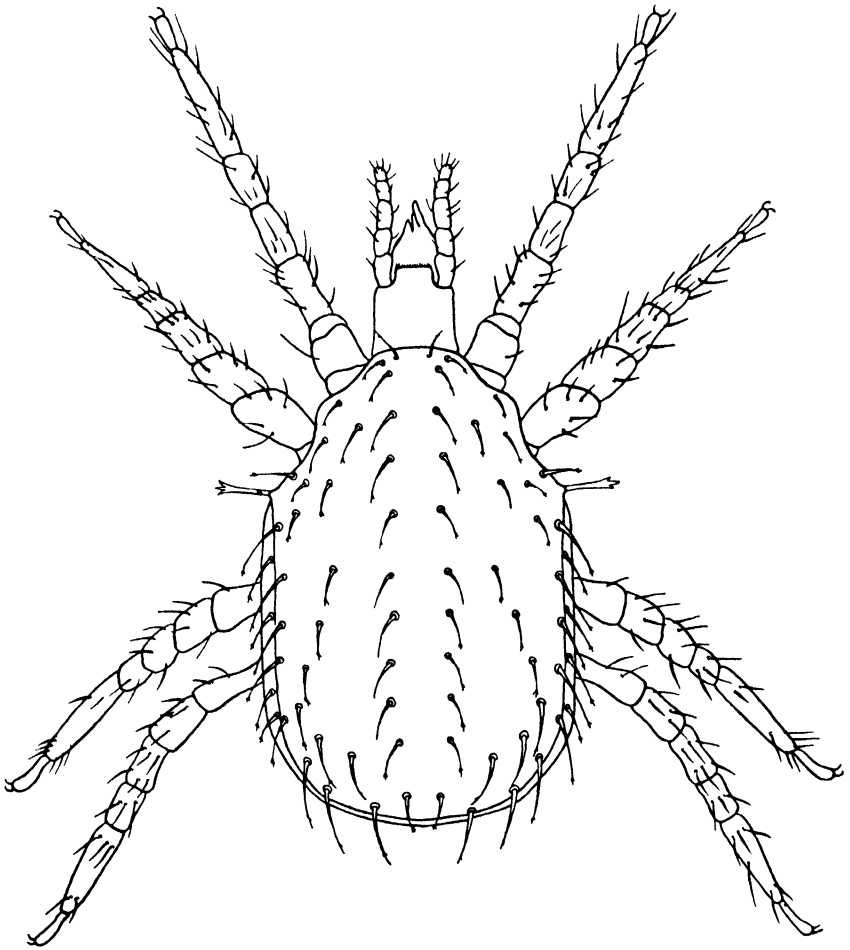


FIG. 82.—Parasitiformes. [Species *Zercoseius ometes*.] After von Vitzthum.

three, sometimes of six segments, each in its own membranous sheath. The pedipalpi have five segments and no tarsal claw. The legs have six or seven segments.

The sub-Order is divided into a super-cohort Mesostigmata, containing the cohorts Gamasides and Uropodina, and a super-cohort Ixodides, which includes the well-known and economically important Ticks of the families Ixodidæ and Argasidæ. A considerable diversity of body-form is shown in these three groups. In the

Gamasides the upper surface of the body is partially protected by hard plates on both prosoma and opisthosoma. In some of the Uropodina this protection is more complete, so that the whole animal is covered by a continuous piece of chitin. On the other hand the Ixodides possess a soft-skinned opisthosoma capable of great distension necessary for the alternate gorging and fasting that is inseparable from the life of a Tick.

The **legs** have the normal segmentation, and in the Ixodidæ the coxæ are immovable. The last three pairs of legs at least are true walking limbs, and their tarsi typically end in a prætarsus, with a fixative pad and a pair of claws. The first pair of legs are used also as sense organs ; they each have one or more specially long sensory setæ, carry no prætarsus and may themselves be developed to a considerable length.

The **mouth-parts** are elaborated (Fig. 83). The palpal maxillæ form the chief part of the lower side of the apparatus : they are separated by a channel, belonging

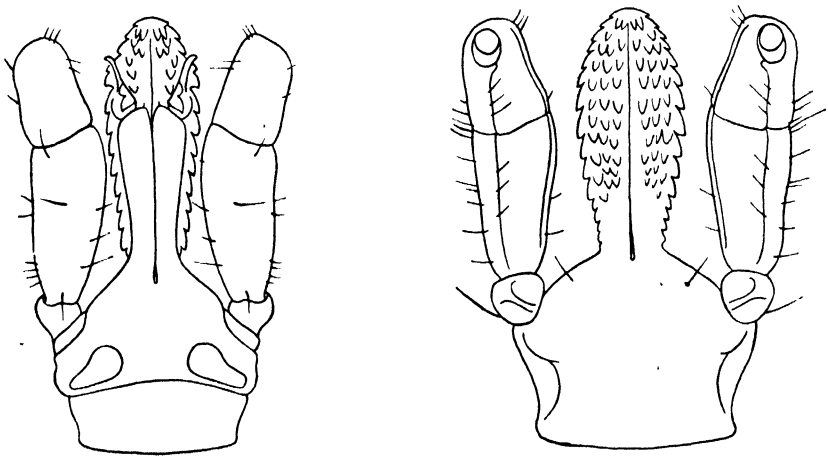


FIG. 83.—Dorsal and Ventral Aspects of Gnathsoma of *Ixodes ricinus*.

to the hypopharynx and serving for the reception of the laciniæ. They also carry the usually horn-like corniculi maxillares. The hypopharynx forms the floor of the oval cavity, which is covered above by the labrum : this has the shape of a dagger-blade, and is set with marginal teeth. Above the mandibles and under the epistome are the cheliceræ. At the sides of the maxillary coxæ are the pedipalpi, with all six segments in most of the Uropodina, but in many forms reduced to three, in the form of a chelate organ.

In the Ixodidæ the movable segments of the pedipalpi are reduced from five to four, and the tarsus is drawn back into the segment before it. The pedipalpal coxæ are fused to the hypopharynx forming a very characteristic hypostome, set with longitudinal rows of backwardly directed hooks. The cheliceræ are chelate, each blade being set with teeth, but the two do not work on each other in the usual way.

An organ which apparently serves the sense of smell is situated on the upper side of the tarsus of the first leg. This is the "**Haller's organ**" of the Ixodidæ.

It consists of a hollow, filled with comb-like teeth, and covered by a thin membrane, a small slit in which allows air to enter the interior. The spines inside are connected to sense-cells. Other Parasitiformes do not possess this organ in its fully developed form, but have a group of setæ in the same place and with the same function.

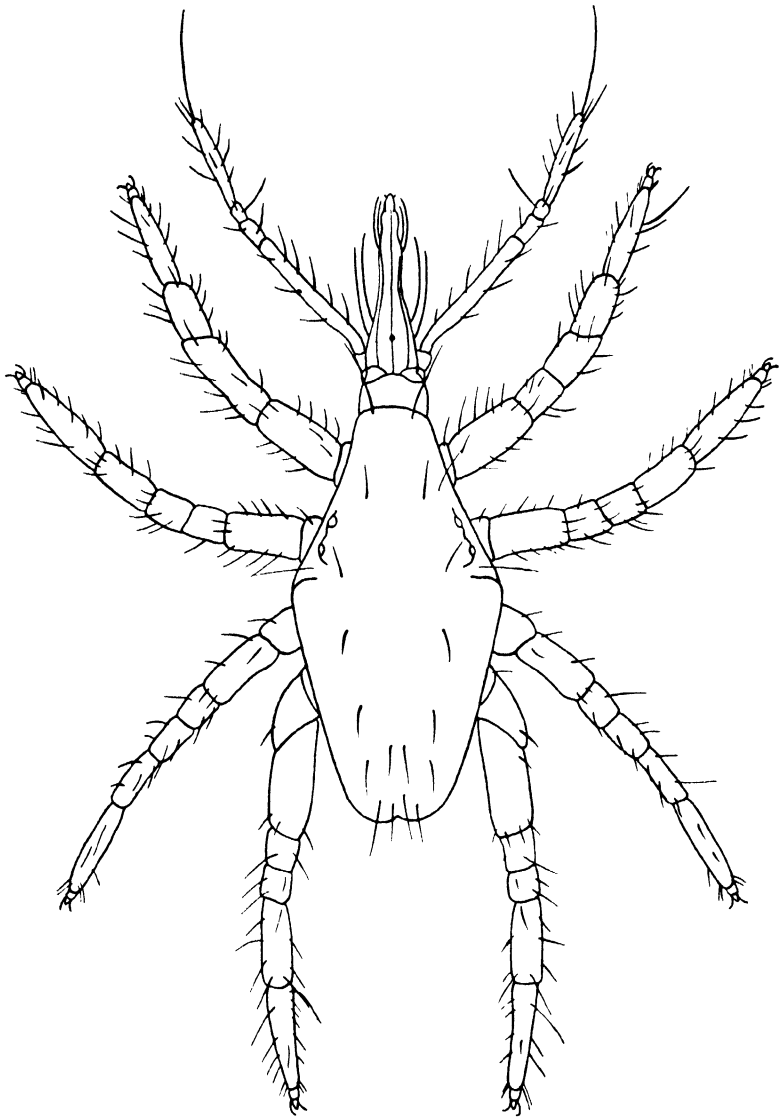


FIG. 84.—Trombidiformes. [Species *Scirus longirostris*.] After von Vitzthum.

Sexual dimorphism is always present in this sub-Order, but is least in the Argasidæ, where it is limited to bodily size and to the character and position of the genital orifice. In many Ixodidæ gynotropic males are found, possessing a small dorsal shield like that of the female.

TROMBIDIFORMES

In this sub-Order a considerable degree of segmentation is retained ; for example the Tarsonemini, except for a few parasites, have five dorsal plates which are composed of united tergites. There is nearly always a transverse division between the pro-

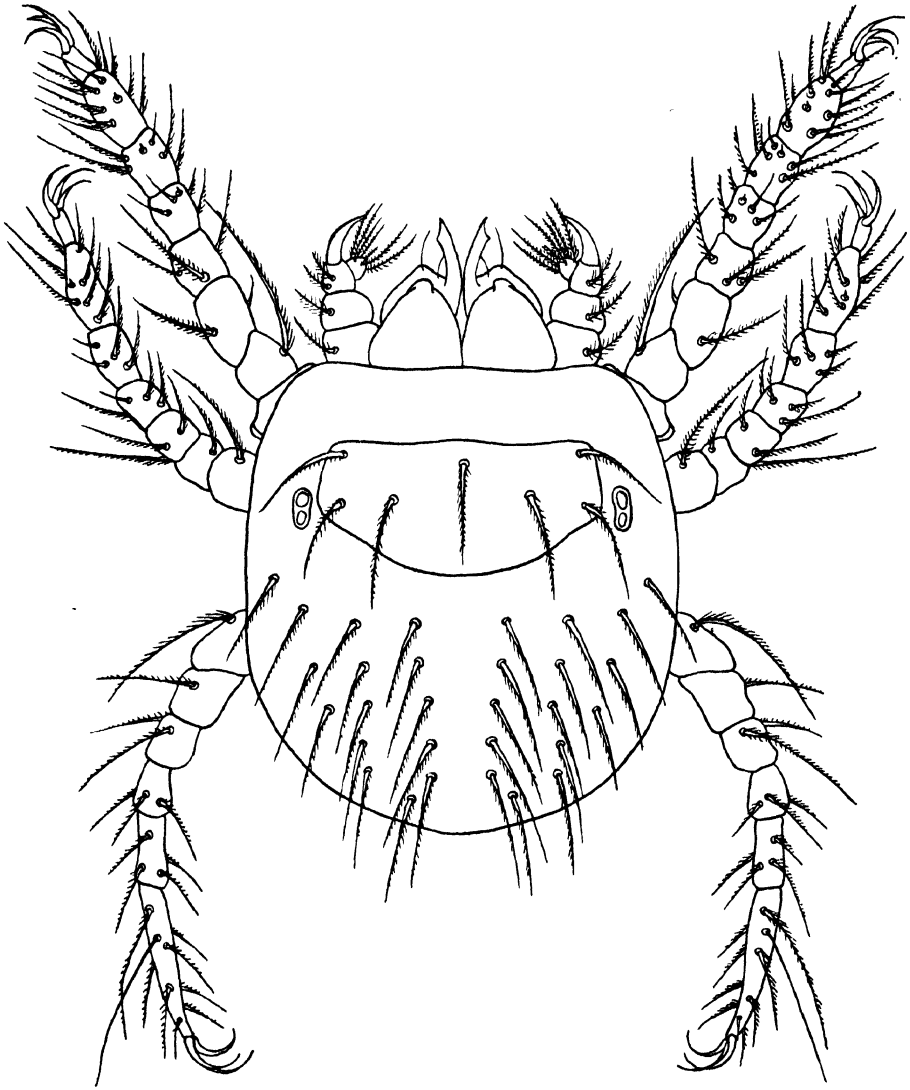


FIG. 85.—Trombidiformes. [Species *Trombicula autumnalis*, Larva.] After von Vitzthum.

terosoma and hysterosoma, and less often a similar distinction between the podosoma and opisthosoma. The ring-like form of the Demodicidæ is, however, not true segmentation, the rings being a secondary, purely ectodermal feature.

The sub-Order is divided into the cohort Tarsonemini which contains the familiar Acarapis and other insect-parasites, the cohort Stomatostigmata which is almost the same as the old Eupodidæ, and a super-cohort Prostigmata including three cohorts. These are, (i) the Eleutherengona, in which are found the " Red-Spiders " or Tetranychidæ, the universal Demodex and the familiar Bdellidæ or Snout-Mites ; (ii) the Parasitengona, which contains the irritating Harvest-Bugs or Trombidiidæ and the fresh-water Mites ; (iii) the Pleuromerengona, which consists of the salt-water Mites.

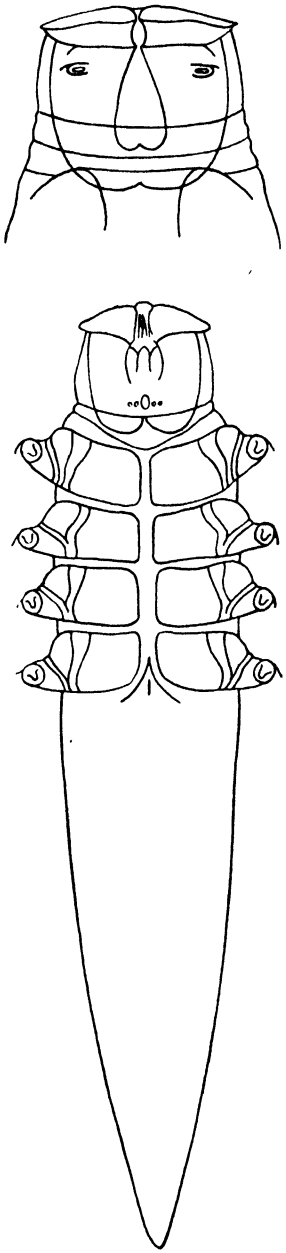


Fig. 86. — Trombidiformes. Dorsal and Ventral Aspects of *Demodex canis*, female. From von Vitzthum.

The **cheliceræ** in this sub-Order are of four different types. They may be scissor-like blades, visibly free from above, but with the pedipalpal coxæ fused to form a plate below them ; they may be clawlike, sliding in a channel formed by the pedipalpal coxæ which may be closed above to form a tube ; they may be piercing organs, working in a tube formed from epistome, hypopharynx and pedipalpal coxæ, or they may be so small that the whole gnathosoma is invisible, being hidden under the propodosoma.

The **pedipalpi** have four or five segments and the legs from five to seven. The legs are often fundamentally normal ; the coxæ are joined to the body, forming hard plates, and in many Water-Mites these coxal surfaces practically form the whole ventral surface. The femora are sometimes divided and the tarsi show secondary segmentation in several genera, as in Linopodes. There may be as many as eighteen tarsal elements and the leg is as thin as a hair and yet terminates in a claw. The contrary condition of fusion of the segments may also occur ; for instance in Myobia the first leg has only three segments, while in Sarcopterinus it is reduced to a mere stump. Yet the short legs of Demodex have the full number of joints. The tarsi end in two claws, usually smooth but sometimes toothed or comb-like. Between them is an empodium, which is either feather-like or consists of a flat pad, more or less covered with setæ.

The **setæ** on the body of the Mites of this sub-Order are of diverse forms, flattened, pointed or plumose, or even reduced to mere articular papillæ. All are believed to have the same function, and they are absent from the water-dwelling genera. There is no Haller's organ on the first tarsi of the Trombidiformes, but in the same place are found well-innervated patches

of setæ, which may have a similar purpose. There have also been described on the propodosoma certain pseudostigmatic organs, which are of unknown function and probably not always of homologous nature. These include very long and fine setæ, bifurcated at the end, set near the middle line, and in adult female Tarsonemini club-shaped setæ on the sides, between the first and second coxæ.

Sex dimorphism is usually lacking in this group.

SARCOPTIFORMES

Segmentation is almost completely lacking in this sub-Order, save that usually the propodosoma is separated by a transverse furrow from the hysterosoma. The sub-Order includes two super-cohorts, the Acaridiæ which contains the Cheese-Mites, Tyroglyphus and its allied consumers of sugar and starch, as well as Sarcoptes, the Itch-Mite, and the Oribatei, the familiar Beetle-Mites. Each super-cohort contains two unequal cohorts, and these are sixty-four families in all.

Generally speaking, the Acaridiæ are soft-bodied and the Oribatei are more or less armoured, but exceptions occur in both groups. Segmentation is almost completely absent in some forms, but as a rule the division between the proterosoma and hysterosoma is visible, at least dorsally.

The **mouth-parts** are never tubular, but are partly or wholly contained in a camerostome on the ventral side of the propodosoma. Generally the cheliceræ are two-segmented cutting or piercing organs. The pedipalpi have from two to five segments and their coxæ are fused to the sides of the hypopharynx.

The **legs** are of four or five segments, with the coxæ sunk in the sides of the body. The Acaridiæ typically possess a prætarsus which carries a single claw ; the Oribatei have no prætarsus, but in the adult state have usually three claws.

The Acaridiæ are almost without exception eyeless ; the Oribatei have usually a single eye or at least a light-sensitive area. The animals are in general nocturnal and the sense of touch is well developed in all species, most of which bear long sensory setæ. In a few Acaridiæ and in most of the Oribatei the mysterious pseudostigmatic organs are found, as in the last sub-Order.

The sexes cannot usually be distinguished in the Oribatei, but in the Acaridiæ the female possesses a genital " bursa copulatrix," opening above the anus.

TETRAPODILI

This sub-Order contains only the Gall-Mites and other plant parasites like those that cause " big bud " in currants. It consists of over six hundred species, included in two families only, the Eriophyidæ and the Phyllocoptidæ.

All these Mites have elongated " worm-like " bodies, in which the original segmentation is indistinguishable. The ring-like appearance of the posterior part is

only an ectodermal feature. A general characteristic is the possession of two long sinuous setæ arising from the posterior end of the body.

The **mouth-parts** consist of maxillæ and cheliceræ: the former touch each other in the middle line, forming a channel above which the piercing cheliceræ slide. The pedipalpi have three segments of which the immovable first is the longest. The third carries a concave sensory plate, which bears a sensitive peg on its under side.

At all stages of growth the Tetrapodili possess four **legs** only. These are short, broad limbs, but consist of the normal number of segments: neither femur nor tarsus is ever secondarily divided. The latter has a dorsal ridge on which are two sensory setæ, and ends in two very small claws. Between the claws is a long comb-like empodium, which in some species is as long as the rest of the leg.

Sex dimorphism is lacking.

Distribution

The Acari are ubiquitous, for their small size, their modes of life and their ability to withstand starvation all help them to achieve universal distribution. As already mentioned, the most northerly land in the world, the north coast of Greenland, numbers Mites among its fauna and they have also been found at least on the fringe of the Antarctic. Mites attain great altitudes, and are, for example, plentiful in the fleeces of the famous sheep, *Ovis poli*, which live at a height of about 15,000 feet on the plateaux of Turkestan. At much greater heights than this they are to be found drifting in the aerial plankton.

Classification

The Classification of the Acari has passed through the stages common to all large groups of animals, the known species of which are constantly increasing in numbers. At present about a thousand genera and at least six times as many species have been described.

At least two of the early systems deserve mention. That proposed by Banks [17] in 1905 was in general use for twenty years, and for simple purposes has much to recommend it. He divided the Order into eight " super-families " with twenty-two families, as follows:

1. Eupodoidea	2 families	5. Gamasoidea	2 families
2. Trombidoidea	6 ,,	6. Oribatoidea	3 ,,
3. Hydrachnoidea	2 ,,	7. Sarcoptoidea	7 ,,
4. Ixodoidea	2 ,,	8. Demodicoidea	2 ,,

Later studies have much increased the number of families but divisions corresponding more or less closely with the original super-families are still to be found.

The classification recommended in Berland's [1] *Les Arachnides* was based on that of Trouessart [79]. This divided the Order into five sub-Orders, according to the position of the orifices of the tracheæ, and included six groups and 42 families, as follows :

1. Astigmata.	1. Vermiformia.	2 families.
	2. Sarcoptiformia.	6 ,,
2. Cryptostigmata.		6 ,,
3. Heterostigmata.		3 ,,
4. Mesostigmata.	1. Gamasina.	11 ,,
	2. Ixodina.	2 ,,
5. Prostigmata.	1. Hydracarina.	2 ,,
	2. Trombidina.	10 ,,

The latest authoritative account of the Acari is that of Hermann Vitzthum [81] in which a most elaborate system is propounded. The first division is into five sub-Orders, which are then further split into super-cohorts, cohorts, sub-cohorts, phalanxes, sub-phalanxes and families. There are 166 families in all.

The following Tables in shortened form carry the division as far as the cohort. Further details will be found in Vitzthum's work already mentioned.

TABLE XX

Separation of the Acari into Sub-Orders

1. Notostigmata.	Eight dorsal opisthosomatic stigmata.
2. Holothyroidea.	Four prosomatic stigmata.
3. Parasitiformes.	Two prosomatic stigmata, behind 2nd, 3rd or 4th coxæ.
4. Trombidiformes.	Two gnathosomatic stigmata.
5. Sarcoptiformes.	No stigmata, or eight podosomatic stigmata.
6. Tetrapodili.	No stigmata.

TABLE XXa

Subdivision of the Parasitiformes

1 (6). First tarsus without Haller's organ .	Super-Cohort	*MESOSTIGMATA*
2 (5). Stigmata behind third or fourth coxæ	Cohort	*GAMASIDES*
3 (4). Gnathosoma visible from above .	Sub-Cohort	*GAMASINA*
4 (3). Gnathosoma mostly invisible from above	Sub-Cohort	*SEJINA*
5 (2). Stigmata behind second coxæ . .	Cohort	*UROPODINA*
6 (1). First tarsus with Haller's organ .	Super-Cohort	*IXODIDES*

TABLE XXB

SUBDIVISION OF THE TROMBIDIFORMES

1 (2).	Stigmata of females behind maxillæ ; males with no stigmata . . .	SUPER-COHORT *TARSONEMINI*
2 (1).	Stigmata median	3
3 (4).	Stigmata behind mandibles . .	SUPER-COHORT *STOMATOSTIGMATA*
4 (3).	Stigmata in front of mandibles (exc. Demodicidæ)	SUPER-COHORT *PROSTIGMATA*
5 (6.7).	Free-living species with homoiomorphic larvæ	COHORT *ELEUTHERENGONA*
6 (5.7).	Parasitic species with heteromorphic larvæ	COHORT *PARASITENGONA*
7 (5.6).	All stages with laterally attached legs	COHORT *PLEUROMERENGONA*

TABLE XXC

SUBDIVISION OF THE SARCOPTIFORMES

1 (4).	Soft-bodied species, generally with no stigmata	SUPER-COHORT *ACARIDIÆ*
2 (3).	With two vertical setæ . . .	COHORT *DIACOTRICHA*
3 (2).	With no vertical setæ . . .	COHORT *ANACOTRICHA*
4 (1).	Adults with armoured bodies . .	SUPER-COHORT *ORIBATEI*
5 (6).	Eight podosomatic stigmata . .	COHORT *APTYCTIMA*
6 (5).	No stigmata	COHORT *PTYCTIMA*

EXCURSUS XII

On Comparative Arachnology

As any science or any branch of science progresses, it passes through very clearly recognised developmental stages. The beginning must always be description, a necessary statement of fundamental facts. In Zoology this is Anatomy.

In the physical sciences, fundamental facts are used to found by inductive reasoning a hypothesis, the consequences of which, obtained by deductive reasoning, can be tested by experiment. But Zoology must rely largely upon more empirical methods and experimental treatment is scarcely applicable to anatomy. Hence there arises the necessity for the frequent checking of observations by comparison, which makes Comparative Morphology the basis of all true Zoology.

In the study of the Arachnida, to which this book is intended to provide an Introduction, the preliminary stage is scarcely past. The structure of the Araneæ, Chelonethi, Solifugæ and perhaps of the Opiliones may be said to be well known, and the structure of the members of the other Orders is not really mysterious. Yet as one reads the monographs of the specialists, one cannot but be struck by the

isolation in which each Order seems to stand. The connecting, unifying threads which join related facts and link up the whole Class into a coherent system of defined modifications of a fundamental plan are not to be found. They have not yet been spun.

There are, within limits, some notable exceptions to this. Buxton's [26] excellent work on coxal glands has revealed and compared their nature in practically every Arachnid Order and is indeed a model of what is meant by the term Comparative Arachnology. Similarly, Kästner has studied the gnathocoxæ and the work of Börner and Hansen has also been of a broader and more comparative nature.

When the study of form is abandoned for the study of function, our ignorance is found to be much greater: indeed, the study of Comparative Physiology is only just beginning to advance in the biology of such familiar animals as the Vertebrata. It is here that comparison is of the greatest help and here that it is likely to make its chief contribution to the advance of Biology, a fact which should not be hidden by the relative ease of experimental study in Physiology. The point, therefore, which it is the purpose of this note to emphasise is that in the future the most useful work is likely to be done by those who take up the study of Comparative Arachnology. Their results should be both interesting and valuable.

XIV

THE FOSSIL ARACHNIDA

The Geological Record

The fossil remains of the Arachnida include representatives of all but one of the living Orders, and, in addition, of seven Orders of Arachnida which are now extinct. But the bodies of many are so soft that they do not provide suitable material for fossilisation, with the result that our knowledge is limited to a relatively small number of specimens with a distribution confined to a few localities.

The chief characteristic of the geography of the ancient Arachnida is its limitation to the northern hemisphere. Fossils have actually been recorded from the following places :

In Great Britain,

Aberdeen	Isle of Wight
Lancashire	Shropshire
S. Wales	Warwickshire

In America

Arkansas	Colorado
Illinois	New York
Virginia	Wyoming

In Europe,

Belgium, Mons
Bohemia, Karalup, Nyran and Raconitz
France
Germany, Prussia and Silesia
Scandinavia, Isle of Gotland
Spain, Aragon

In Asia,

Birmania

This list of localities cannot be taken to possess any real significance, for it merely illustrates the fact that fossils have been more frequently sought by European and North American geologists, and also that the past history of the continents of the southern hemisphere has not been favourable for the formation of fossils.

The distribution of these remains in time is, however, very much more interesting, and may conveniently be summarised in tabular form, part of which is taken from Berland [1].

This Table shows that the Arachnida have been in existence since the Palæozoic epoch, that it was, indeed, fully established by the Carboniferous era and represented

TABLE XXI

GEOLOGICAL DISTRIBUTION OF ARACHNIDA

	PRIMARY.						SECONDARY.			TERTIARY.				RECENT.
	CAMBRIAN.	ORDOVICIAN.	SILURIAN.	DEVONIAN.	CARBONIFEROUS.	PERMIAN.	TRIASSIC.	JURASSIC.	CRETACEOUS.	EOCENE.	OLIGOCENE.	MIOCENE.	PLEISTOCENE.	
Copura	×													
Eurypterida	×	×	×	×	×	×								
Synxiphosura	×		×											
Xiphosura							×	×	×		×			
Scorpiones			×		×		×				×			×
Kustarachnæ					×									
Pedipalpi					×									×
Araneæ				×	×			×		×	×	×		×
Palpigradi														×
Anthracomarti				×	×	×								
Ricinulei					×									×
Chelonethi											×			×
Solifugæ					×									×
Haptopoda					×									
Phalangiotarbi					×									
Opiliones					×						×			×
Acari				×							×		×	×

by forms which were not widely different from the species living to-day. The most primitive Orders were apparently all marine and their respiratory organs were gill-books borne on their appendages. The change from an aquatic to a terrestrial habitat occurred during or after the Silurian age.

The conclusions which Berland [1] has drawn from his Table are sufficiently striking. The persistence of the type of Silurian Scorpion, absolutely unchanged save in unessential details, is paralleled by the close resemblance of Carboniferous Pedipalpi, Solifugæ and Opiliones to living forms. The Araneæ were established even earlier, in the Devonian strata.

Simultaneously entire Orders have appeared and disappeared, leaving no more evidence of their ancestry than of their descendants. Such evolution as can be perceived is not a progressive change, and progress is the essence of evolution, but a mere replacement of one form by another, apparently equivalent or comparable to it. This implies that the study of fossil Arachnida leads to the conclusion that the hypothesis of an evolution taking place by slow successive degrees is simply not in accordance with the facts.

XIPHOSURA

Fossil species of Limulus occur from the Triassic to the Oligocene and at least seven species have been described. The earliest of these were found in the Buntersandstein of the Vosges and the Keuper of Lorraine (*L. vicensis*). In the famous lithographic stone of Bavaria the species *Limulus walchi* is abundant, and Jurassic species occur in Sweden and in England. In the Cretaceous of Lebanon is another. The species *Limulus decheni*, in the Oligocene brown coal of Teuchern, near Merseburg, is of interest because of its great size; it is the largest of the genus.

All these species are very closely related to the living Limulus of to-day. The earlier genera which had free metasomatic somites are here treated as a separate Order, the Synxiphosura.

SCORPIONES

Fossil Scorpions range from the Silurian to the Oligocene. The earliest known Scorpion is the Isle of Gotland species, *Palæophonus nuncius*, described in 1885 by Thorell and Lindstrom [78]. This Scorpion differed from all living forms in the shape of its tarsi, which were sharply pointed and possessed no claws. The genus now contains three species, the other two having been found in Lanarkshire, Scotland, and with an allied genus of one species, *Proscorpius osborni*, from Waterville, N.Y., compose a separate sub-Order, known as the Apoxypoda. It has been suggested that the mesosomatic sternites of Palæophonus are leaf-like gill-bearing appendages, like those of Eurypterus. If this be true the primitive Scorpions may have been aquatic, or perhaps even marine, but by the Carboniferous the change to tracheal breathing had taken place.

Carboniferous Scorpions are fairly numerous and four families have been distinguished.

1. Isobuthidæ. Posterior coxæ touching the genital operculum. Isobuthus, Eobuthus and Palæobuthus. (4 species.)
2. Cyclophthalmidæ. Hand of pedipalpi wide with short fingers: sternum pear-shaped. Cyclophthalmus, Palæomachus, Archæoctonus and Eoctonus. (6 species.)
3. Eoscorpidæ. Hand narrow with long fingers; sternum pentagonal. Eoscorpius, Trigonoscorpio, Palæopisthacanthus and Microlabis. (12 species.)
4. Mazonidæ. Eyes touching anterior edge of prosoma. Mazonia. (1 species.)

These Scorpions showed all the features that characterise the living Scorpions, and it appears that the Order really reached its acme during this era. The specimens have been discovered in Bohemia, England, Scotland and Pennsylvania.

Triassic Scorpions are rare and Berland points out that this is to be expected, for animals which prefer a dry habitat are not likely to die in circumstances favourable

to preservation as fossils. Nevertheless, Wills [84] in 1910 described several almost complete examples, as four species of a genus Mesophonus, from the Lower Keuper rocks of Worcestershire.

Three Tertiary Scorpions have also been found. One of these, *Tityus eogenus*, preserved in amber is to be included in the recent family Buthidæ, so marked is its resemblance to living forms.

PEDIPALPI

When the rather numerous species which were at first wrongly assigned to the Pedipalpi have been removed to their true Orders, the fossil Pedipalpi are confined to the Carboniferous age.

The Uropygi are here represented by the genus Geralinura. This includes five species, found in the Coal Measures of Bohemia and of Scotland and in the Pennsylvanic rocks of Mazon Creek, Illinois. In every respect these are quite typical members of the sub-Order.

There are three genera of Amblypygi. These are Græcophonus, with two species, one from Mazon Creek and one from Coseley in Worcestershire, and Telyphrynus and Protophrynus, each with a single species from Mazon Creek.

There are no known fossil Pedipalpi from the later strata ; the Bavarian Jurassic genus Stenarthron does not belong to this Order ; the Phrynus of Gourret was a Mygalomorph Spider and Eophrynus and Geraphrynus belong to the Anthracomarti.

ARANEÆ

The Palæozoic Araneæ, of which at least fifteen species have been described, are of interest because no less than twelve of them belong to the sub-Order Liphistiomorphæ. This sub-Order, at present limited to nine species in Malaya, China and Japan, was apparently the dominant type of Spider in those remote times and was widely spread over the northern hemisphere. These twelve species have been placed in two wholly extinct families—

Arthrolycosidæ :

Arthrolycosa, Protolycosa, Eocteniza. (4 species.)

Arthromygalidæ :

Arthromygale, Racovnicia, Geralycosa, Perneria. (8 species.)

Protolycosa, the first of these to be described, came in 1866 from Kattowitz in Upper Silesia, the two Arthrolycosa (Fig. 87) from Illinois and Eocteniza from Coseley, Worcestershire. All the Arthromygalidæ were described from Nyran, Bohemia, in 1888 or 1904.

Three members of the Arachnomorphæ have also been found in Palæozoic strata, Eopholcus and Pyritaranea from the Carboniferous of Bohemia and Archeometa from Coseley. No Palæozoic Mygalomorphæ have been discovered.

Records of Arachnida from the Mesozoic rocks are rare and only four species of Spiders have so far been found. All came from the Oolitic limestone of Pappenheim, Bavaria.

Tertiary formations, including amber, have however yielded over two hundred and fifty species of Spiders, from the Miocene of Rott, Germany, and Aringen, Switzerland, and from the Eocene of Aix, the Isle of Wight and Florissant, Colorado. The Carboniferous type of Liphistiomorph is found not to have persisted in Europe until

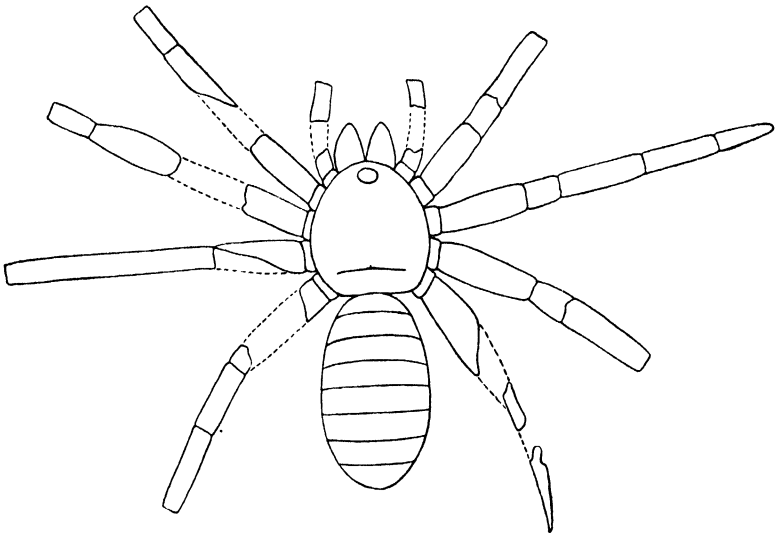


FIG. 87.—*Arthrolycosa antiqua*. After Petrunkevitch.

the Oligocene era. Mygalomorphæ are found both in European and American Cainozoic strata : Arachnomorphæ belonging to many of the recent families and genera have been very plentiful. Over one hundred and fifty species have been found in amber, and several extinct genera appear to have been common to America and Europe.

There is still no knowledge of fossil Araneæ from the southern hemisphere.

RICINULEI

This Order appears to have been more numerous in Carboniferous times than it is to-day, for the number of fossil specimens that have been discovered is almost comparable to the number captured as living animals. Six fossil species have been described, belonging to two genera.

The genus Polyochera contains three species, *P. alticeps*, *P. punctulata* and *P. glabra*. The first of these came from Coseley in Worcestershire, the other two from Mazon Creek, Illinois.

The genus Curculioides dates from 1837, the year before the description of the

first living Ricinuleid. It now contains three species, *C. ansticii* from Coseley and *C. scaber* and *C. sulcatus*, both from Mazon Creek.

These two genera differ from the recent ones in form of the second coxæ. In the living Ricinulei these coxæ are broad and meet in the middle line; in the fossil genera they are triangular and do not touch each other. The genus Curculioides was at first placed in a separate family, the Holotergidæ, because the opisthosoma seemed to be covered with a hard unsegmented shield, showing none of the transverse sutures characteristic of all the other genera. Ewing [32*a*], however, believes that such a separation is unjustified.

PALPIGRADI

No fossil Palpigradi have been found. This is the only Order of Arachnida not represented among the extinct species of the Class.

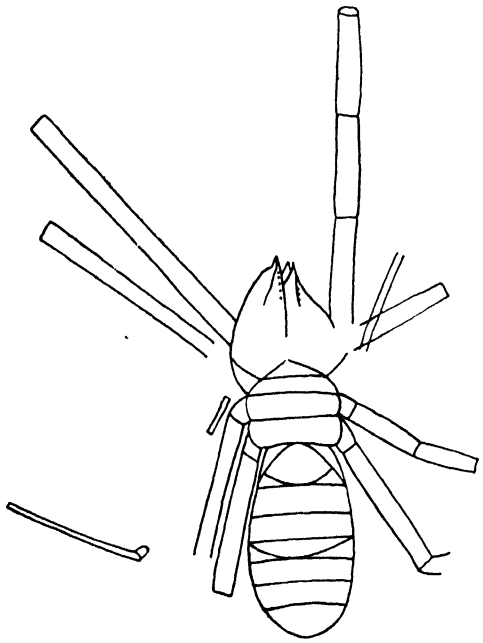


FIG. 88.—*Protosolpuga carbonaria*. After Petrunkevitch.

SOLIFUGÆ

One specimen only has so far been described as belonging to this Order. This is *Protosolpuga carbonaria* (Fig. 88), and comes, in a rather poor state of preservation, from Mazon Creek, Illinois. It is a species 2·4 cm. long, with a typical broad head and the large cheliceræ characteristic of the Order. The pedipalpi are strong and heavier than the legs, the second pair of which are unusually slender.

CHELONETHI

No fossil False-Scorpions of the earlier Epochs have been discovered, but a fairly large number of species preserved in amber have been described. Some of these have been assigned to recent genera, and it is of particular interest to note that even in those remote times False-Scorpions had adopted the same method of securing dispersal that they use to-day. One specimen was found in amber attached to the leg of an ichneumon fly, just as it might have been found at the present.

Amber-enclosed Chelonethi have come from Florissant, from the Baltic and from Birmania, showing a wide dispersal comparable to the present condition.

OPILIONES

Fossil Opiliones are not numerous. From the Carboniferous three genera, including four species, are known. These are *Dinopilio gigas* from Rakonitz, Bohemia, *Nemastomoides elaveris*, which has occurred both at Commentry in France and at Ellismuir in Scotland and is rather like a modern Nemastoma, and two species of Protopilio, *P. longipes* (Fig. 89) and *P. depressus*, both from Illinois, and something like the recent Cyphophthalmi.

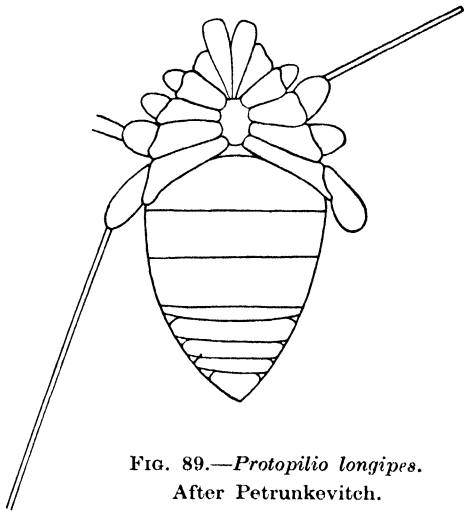


FIG. 89.—*Protopilio longipes*. After Petrunkevitch.

Two species of Phalangium have been described from the Oligocene of Florissant, and about five-and-twenty species, many of them very like living species, have been found in Baltic amber. Of these much the most interesting is the species *Caddo dentipalpus*. This genus is represented to-day by only two very rare species, restricted to the eastern United States and Canada. It is characterised by large eyes on a low divided tubercle, and the fossil species is very typical and closely allied to the living ones.

ACARI

The oldest known fossil Mite belongs to the Devonian age, and was found in the Old Red Sandstone of Aberdeen. Its name is *Protacarus crani*, and to some extent it resembles the recent Eupodidæ, but has also some primitive characters.

Oligocene amber contains a fair number of isolated genera. Some of these appear to be extinct, but some, especially among those belonging to the Oribatei, belong to recent genera, and when the impossibility of a complete microscopical examination of the fossil is taken into consideration, cannot actually be distinguished from living species. From the Green River strata of the same age in Wyoming a specimen has been described as *Ixodes tertiarius*, but it seems to be doubtful whether the animal was really a Mite. Similar doubt is associated with a specimen from the Peat of Rott, which may, or may not, have been a Limnochares.

From peat, too, galls have been obtained which were probably the work of Tetrapodili.

XV

THE EXTINCT ARACHNIDA

The fossil remains of prehistoric Arachnida include, in addition to the early representatives of recent Orders described above, evidence of at least six Orders of undoubted arachnid character, which are now extinct. Except for the Eurypterida which are to be found from the Cambrian to the Permian, the extinct Orders are almost all of Carboniferous age. It is an interesting fact, which seems to have escaped notice, that in half of these Orders the form of the chelicerae is unknown. This shows that these appendages were too small to project beyond the front edge of the prosoma, and it may be suggested that the ultimate extinction of the Kustarachnæ, Anthracomarti and Haptopoda may have been hastened by their possession of weak, inefficient mouth-parts.

THE ORDER COPURA

This Order, also known as the Limulava, consists of but one family, the Sidneyidæ, described by Walcott. There are two genera, Sidneyia and Amiella, from the Middle Cambrian Ogygopsis shale near Field, British Columbia.

The **prosoma** is uniform and has marginal or lateral eyes : its ventral surface bears a large epistome and five pairs of appendages. Some of these appendages are biramous and the coxæ of the three posterior pairs have masticatory gnathobases. The **opisthosoma** consists of twelve somites ; the first nine of these bear a pair of branchial appendages each. The last three are narrow and annular, without branchial appendages and the terminal segment has a central spatulate process which together with a pair of lateral swimmerets forms a fan-like caudal fin.

The Order has features which make it doubtful whether it belongs to the Arachnida, for its biramous limbs and compound telson give it crustacean affinities. The view of Walcott, the founder of the Order, is that it should occupy an intermediate position between the Trilobita and the Eurypterida.

THE ORDER EURYPTERIDA

This Order is one of extinct aquatic Arachnida wholly restricted to the Palæozoic. It includes, among the most primitive of the Arachnida, the largest known Arthropoda, and is one of the most interesting groups of fossil animals. The best-known genera are Eurypterus (Fig. 90) and Pterygotus.

The body of a typical Eurypterid is elongated and something like that of a Scorpion. The prosoma is uniform and bears two lateral eyes and a pair of median ocelli. The mesosoma and metasoma consist of six somites each, and the last segment bears a telson.

The **prosoma** consists of six fused somites, rounded in front and covered by a thin carapace which is ornamented with fine scales and tubercles. This bears the eyes. The median pair are simple ocelli, but the large bean-shaped lateral eyes are compound. Their surface is smooth in Eurypteridæ and faceted in Pterygotidæ; the structure of the latter has been shown to be identical with that of the lateral eyes of Limulus.

There are six pairs of **prosomatic appendages.** Of these the first pair alone are pre-oral, the cheliceræ; five others, the legs, lie on each side of the elongated mouth, which is bounded posteriorly by a metastoma. The legs are seven-jointed. The coxæ are furnished with teeth on their inner margins and thus function efficiently as masticating organs, as in both Limulus and Apus. The six distal segments form the locomotor portion of the leg, attached to a small oval epicoxite, very similar to that of Limulus. But the legs are not all alike. The fourth pair are slender and devoid of spines; probably they functioned as balancing organs. The fifth pair are invariably larger and flatter and terminate in oval plates or paddles. These were doubtless the main swimming organs, but they may also have been used as anchors or as spades for digging up the mud in which the animal may have hidden itself.

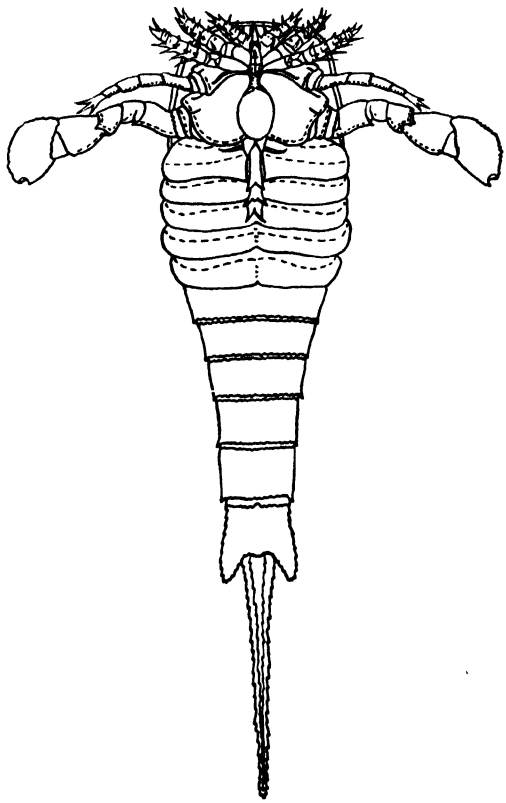


FIG. 90.—*Eurypterus fischeri.* After Holm.

The six mesosomatic somites bear plate-like appendages, each of which slightly overlaps the one behind it. These have oval branchial lamellæ on their inner surfaces. The first and second somites are covered by the genital operculum. This consists of two plates, meeting in the middle line and carrying an additional median lobe. In many species this genital operculum is quite elaborate, and it also enables two sexes to be distinguished. The other mesosomatic appendages have no median lobe.

The **metasoma** is composed of six tapering cylindrical somites with no appendages.

The last somite is produced into a lobe on each side, and between these rises the telson which is either a long pointed spine or a short flat plate.

In any description of the Eurypteridæ, several resemblances to Limulus are obvious. Both have a prosoma of fused somites with two simple and two compound eyes on its carapace, while the structure of the cheliceræ and the number and position of the appendages is the same. Both have toothed coxæ functioning in mastication and both have epicoxites. On the mesosoma both have a genital operculum and similar branchial appendages behind it. In neither is there any indication of a nauplius or a zoæa stage.

According to the geological records, many of the genera of the Eurypterida were short lived. A number of them seem to have originated in the Ordovician, but not to have survived to the Silurian. Pterygotus ranges from late Ordovician to early Devonian, Eurypterus to the Permian and Stylonurus to the early Carboniferous. The group was at its highest state of development in the late Silurian.

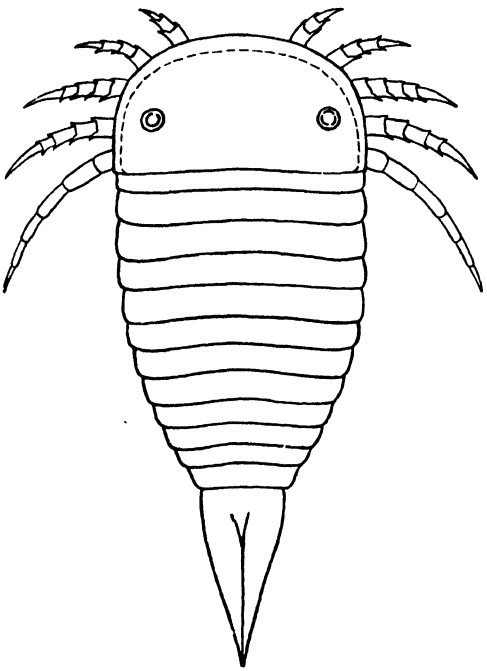


Fig. 91.—*Strabops thacheri.*

Eurypterus reaches a length of three feet. It is only rarely found in Old Red Sandstone and its classic locality is the Isle of Œsel, where specimens from the fine Silurian marl are so perfectly preserved that they can be separated from their matrix and mounted for microscopic study as if they were recent material. Pterygotus was a gigantic form with long chelate cheliceræ, and is best known in Britain from the Old Red Sandstone. Stylonurus also reached ten feet, with very long legs of the fourth and fifth pairs. The enormous size and the grotesque form of these animals were gerontic characters, preliminary to their extinction.

From the organisms with which they are associated it is probable that the Eurypterida were originally marine forms and that they became gradually adapted to brackish and possibly even to fresh-water conditions. They must have been sluggish, crawling, bottom-dwelling animals, but one genus, Dolichopterus, included good swimmers, and Pterygotus was most likely insidiatorial.

The earliest certain Eurypterid was the Cambrian Strabops (Fig. 91) a primitive and generalised form from the Potosi limestone of Missouri. It is 2¼ inches long, with a small but wide prosoma and small eyes, set farther back and farther apart than in Eurypterus. Its twelve opisthosomatic somites are not differentiated into

mesosoma and metasoma. The telson is short, broad and pointed. It may be regarded as a progenitor of the later Silurian species and, according to some authorities, the Eurypterida pass through a so-called strabops-stage during their nepionic development.

The Eurypterida are usually divided into two families :

i. Eurypteridæ. Body elongate, prosoma subquadrate to sub-triangular, telson spiniform. Compound eyes smooth, generally near the middle of the cephalic shield. No epistome. Cheliceræ not extending beyond front of carapace. Female genitalia with several lobes.
Examples—Strabops, Eurypterus, Dolichopterus, Slimonia, Stylonurus.

ii. Pterygotidæ. Body elongate, prosoma semi-elliptical, telson usually spatulate. Compound eyes faceted and marginal in position. Epistome present. Cheliceræ often very long. Female genitalia simple.
Example—Pterygotus, Hughmilleria.

THE ORDER SYNXIPHOSURA

This Order is sometimes united to the Xiphosura, but it shows certain differences from Limulus. It is a small group which includes the middle Cambrian family Aglaspidæ and several Silurian genera which are less well-known.

The body is elongated, with a semicircular prosoma like that of the Xiphosura. The median axis is more or less distinct and there are no facial sutures. Compound lateral eyes are usually present, but median ocelli have been found only in the genera Belinurus and Prestwichia. The mesosoma and metasoma are composed of free segments, trilobed in form, with flattened, extended pleura which usually terminate in lateral projections or spines. The appendages are seldom well preserved, but as far as they are known they seem to bear a general resemblance to those of Limulus.

The Order has been divided into two sub-Orders, Aglaspina and Bunodomorpha.

Sub-Order Aglaspina.—The body is rather sharply divided into two regions only, a prosoma of six somites and an opisthosoma, also of six somites, the last of which carries a telson, in the form of a caudal spine. On the ventral side of the prosoma there is an epistome and five pairs of movable appendages. Opisthosomatic appendages have also been observed. The sub-Order includes but one family, the Aglaspidæ, whose genera are Aglaspis, from the upper Cambrian of Wisconsin, and Molaria, Habelia and Emeraldella, all from British Columbia.

Sub-Order Bunodomorpha.—This includes the less well-known Silurian forms, which have more than six opisthosomatic somites. The genus Neolimulus, from the Silurian in Scotland, connects Limulus with the Synxiphosura, and has an opisthosoma of nine somites. The anterior somites were much the broadest, but there is no division of the opisthosoma into two regions and apparently all the somites were free. The genus Bunodes, from Œsel, has six mesosomatic and four metasomatic somites with a long telson. In Hemiaspis, from Scotland, there are six mesosomatic

and three metasomatic somites, also with a spine-like telson. The mesosomatic segments have broad, short tergites, the pleura of the sixth being divided into two lobes, and perhaps representing two somites. The three metasomatic somites are much narrower and longer. This possession of metasomatic somites and a shorter spine has been taken to indicate that the telson of Limulus has been formed from the posterior opisthosomatic somites. The sub-Order includes one family, the Hemiaspidæ, whose genera are Neolimulus, Bunodes, Hemiaspis, Bunodella, Pseudoniscus and Bunaria in the Silurian, Protolimulus in the Devonian and Prolimulus in the Permian.

THE ORDER KUSTARACHNÆ

This Order consists of but a single family, the Kustarachnidæ, with only genus, Kustarachne, described in 1890 by Scudder [74]. It includes three species from the Carboniferous (Pennsylvanic) of Mazon Creek, Illinois, each represented by a unique specimen. Yet scanty as the material is, it cannot be associated with any other Order. Its nearest relatives seem to be the Pedipalpi.

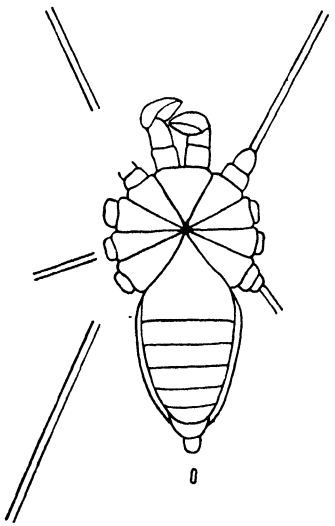


FIG. 92.—*Kustarachne tenuipes.* After Petrunkevitch.

The prosoma is uniform, and there are two round eyes situated close together on a transverse oval tubercle some little way from the anterior margin. There is probably a pedicle between the two parts of the body. The opisthosoma is segmented and possesses ten sternites in *K. extincta* and seven in *K. conica* and *K. tenuipes* (Fig. 92). The last somite is ring-like and probably carries a whip-like telson. The cheliceræ of these fossils are invisible. The pedipalpi consist each of four segments in addition to the coxæ which are completely fused together; the last two segments form a small chela. The legs have large triangular coxæ, apparently all immovable, radiating from a very small central sternum. There are two segments to each trochanter, the first rectangular, the second triangular. The remaining segments of the legs are very long and slender.

THE ORDER ANTHRACOMARTI

This Order is the largest of the groups of Carboniferous Arachnida; it is well represented in Europe, in England and in America and contains in all thirty-eight species in nineteen genera.

It was originally divided by Pocock [69] into four families, but Petrunkevitch [66] in 1913 gave reasons for preferring an arrangement in two families only. A

new family was described by Hirst [47] in 1923, and the present classification thus includes—

i. Anthracomartidæ.
ii. Eophrynidæ.
iii. Palæocharinidæ.

In this Order the cheliceræ are unknown and the pedipalpi are short and leg-like. The legs have seven joints with movable coxæ articulated to a sternal plate. The prosoma is uniform and is triangular in shape, and there is a movable joint, but not a pedicle between it and the first somite of the opisthosoma. The opisthosoma is segmented, with ten tergites of which the eighth overlaps the small ninth and tenth. The first tergite is longer than those which follow it and in front of it are one or more tergal sclerites more or less overlapped by the hind-edge of the prosoma. The tergites are divided by one or two longitudinal grooves on each side so that there are one or two rows of pleural sclerites between the upper and lower plates. There are nine sternites. The anus is covered by an operculum which represents the eleventh and last tergite.

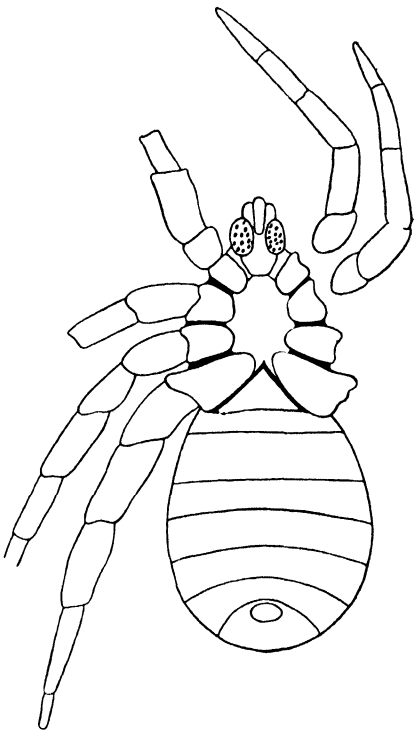


Fig. 93.—*Trigonomartus pustulatus*. After Petrunkevitch.

The family Anthracomartidæ consists of four genera in which the pleural laminæ are divided. The type-genus Anthracomartus contains eleven species from a wide range of localities and one of them, *A. trilobitus* from Arkansas, is known from no less than twenty-two specimens. Of the other genera, Maiocercus comes from the Rhondda Valley, Brachypyge from Mons and Eotrogulus from France; each of these contains but one species.

The family Eophrynidæ has undivided pleural laminæ. It consists of as many as seventeen genera, of which only one, Trigonotarbus, has three species, while three others have two and the rest but a single species each. The family is represented in France and Germany, and there are four species from Coseley, near Dudley, and one from South Wales. The American species include three from Mazon Creek, Illinois (Fig. 93), and one, *Adelocaris peruvianus*, from Peru.

The family Palæocharinidæ was described by Hirst [47] for the genera Palæocharinoides and Palæocharinus from the Old Red Sandstone at Aberdeen.

The Order Anthracomarti has a characteristic opisthosoma, but in other respects it is almost intermediate between the Opiliones and Pedipalpi.

THE ORDER HAPTOPODA

This Order consists of a single family, the Plesiosironidæ, with but one genus Plesiosiro, containing only one species, *Plesiosiro madeleyi*.

The pedipalpi are short and leg-like, and the legs of the first pair have tarsi of seven joints. From this fact it may be inferred that these legs had a tactile function like the corresponding limbs of the Pedipalpi. The **prosoma** is uniform, but the opisthosoma consists of eleven somites. There is no pedicle, the two portions of the body being united across their whole breadth. A distinct sternum separates the coxæ of the legs, none of which developed maxillary lobes. The opisthosomatic somites have tergites and sternites, separated by soft pleura.

The Order very closely resembles the Phalangiotarbi and might perhaps have been united with it: the chief distinguishing feature is the segmentation of the anterior tarsi. Its only species was found in the Carboniferous of Coseley, near Dudley, and was described by Pocock [69], who founded the Order, in 1911.

THE ORDER PHALANGIOTARBI

This Order contains fifteen species, usually arranged in three families. It occurs in both England and America, and, with the sole exception of *Phalangiotarbus subovalis*, all the British specimens came from Coseley and all the American specimens from Mazon Creek.

The **prosoma** is uniform, with two eyes. The sternal area is very small, with the large wedge-shaped coxæ of the legs arranged round it in a characteristic way, the anterior coxæ concealing those of the pedipalpi. There are no gnathobases; the genital sternite lies between the last pair of legs. The cheliceræ are almost unknown; the pedipalpi are short and leg-like. There is no pedicle. The **opisthosoma** is composed of ten to twelve segments and differs from that of all other Orders in the progressive increase in length of the first nine somites. Several of the anterior tergites are soft, with thickened posterior edges and the pleura are also soft and devoid of sclerites. The anus is covered by an operculum, the reduced tergite of the last opisthosomatic somite.

The family Heterotarbidæ contains one genus and one species, *Heterotarbus ovatus*. This species, about 14 mm. long, has very small chelate cheliceræ. Its pedipalpi are invisible, save for their trochanters which separate the first pair of legs. The first legs are long and slender, the rest short and stout. The opisthosoma consists of ten somites, five short followed by five long ones. The coxæ and cheliceræ of this species place it between the Opiliones and the rest of its own Order.

The family Phalangiotarbidæ contains four genera. The legs are all short and stout and the sternum oval with the surrounding coxæ increasing in length from the first to the fourth. There are ten opisthosomatic tergites. The genus Geratarbus

contains two American species, *G. lacœi* and *G. minutus*, which have a small oval sternum and the first pair of coxæ touching each other. The genus Discotarbus consists of one American species, *D. deplanatus*, which has a triangular prosoma and a wide rounded opisthosoma. Its sternum is divided into three areas. The genus Metatarbus, which also consists of one American species, *M. triangularis*, resembles the latter, but has an elongated oval abdomen. The only European genus is Phalangiotarbus, with one species, *P. subovalis*. It differs from its American allies in having a straight posterior edge to the prosoma instead of a procurved margin.

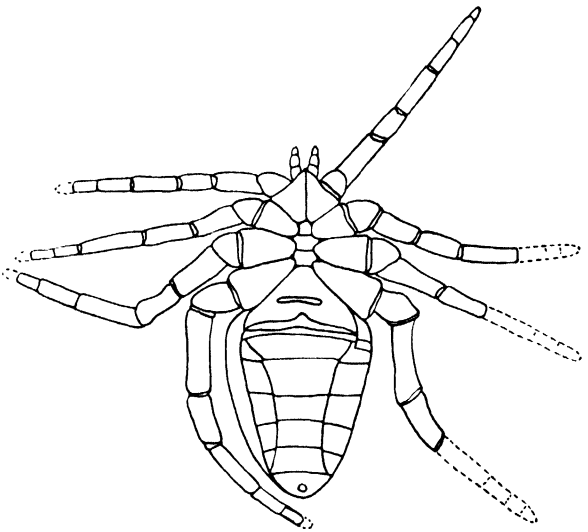


FIG. 94.—*Architarbus rotundatus*. After Petrunkevitch.

The family Architarbidæ contains two genera and nine species. In this family the coxæ of the first pair of legs are contiguous throughout their entire length, and hide the cheliceræ completely (Fig. 94). The genus Architarbus has a remarkable prosoma, pointed at both ends. The anterior margin is drawn out to a sharp point, almost like a spine. The posterior projection has curved sides meeting at a rounded point which somewhat displaces the anterior somites of the opisthosoma. This part of the body is rounded and the first six somites are very short. This is a relatively large genus, with three American and five European species. The genus Opiliotarbus has a prosoma with a straight posterior edge and a much reduced sternum. It contains but one species, *O. elongatus*, from Braidwood, Illinois.

EXCURSUS XIII

The Trilobita

The Trilobita are an extinct Order of marine Arthropoda whose relationship to the Arachnida has already been mentioned and must be more fully considered. The suggestion that the Trilobita be regarded as primitive Arachnida was made by Lankester in 1902 and derived a certain amount of support from several fossils which seemed to link the Trilobita to the Eurypterida.

The body of a Trilobite is divided into head, thorax and abdomen, and is wholly protected above by a hard shield. This is marked longitudinally by two

furrows which separate the median axis from the lateral pleura, and give the animal the three-lobed appearance to which it owes its name. The head is composed of five somites and carries compound sessile eyes. The first pair of appendages are uniramous antennules of sensory function. The next four are biramous and are both ambulatory and masticating limbs. The thoracic somites vary from two to twenty-nine in number, and the number of abdominal somites is also variable. Each of these segments except the last carries a pair of jointed biramous appendages, the coxæ of which form gnathobases.

The larva of the Trilobite was a protonauplius known as the protaspis. This had only a few somites, but their number increased with each successive moult.

The Trilobita were of pre-Cambrian origin ; they are the dominant fossil of the Cambrian and are still plentiful in the Ordovician and Silurian strata. They began to decline in the Devonian and their last survivors lingered into the Permian. In almost every respect they are primitive animals. Their larval form, their hypostome and metastome guarding the mouth, their slender jointed antennules and their biramous limbs are all features in which they resemble the Crustacea and differ from the Arachnida. They are distinguished from all other Arthropoda in having compound eyes on free cheek-pieces, which are apparently the pleura of a vanished somite. Their relationship to the Crustacea was, however, settled by the discovery of the typically crustacean character of their appendages.

The Crustacea differ from the Trilobita in having two pairs of pre-oral appendages, and there remains a possibility that fossil Trilobites may yet be found to link together the otherwise isolated phyla Crustacea and Arachnida. If ever this should happen, the Trilobita would be regarded as the common ancestor of the two groups.

XVI

THE DOUBTFUL ARACHNIDA

For many years, three other Classes of Arthropoda have been traditionally united to the Arachnida, though not always with much justification. These are the Pycnogonida or Pantopoda, " Sea-Spiders," the Tardigrada, " Water-Bears," and the Pentastomida or Linguatulidæ. The pronouncements of authority on the relations of these classes are by no means consistent.

In the *Cambridge Natural History* (1909) the Tardigrada and Pentastomida were separately described by Sir Arthur Shipley in an *Appendix to the Arachnida*. He wrote, " They are thought to show affinities with the Arachnida, but their connexion with this Phylum [? Class] is at best a remote one." The Pycnogonida were given independent treatment in a Class of their own. Professors J. T. Parker and W. A. Haswell in their well-known textbook adopted practically the same arrangement.

In 1913 Dr. Friedrich Dahl included all three Classes as Arachnida in the " Ubersicht der Ordnungen " of his *Vergleichende Morphologie und Physiologie der Spinnentiere*, while Professor J. H. Comstock in the *Spider Book* excluded them.

In 1924 Professor H. J. van Cleave in his *Invertebrate Zoology* included the Pentastomida among the Arachnida, but placed the Pycnogonida and Tardigrada in separate Classes.

In the recent *Invertebrata* of L. A. Borradaile and J. T. Potts (1932), the latter wrote that the Tardigrada and Pentastomida " have been associated with the arachnids, but no sufficient reason can be advanced for this." The Pycnogonida are treated as a Class of Arachnida, and in the Classification at the beginning of the volume, the Tardigrada and Pentastomida are also included in the Sub-Phylum of Arachnida.

In Kukenthal and Krumbach's magnificent *Handbuch der Zoologie*, the Pantopoda are included among the Chelicerata but the Tardigrada and Linguatulidæ are not.

Obviously a purist would limit the Arachnida to the ten recent and seven fossil Orders described in the preceding pages, but this position must be justified, and, from the scientific point of view, it is clearly worth while to discuss the claims which these animals may have to be considered as Arachnida and to give reasons for excluding them.

THE PYCNOGONIDA

Sea-Spiders or Nobody-Crabs

The Pycnogonida are a group of marine invertebrates of wide distribution, generally of no great size and seldom found together in large numbers. Two typical genera are Pycnogonum and Phoxichilus.

The most striking of their external features is the reduction of the opisthosoma to a small knob, so that the animal gives the impression of consisting merely of a bunch of legs (Fig. 95). In the front of the prosoma is a tubular proboscis with a small mouth at its tip. The first pair of appendages are chelate and overhang the proboscis; they are known as the chelophores. The second pair are the tactile

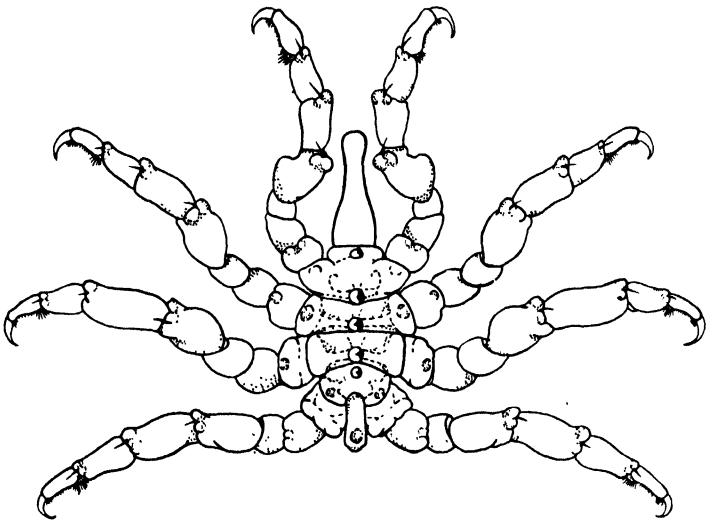


Fig. 95.—*Pycnogonum littorale.* Specimen from Plymouth, 1932.

pedipalpi, and the third pair are the ovigers, specialised for carrying the eggs and usually carried bent back under the body. The four remaining pairs of appendages are legs, with which the Pycnogonid crawls about, extremely slowly.

The internal structure is peculiar, for the alimentary and reproductive systems, which are normally situated in the abdomen, are found in the legs. Diverticula from the gut pass to the very ends of these limbs and, in the female, the eggs may be seen developing in their fourth segments. The young hatch as small larvæ, with only the three anterior pairs of appendages.

Ever since the first Pycnogon was described by Strøm in 1762, the problem of their affinities has been debated. Are they Crustacea, are they Arachnida or are they neither ?

The crustacean affinities are not very conspicuous, and are almost limited to the superficial features of the larva. The short, unsegmented body, median eye and

three pairs of appendages are reminiscent of the Nauplius, but of these limbs the first are chelate and the others are uniramous. These are not crustacean characters, nor is the possession of a proboscis. On the other hand, there is no larva among the Arachnida which in any way resembles the larva of a Pycnogonid (Fig. 96).

Yet unmistakable resemblances to the Arachnida cannot be denied. Both groups have one pair of pre-oral appendages, both have simple ocelli grouped on a median tubercle, and both have diverticula from the mesenteron approaching the legs. In the higher Arachnida, as in the Pycnogonida, no appendage forms lateral jaws or mandibles.

The essential difference between the two groups is found in the number and

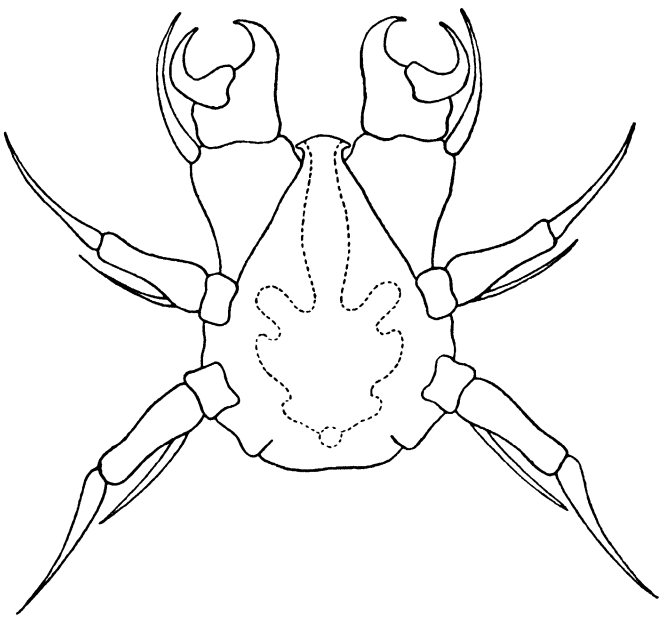


FIG. 96.—Larva of Pycnogonid. After Dahl.

arrangement of the appendages. The fact that each has four pairs of legs is fortuitous, and is no more a fundamental resemblance between them than is the possession of three pairs of limbs by the larvæ a fundamental resemblance to the Nauplius. For the Arachnida have two pairs of appendages, the chelicerae and the pedipalpi, in front of the legs, which belong to the adult somites 3 to 6, while the Pycnogonida have chelophores, pedipalpi and ovigers in this position, so that their legs belong to segments 4 to 7.

Moreover, from the Antarctic three genera of Pycnogonida are known, by name Pentanymphon, Decolopoda and Pentapycnon, in which five pairs of legs are present, and in 1933 a species, *Dodecolopoda mawsoni*, was described by Calman [27*a*] also from the far South, with six pairs of legs. This provides evidence for reasonable

conjecture. Either the Pycnogonida have been derived from early normal " Arachnida in which the established number and order of the body segments and limbs had lost their stability " (Calman [27]) or the Pycnogonida, derived like Arachnida and Crustacea from a Trilobite-like ancestor, have selected and preserved a rather different set of the ancestral characters.

If this be true, the resemblances to the Crustacea become intelligible and the closer relationship to the Arachnida can be admitted without the necessity for assuming that all the points of similarity are due to convergence. And, finally, the Pycnogonida can justifiably be placed in a Class by themselves, without the feeling that by so doing the problem of their relationships is merely being evaded.

THE TARDIGRADA

Water-Bears

The Tardigrada are a group of obscure animals among the smallest of multicellular organisms in existence and the most widely distributed. Their length is not more than a millimetre and is often much less, and they are found in many situations all over the world. One species, *Macrobiotus arcticus*, which occurs in Arctic waters and is not uncommon in the lakes of Ross Island in the Antarctic,

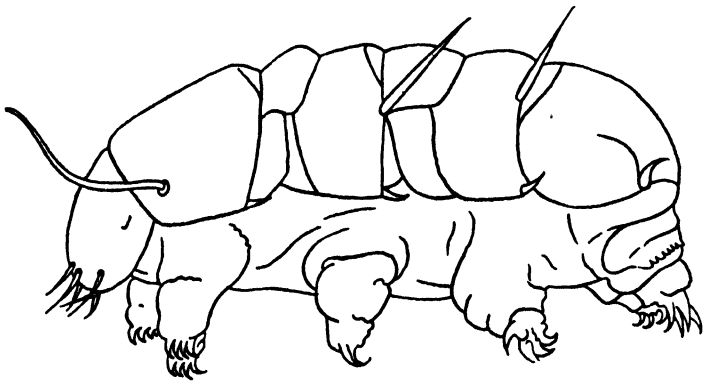


Fig. 97.—A Tardigradi. [Species, *Echiniscus spinulosus.*]

provides an example of the phenomenon of bipolarity as well as an illustration of the great range of the group.

The structure of these animals, on which their place in our system depends, is peculiar (Fig. 97). The whole body is surrounded with a cuticle, which is cast at intervals, and the permanent epidermis lies below it. Both cuticle and epidermis are usually transparent, but brown, black or red pigment occurs in some genera. There are eight legs, unjointed save in the genus Lydella, bearing claws supplied by the cuticle. The inside of the body is a space full of transparent fluid, the blood, with the internal organs lying in it, and with floating corpuscles which contain a

reserve of food materials. The alimentary canal is a straight tube, consisting of a chitin-lined mouth, a spherical suctorial pharynx, a large stomach and a rectum with a pair of lateral, probably excretory, cæca. The ovary or testis is a single organ opening in company with an accessory gland into the rectum. Tardigrada are well able to withstand desiccation, and in an almost unrecognisable state resembling a grain of sand can survive long periods of drought.

It seems clear that the Tardigrada must be Arthropoda. They show segmentation, have parapodial limbs ending in claws and excretory organs to some extent similar to Malpighian tubes. They also show the negative character of not possessing cilia.' At the same time they have very clear distinctions from the Arachnida. Their cuticle, in which the eggs are sometimes laid when it is shed, their vegetarian diet and their unstriated muscle fibres are positive differences ; the absence of paired sense organs, of paired mouth-parts, of coxal glands and of circulatory and respiratory organs are negative differences. Some of these may in part be attributed to the small size of the animals. The development of the egg is simple and direct and, like the general structure, gives no indisputable evidence of degeneration. For all these reasons there does not seem to be any justification for including the Tardigrada among the Arachnida.

In the nature of their alimentary canal and the character of their legs they recall Peripatus and the balance of evidence seems to point to their being Arthropods even more primitive than the Onycophora. But they are hardly similar enough to Peripatus to share that Class with it and there seems to be no alternative but to make them an independent Class, one of the lowest twigs on the Arthropod branch.

THE LINGUATULIDÆ

The Linguatulidæ are a group of parasitic organisms of which the adults live in the lungs and air-passages or sometimes in the gut or coelom of Reptiles and occasionally of Birds and Mammals, and of which the larvæ occur free or encysted in an intermediate host, usually a Fish or a Mammal.

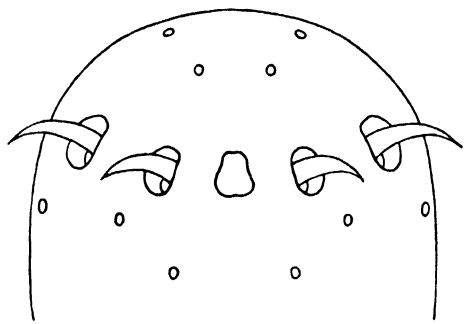


Fig. 98.—Head of Waddycephalus. After Hett.

An adult Linguatulid is a whitish worm-like organism varying in length from a few millimetres to as much as nine centimetres. The body is of two divisions, a short anterior part, known as the head or cephalothorax, and a longer, posterior, abdomen. Sometimes a waist-like constriction separates these two parts, sometimes there is no division between them. The head bears the mouth, terminally or sub-terminally, and also two pairs of chitinous hooks, a pair on each side of the mouth (Fig. 98). These hooks can be moved by the animal and serve as organs of attachment. Sensory papillæ are

also found on the head and on the abdomen are numerous " stigmata," which are really orifices of epidermal glands. The abdominal part of the body is annulated, flattened or cylindrical in shape, and, like the head, wholly covered by a thick chitinous cuticle. This is continued into the mouth, rectum and the other apertures of the body, which include the hook-pits on the head, the gland-ducts and the genital apertures. The male orifice is just behind the mouth ; the female orifice is in the same position or at the posterior end of the body, just in front of the anus.

The life-history in certain exceptional cases may be completed in a single host,

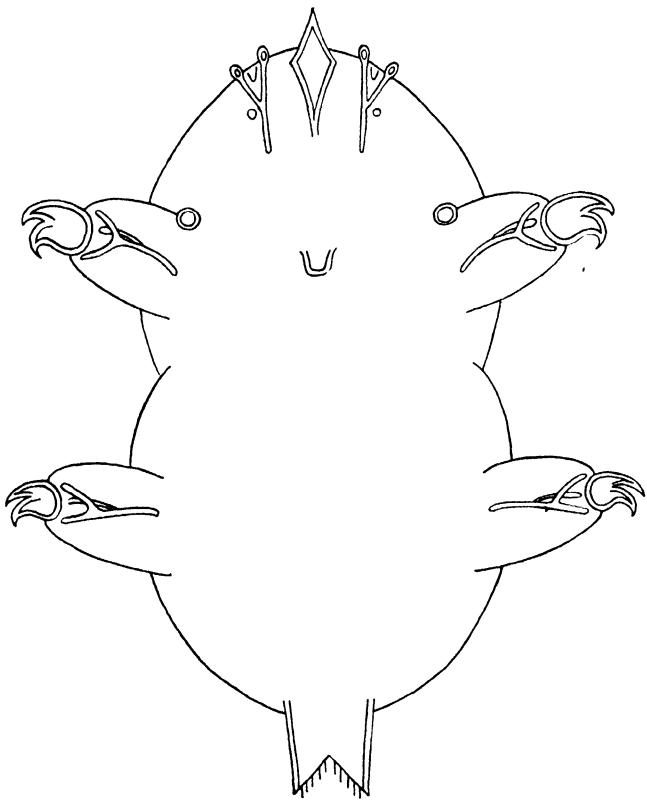


FIG. 99.—Larva of *Porocephalus proboscidens*.

but normally two are involved, an intermediate host for the larvæ and a final host for the adults. The female appears to be fertilised by the male before she has finished increasing in length. The male remains active and is more easily sneezed out or otherwise ejected by the host, but the female fixes her head ever more firmly into its tissues. The eggs are laid freely in the lungs of the reptilian host and pass thence by way of the mouth into the alimentary canal. Thus they reach the exterior with the ejecta and, thus scattered over the vegetation or strewn into the water, are swallowed by the intermediate host as it feeds.

In the gut of this second host the egg membrane dissolves and the embryos are liberated. Assisted by a boring apparatus and two or three pairs of hooked limbs they pierce the canal-wall and are carried by either the blood or the lymph to the liver, mesentery or other part of the body. Here they encyst. In the cyst development, consisting of a number of moults, proceeds until, perhaps, eight months later the full-grown larva emerges (Fig. 99).

If the infection of the intermediate host is slight these larvæ die. If the infection is very heavy the presence of the larvæ may be the actual cause of the host's death. The normal course of events appears to be that the host is enfeebled, and in this weakened condition falls an easy prey to its carnivorous enemies. In this way the larvæ enter the mouth of the final host with its food. From here they probably proceed direct to the lungs. If larvæ are eaten while still encysted they will not be freed until the cyst is dissolved in the stomach and their later history is, in such a case, uncertain. The larva now undergoes a final moult, becoming an adult, and further development consists merely in increase in size.

It is clear from this account that the Linguatulidæ have a better claim to be considered as Arachnida than have the other two groups discussed above. At the same time there are certain very obvious differences between the Linguatulidæ and the typical Arachnida, so that the problem really turns on considering whether these differences are modifications attributable to their parasitic mode of life. If they are so attributable then undoubtedly the Linguatulidæ must be considered to be Acari, as Sambon [72] has recently done. They must be regarded as modified to live as internal animal parasites, forming, in fact, a family comparable to the vegetable parasites, the Eriophyidæ. Indeed the similar annulated form of the opisthosoma in the two groups is striking. On the other hand there is much both in internal structure and life-history which sharply distinguishes the Linguatulidæ from all Arachnida. To give a simple example, one of the features in which all the normal Arachnida resemble each other is in the genital glands, the ducts of which almost invariably open at the anterior end of the opisthosoma. In the Linguatulidæ the genital orifice has two alternative positions, neither of which is the position characteristic of the Arachnida.

The only other group with which the Linguatulidæ might be associated is the Annelida, and here too there are both resemblances and differences enough to maintain the difficulties of the question. On the whole, the most reasonable solution to this problem seems to be that of Heymons [44*a*], who has placed the Linguatulidæ in a Class by themselves, intermediate between the Annelida and the Arthropoda.

III. EPILEGOMENA

XVII

ECONOMIC ARACHNOLOGY

The Arachnida, Mites obviously excepted, are not animals that attract attention because of an economic importance. Indeed, it is possible to argue that the relative neglect from which they suffer is due to this fact, for Spiders in particular, the commonest and most obvious of the Arachnida, are of no direct value and do no direct damage. Of the rest, Scorpions are an irritation, or perhaps more, in certain countries, but the others are inconspicuous. As far as one can see, every one of the Solifugæ, Palpigradi, Chelonethi and Ricinulei might be simultaneously obliterated without any immediate effect on prices in the world's markets.

This, however, takes a narrow, specialised view of economic importance, limiting that term only to such creatures as may be described as pests. When Spiders catch flies, as they do in vast numbers, and when the other Arachnida capture whatever their prey may be, they are one and all playing their parts in the universal drama of life. They hold the balance of Nature, and to this extent each one is important. For we know, only too well, how surprising may be the consequences when the uncontrolled acts of men or some natural cataclasmic event disturbs this equilibrium, and how the removal of some enemy may be followed by the almost unlimited increase of a species until a subsequent happening limits the reproduction and the balance is restored.

Let it be therefore admitted that there is an indirect economic importance for all the Arachnida, each one of which takes its share in this process. The long-legged Harvestman, so commonly condemned as useless, is a cog in the wheel, and gives things a push in some direction. We do not know enough to say precisely where, but it is certain that the natural world would be somehow different if the Harvestman were not there.

The following are, however, examples of direct economic importance for Arachnida other than Acari.

i. Limulus has been used in America as food for both pigs and poultry, and in some parts it is believed that this food makes the hens lay. Females are preferred on account of the eggs they carry. The Siamese hunt the species *Tachypleus* (*Limulus*)

gigas for the sake of its eggs, and a female is sold for the equivalent of 10*d*. The eggs are said to look like caviare and to taste like potato.

ii. Scorpions of several genera, e.g. Buthus and Centrurus, are distinctly poisonous to man.

iii. Spiders of a few species are definitely known to inflict poisonous bites on man. A fuller treatment of the subject of arachnid venom is given elsewhere in this book (see p. 58).

iv. If the practice of homœopathic therapeutics can be included as involving economic importance, Spiders demand further mention. The venom from *Tarentula hispana* is said to influence the nerves supplying the human uterus and ovaries, and to be a remedy for hysterical conditions and similar nervous complaints. *Tarentula cubensis* is similarly described as a cure for abscesses and swellings of any kind. Venom from *Mygale lasiodora* is the basis of a remedy for chorea, but *Araneus diadematus* is more efficacious when the symptoms are aggravated by wet weather.

The Acari, or Mites and Ticks are, however, the Arachnida whose influence on human affairs is sufficiently far-reaching to justify this section. They include species which attack growing crops, stored crops and manufactured produce, species which are parasitic on man, on domestic animals and on cultivated plants, and species which, while parasitic, are hosts or bearers of disease-producing protozoa and bacteria. Although the number of species of Mites is very great, their influence is chiefly felt through the large number of individuals which spring into existence wherever and whenever conditions favourable to their multiplication obtain. The work of the economic acarologist, like that of his brother entomologist, consists largely in the study of the life-histories of these animals, in order to determine the point at which they may be most successfully attacked. The Mite does not collaborate in this with much enthusiasm, and, as Shipley says, of Lice, " When you want them to live they die, and when you want them to die they live, and multiply exceedingly."

In the following, some account is given of a representative selection of acarid pests. No attempt at encyclopædic completeness can be made in a limited space, for the subject is a wide one.

Among human parasites may be distinguished innocuous forms, irritating forms, forms which convey protozoal diseases and forms which convey bacterial diseases. Much the commonest of the first group is *Demodex folliculorum*, which lives in the hair follicles of man, with related species or varieties in dogs, cats, pigs and oxen. These parasites are very often found in the sebaceous glands of the forehead, nose and chin. They may be discovered by pressing out the contents of the blackhead pastule and examining this in a drop of xylol under a microscope. The mite is elongated, with a tapering annulated abdomen. The female lays oval eggs, from which a legless larva first emerges. It is possible that the parasite may assist in spreading of a tropical skin disease called *Lichen spinulosus*.

A pest only too well-known both in this country and in America is the so-called

Harvest-Mite. These occur commonly in fields in autumn and are the larvæ of two or more species of *Trombidium*. Before their true nature as acarine larvæ was recognised they were described under separate names, such as *Leptus autumnalis*, etc. Their habit is to pierce the skin on the knees, wrists or ankles of those working in the fields ; and rabbits, hares and moles are also attacked. The amount of irritation which they cause differs with different people ; there may be a troublesome rash and some degree of fever. It is believed that these " Chigger-Mites " in America are agents in the spreading of typhus-like diseases, but this does not seem to occur in Britain.

Rather more serious are the various " Itch-Mites," of which the most widespread is the well-known *Sarcoptes scabei*, the cause of human scabies. These Mites look like minute grey tortoises ; the females are 330 to 450 μ long by 250 to 350 μ broad, the males from 200 to 235 μ by 145 to 190 μ. The males soon die, but the female burrows under the skin in the soft places between the fingers and toes, on the wrists and ankles, the pelvis and buttocks and the backs of the knees. The female can bury herself in little more than two minutes, and is usually most active in doing so at night, when the irritation is at its worst. The burrow is only about as wide as the Mite and the backward-pointing spines on her body prevent her from returning to the surface. Thus she proceeds until the burrow may be half an inch long, made visible to a lens by dark dots of excrement. As she goes she lays oval eggs, forty or fifty in number and a tenth of a millimetre in length, a very large size compared to that of the mite. In less than four days the first eggs hatch and the six-legged larvæ spread the infection, both to other parts of the body and to other persons. One of the best cures for the trouble is Ehlers ointment. The bedding and clothing of the patient should be freed from the Mites by baking.

Several similar Mites which are normally parasites of horses, cats and other animals occasionally infect man, but they are not so serious as *S. scabei*. There are also a number of Mites which live on vegetable matter and which attack men working on particular crops, causing intense irritation. Of these, a variety of the Cheese-Mite, *Tyroglyphus longior*, var. *castellanii*, is the Copra Mite. When the coconut kernels have been extracted from the nuts and dried, a dust-like product is often found which swarms with Mites. These attack the bodies, but not the faces, of the coolies and others engaged in the copra industry. They do not burrow in the skin, but the irritation of their presence is no less serious. Certain individuals are always free from their attention.

Water-itch is due to the Mite *Rhizoglyphus parasiticus* which attacks the coolies employed on Indian tea-plantations and grain-itch is caused by the interesting *Pediculoides ventricosus*. The well-known pests, the Weevils, such as *Calandra granaria*, the Grain-Weevil, and *C. oryzæ*, the Rice-Weevil, are kept in check by various hymenopterous parasites of the families Chalcidoidea and Vespoidea which attack the Weevil larvæ. But these welcome parasites are themselves liable to be killed by the Mite *Pediculoides ventricosus* which lives on the stems of corn, feeding on the

vegetable juice. This Mite is therefore a triple pest. It attacks and weakens the growing crops, it assists the undesirable Weevil by killing the Weevils' enemies and it produces very severe skin eruptions in the hands and arms of workers in corn, cotton and straw.

Among the disease-carrying Mites, by far the most important is the Tick *Ornithodorus moubata*, known by the African natives as the Kimputu and the Madagascar natives as the Poroponjy. This Tick is a human parasite; its body acts as intermediate host for protozoon *Spirichæta duttoni*, which when parasitic in the blood-corpuscles of man causes relapsing fever or African tick-fever. It is widespread in Portuguese East Africa, Congo Free State and other parts of Africa.

The unfed Tick weighs little more than two milligrams, but it can absorb more than ten times its own weight of human blood, and the adult will feed continuously for three hours, becoming in the process almost as large as a cherry. It is obvious, therefore, that it can only successfully attack men while they sleep, and this is the more necessary since its actual "bite" is painful. It takes a firm grasp with its forelegs, and, raising its abdomen, drives its mouth-parts through the skin. While it feeds it continuously secretes a clear fluid from glands which open between the first and second coxæ. It also voids excretory matter, with which the pathogenic bacteria are mixed. These bacteria regain entry into the human body through the wound made by the Tick, thus infecting the person bitten with the fever.

When gorged the Tick drops to the ground and at this stage is liable to be eaten by ants or rats. The eggs which are laid in batches of about one hundred and fifty look like tiny bunches of golden grapes. In three weeks a six-legged larva has developed, but it remains inside the egg-case until it moults, producing the eight-legged nymph. In three more moults this becomes adult.

Another Tick, *Dermacentor andersonii* var. *venustus* is responsible for the spreading of spotted fever. This Mite has a more adventurous life-history. The female can lay as many as four thousand eggs in a month and the larvæ which hatch from them, generally known as Seed-Ticks, must now feed on a small mammal, like a squirrel, for three to eight days. This doubles their size, to about 1·5 mm., when they drop off, moult and become nymphs. The nymph feeds on a larger mammal, such as a goat, until it is about four millimetres long, when it again drops to the ground and after two moults becomes an adult. The adults attack larger mammals still, a horse, a cow or a man providing them with food for four days. This makes the female twelve millimetres long. Fertilisation occurs on the final host and the eggs are laid a week later. The adults are the only stage of this Mite that infest man.

The domestic and other animals attacked by Mites include animals of every size from cattle to bees and silkworms. Some of them are of no economic significance; for example the occurrence of Halarachne in the lungs and air-passages of seals and of Pneumonyssus in the lungs of old-world monkeys is only of interest as showing how widely the Acari have sought for favourable environment.

Common mange in cattle, horses and dogs is due to the mite *Psoroptes communis*.

These Mites do not burrow, but live in colonies on the surface, feeding on the skin and causing scabs. The inflammation which follows makes the animal scratch and thus lose much hair. A variety, *Ps. communis*, var. *ovis*, is one of the most dreaded pests of sheep, whose thick fleece is a favourable shelter for many organisms. The bites of this Sheep Scab Mite rapidly cause loss of condition and infection quickly spreads throughout the whole flock. The fleece of the animals attacked becomes rough and matted and is easily rubbed off, while in addition the bites produce a copious flow of blood. This forms a scab, under which the Mites shelter. These parasites are comparatively vulnerable while living on the sheep and dipping in a lime and sulphur wash is an efficient way of destroying them. The life-cycle is complete in about fifteen days, so that a second immersion about a fortnight after the first is necessary to destroy Mites which have hatched from eggs that resisted the first dipping.

By far the most important of the acarine parasites of cattle is the Tick *Margaropus annulatus*, for it is the chief agent in the spread of redwater or Texan fever. This is due to a protozoon, *Piroplasma bigeminum*, a pear-shaped or circular animal, parasitic in the red blood corpuscles of cattle, sheep, dogs and horses. Their presence destroys the corpuscle, so that the red colour appears in the urine of the infected animal, giving rise to one of the many popular names of the disease technically known as piroplasmosis or babesiasis. As the protozoa multiply the number of red blood corpuscles decreases, so that a blood-count reveals a drop from seven or eight million corpuscles per cubic millimetre to less than one million. The consequence to the animal is loss of appetite, wasting of flesh, and, finally, insensibility and death. The disease has long been spread throughout the whole world and its cost to the United States alone has been estimated at a hundred million dollars annually.

More than one species of Tick is responsible for this damage. Besides *Margaropus annulatus* which is found in America, with sub-species in Australia and Africa, *Hyalomma ægyptium* and *H. punctata* are culpable in Africa and *Ixodes hexagonus* and *I. ricinus* in Europe and Britain. The life-histories of all these are essentially similar. The eggs are laid by the female on the ground and the Seed-Ticks or larvæ climb up the vegetation to await the passing of a possible host. During this time they can neither feed nor grow, but they can safely fast for an incredible time. As soon as they are attached to a host they begin to feed, moult and grow to the adult state. If the Tick already carries the Piroplasma, the host is infected with the disease; if the cattle are already sufferers, the protozoa pass into the body of the Tick. Here they apparently enter the gonads so that when the mature Tick finally leaves the host and lays her eggs, the larvæ produced are already carriers capable of transmitting the fever to fresh cattle. The power of the Tick to withstand starvation, the fact that a single pair can theoretically produce seven thousand million offspring in six months and their ability to parasitise horses, mules, deer and buffaloes as well as oxen are factors which all assist the spreading of the disease.

The Common Tick *Ixodes ricinus* also transmits piroplasmosis in dogs, as does *Rhipicephalus sanguineus* in India, *Hæmaphysalis leachi* in India and *Dermacentor*

reticulatus in Europe. In Africa, *Rhipicephalus evertsi* transmits piroplasmosis in horses and *R. bursa* in sheep. As a general rule the disease is peculiar to each species for the Piroplasma is pathogenic to one mammal only.

Birds are also subject to the attacks of Mites, and the familiar " Red Mite " is the commonest pest of cage birds and poultry. The Mite in question is *Dermanyssus gallinæ*, a species about one millimetre long, which feeds on the blood of birds while they are roosting at night. After filling themselves, they return to hiding-places in the bird-cage or hen-coop, where their eggs are laid and hatched. They do not transmit disease, but cause loss of condition owing to the quantity of blood they take from the birds.

Mites of the degenerate genus Syringophilus have a world-wide distribution as parasites in the interior of birds' feathers. These mites enter the feather by the superior umbilicus and live in the quill, feeding upon the contents until the feather is moulted or the bird dies. They then escape through the base of the feather and seek a new host.

The chicken Itch-Mite is *Sarcoptes nutans*. These attack the birds' legs, between the scales of the feet, so that the scales stand up and separate, a chalky secretion being formed between them. In the cavities below the scales the Mites live and multiply, causing serious inconvenience and loss of power to the bird, but not infecting it with bacterial or protozoal disease.

On the other hand, a spirochæte parasitic in the blood of birds and known as *Spirochæta marchouxi*, is conveyed from bird to bird by the Tick *Argas persicus*. This Mite is widely distributed and is common in the southern States of America ; it is one of the most dreaded pests of the East, where the inhabitants have been known to desert an infected town, rather than attempt to destroy the Mites. The female Argas is about eight millimetres long : it feeds on the birds at night and lays its eggs on the ground or in a crevice. It has been shown to retain its power to transmit spirochætosis after five months' fasting. Geese, ducks and guinea-fowls are particularly sensitive to the presence of the spirochæte in the blood ; they suffer from diarrhœa and anæmia, which produce such weakness that the bird cannot hold up its head.

A yellow and white Tick, *Argas reflexus*, commonly found near dove-cotes and pigeon-houses, is also willing to attack men, producing very irritating bites. Poultry are also liable to attack, which is often fatal, from *Ornithodorus turicata*.

An internal parasite of poultry is the Air-Sac Mite, *Cyrodites nudus*, which lives in the lungs and is sometimes found in the heart and other organs. These Mites have suctorial mouth-parts and do not in any way pierce the pleural membrane, but their continual movements set up inflammation of the lungs or endocarditis of the heart.

Last among animal pests may be considered *Acarapis* (*Tarsonemus*) *woodi*. The honey-bee is widely subject to a malady popularly known as Isle of Wight or Acarine disease, due to this Mite, which is one of the smallest of all the Arachnida. The Mite lives inside the tracheæ of the bee, especially in the thorax. It pierces the sides of

the tracheal tubes and feeds on the tissues of its host, disturbing control of the flying muscles so that the wings stand out from the sides of the body and the bee cannot fly.

The eggs are laid in the tracheæ, where they hatch and the larvæ grow to maturity within fifteen days. Increase in the number of parasites chokes the spiracles, so that the bee dies. Before this the Mites emerge to seek fresh victims and infection spreads by direct contact. The youngest bees are the most attractive to the Mites and a bee over nine days old is generally immune from attack.

Control of the disease may be obtained by suitable methods of manipulation, such as those which tend to separate old from young bees, or by encouragement of prolific but short-lived strains which die before the parasites have become very numerous. Alternatively a substance may be evaporated in the hive, which kills the Mites but not the bees. A mixture of four parts nitrobenzene, one part safrol oil and two parts petrol is recommended. It is allowed to evaporate in the hive, preferably in late autumn, the dose depending on the size of the frame and also on the season of the year.

The purpose of economic arachnology is the control even to extinction of the offending Arachnid, and to do this with hope of success demands a knowledge of the life-history of the parasite and of the various adaptations by which it is enabled to survive our attacks.

Ticks in general pass through four stages in the course of their lives—egg, larva, nymph and adult, the transition from one to the next being made by one or more ecdyses or moultings of the exoskeleton. According to their moulting habits, Ticks may be artificially divided into four classes. The first Class pass the whole of their lives on the bodies of their hosts, both larval and nymphal moults occurring thereon. The tropical Horse Tick, *Dermacentor nitens*, is an example ; others occur in the genus Margaropus. Knowledge of this fact obviously implies that measures undertaken to kill Ticks must be applied to the animals attacked, as dips or washes, and not to the pasture.

Secondly, the larva may moult on the host but the nymph on the ground. The " garapata " of Mexico, or spiny Ear-Tick, which attacks horses, oxen and sometimes men in the ears, is an instance of this, and men have been infected as a result of sleeping in the open where the herds had previously been. The genus Rhipicephalus also belongs to this group.

The third group is the reverse of the second ; the larva moults off the host and the nymph upon it. The disease of sheep and goats known as heartwater, is spread by the Bont Tick, *Amblyomma hebræum*, which does this.

Fourthly, all moulting may occur on the ground after a bout of feeding from the host. The common Castor-Bean Tick of sheep, *Ixodes ricinus*, which also attaches itself to our dogs, belongs to this Class, as does the ill-famed *Ornithodorus moubata*. It is clear that in these instances animals may be infected by merely passing through a pasture which had been used by an infected herd or flock, perhaps more than a

year before. The Mites' power to resist starvation is here evident, and leads to a consideration of its other adaptations.

These may be divided into adaptations of structure and adaptations of habits. The former include the grappling irons or hooked claws with which the tarsi terminate and their occasional replacement by suckers, as well as the hooks on the mouth-parts which make the parasite when once fixed on a host very difficult to remove. A curious feature, shown by some Ticks which, like *Argas persicus*, drop from the host to moult, is their change of bodily shape. While sucking they are bloated and almost spherical but before they drop they assume a flattened state which is much better for seeking concealment in crevices.

Adaptive habits are most important and valuable to the parasite. Tick larvæ, waiting on the grass for a mammal to pass, stand erect and wave their front legs in the air as any disturbance occurs. If these legs come in contact with any solid surface they cling most tenaciously, a variant of stereotropism which Brumpt [25] has named histotropism—the attraction of the skin.

The habits of the animal host are reflected in those of the parasite. Rabbits for instance are attacked by *Hæmaphysalis leporis*, and this Mite only drops from the rabbit during the day. During the day rabbits rest in their burrows, so that when the Tick again requires a host it is in a more favourable situation than it would be if it had dropped at night when the rabbit was foraging abroad. Precisely the opposite is true of fowls, which roost at night, and *Argas persicus* only leaves the birds then.

Lastly, Ticks often affix themselves in inaccessible places so that the animal cannot easily scratch or rub them off. The ear, the habitat of *Ornithodorus megnini*, is an example, as is the habit which several bird-parasites share in attaching themselves to the birds' heads.

The arachnid parasites and depredators of crops and plants of all kinds are hardly less numerous or widely spread than are the pests of animals. The little "Red-Spiders," the Mites *Tetranychus telarius* and its congener *T. bimaculatus*, are probably the most frequently encountered enemies of the gardener. These Mites are very small, but they multiply so rapidly that they easily become a serious menace. In glass-houses, *Tetranychus telarius* attacks cucumbers and tomatoes; in the open, hops and starberries. Trouble begins as soon as the rising temperature of spring awakens the hibernating Mites and continues throughout the summer as successive generations feed and lay their eggs on the leaves of the plants. In October the females are fertilised and change from dull green to brilliant scarlet. They now become gregarious and live in a communal web. Fumigation with naphthalene is recommended for cucumbers and spraying with petroleum emulsions for tomatoes. Carnations and peaches are best protected by a liver of sulphur spray, applied in the evening or during dull weather.

In America, *Tetranychus bimaculatus* often becomes numerous and may completely strip the leaves from almond or plum trees. Citrus trees are also liable to attack by *Tetranychus mytilaspidis* and *T. sexmaculatus*. The treatment recom-

mended for these is dusting with flowers of sulphur or spraying with one pound of sulphur mixed with five gallons of water.

On the Pacific coast fruit trees are liable to attack from the Mite *Bryobia pratensis*, the eggs of which are laid on the branches of the tree and hatch just about the time that the buds open. The control of this pest aims at killing the larvæ before they have actually hatched from the eggs: for this purpose a lime and sulphur wash is applied. The strength recommended is

Quicklime	5 lb.
Flowers of Sulphur	11 lb.
Water	5 gallons.

This is diluted ten times for use against Mites. Against soft-bodied insects it may be diluted fifty times. The same species of Mite seriously damages grass and clover crops, and in autumn sometimes enters houses in large numbers.

In Great Britain the Mite which most frequently demands the attention of fruit-growers is the black-currant Gall Mite, *Eriophyes ribis*. This is now widespread in Britain and Western Europe and it is also known in Canada and British Columbia. It produces "big bud" in black-currants and also attacks white- and red-currants, flowering currants and gooseberries.

The name "big bud" is given because the presence of the parasite causes the buds to swell to almost double their normal size and to die in the early weeks of the summer. The buds of red- and white-currants swell only if the infestation is particularly severe, but they die just as do those of black-currants. In the gooseberry the leaves are often attacked as well, and become yellowish in colour and undersized.

The Mite that causes this trouble is barely one-tenth of a millimetre long. They are to be found by microscopic examination of parasitised buds between July and March when the Mites are living in the tissues. Here the eggs are laid. On the death of the bud the Mites move to the leaves and on bright days when a slight wind is stirring attempt migration. This they achieve either by clinging to the legs of passing insects or by springing upwards and being blown on the wind as aerial plankton. When this migratory instinct is strongly roused many thousands of Mites leave a bud in a day and little bunches of a hundred Mites together may be seen rolling out of the buds on the leaves below.

Control of this pest is achieved as for Bryobia. The bushes are sprayed with the lime-sulphur wash (one part of the concentrate to eleven of water) in the early spring, when the flower racemes have begun to appear but before the flowers have opened. Badly infected bushes should be grubbed and burnt.

The black-currant is also attacked by two other Gall Mites, *Phyllocoptes masseei* and *Oxypleurites neglectus*, but these, although disfiguring, are not responsible for great damage.

The genus Eriophyes contains a very large number of species, all of which are plant parasites. Another species well known as a pest all over England is the pear leaf Blister-Mite, *Eriophyes pyri*. It attacks the apple and rowan as well as the pear

and is known also in Europe and America. The leaves of the infested trees open in spring with small yellow or green spots, which soon turn brown. Then the leaf blackens and dies. This is due to the presence of the Mites which, having wintered under the bud scales, burrow into the leaves where they lay their eggs. The young spread the trouble by burrowing in another leaf and this is continued throughout the summer. Before the fall of the leaf, the Mite is safely hidden in a bud for wintering. But in the buds they are less well protected than in the leaves, and hence are best attacked with the lime-sulphur spray in November after leaf-fall or in February before the buds open.

Two other important pests of fruit trees may be taken together. They are *Oligonychus ulmi*, the apple Red-Spider, found on apples, raspberries, plums and pears, and *Bryobia ribis*, found on gooseberries. These are leaf-eaters, which bite the under-side of the leaves to suck the sap. In general they pass the winter as eggs, and are best controlled by a spraying before the blossom has appeared and another after the blossom has gone. For Bryobia one post-blossom treatment is sufficient.

Reference may here be made to the large number of species of the extensive genus Eriophyes which are responsible for the formation of galls on the leaves of trees and other plants. Mite-galls can be distinguished from galls due to insects, since the former have an aperture through which the Mite escapes, while insect larvæ are usually completely imprisoned. Mite-galls are generally covered with a felted mass of " hair," the product of epidermal cells stimulated to abnormal growth, and in the middle of this dense mass the Mite is often difficult to detect.

As examples of common Mite-galls the red growths seen on Sycamore leaves may be mentioned. The " witches brooms " or bundles of small twigs so often seen on the birch and other trees are due to the attacks of Mites, as are the round red galls on alder and the " nail-galls " on lime trees. Mite-galls are also found on lichens of the genus Ramalina. Interesting as is this widespread parasitism, it cannot claim more than passing mention here, since its economic influence is insignificant.

Among house and factory pests, the Cheese-Mites are undoubtedly the first to demand consideration. At least two species of Mite may be found in cheeses, *Tyroglyphus siro* and *Tyroglyphus longior*. The two species are often found feeding together and they are able to live on many other substances besides cheese. These Mites are viviparous, a fact which saves time in their development, with the result that in favourable circumstances they multiply with extreme rapidity and soon completely consume a piece of cheese. When this change from plenty to scarcity occurs, the oldest and the youngest individuals generally perish. The rest, however, have the power of transforming themselves into a form, known as the hypopus, specially adapted for resistance and distribution. The hypopus has a hard brown protective covering, very different from the soft body of the active Mite, and it awaits the arrival of a fly or some other visitor. The hypopus then clings to the hairs on the legs of the insect and is thus transported to other surroundings.

The species *Tyroglyphus longior* may be found in bran and flour as well as in cheese and a variety *T. longior* var. *castellanii* in copra. These may cause " itch " in those

who handle the flour and they have been known to cause conjunctivitis. The Mite *Glycyphagus domesticus* is found in sugar and its allies occur in straw and hay. The Flour-Mite, *Aleurobius farinæ*, is a common pest in grain, bran, oatmeal, flour and cheese, where it is responsible for much damage. It bores a hole in the epicarp of the corn grain and eats the whole of the contents. Its life-history may, under favourable conditions, be completed in less than a fortnight, so that it can multiply very rapidly.

Control of these Mites is best obtained by attention to the humidity of the atmosphere of the store rooms. When the evaporating power of the air increases, the resistance of the Mites is seriously diminished, and free circulation of dry air is fatal even to their eggs. Since these Mites travel on the legs of flies, all measures which tend to diminish the number of flies or, by screening, to exclude them from the store are to be recommended.

In conclusion it may be pointed out that while there is often a large entry on the credit side of economic entomology, and the beneficial and useful insects to some extent compensate for the depredations of the others, there is no such benefit to be attributed to any Mite. Mites which perform actions which assist the human race to solve the problems of living seem not to have been evolved.

XVIII

PRACTICAL ARACHNOLOGY

The practical side of Arachnology includes the collecting of living material from the field, the anatomical study of their bodies in the laboratory and the observation under controlled conditions of the behaviour of the animals themselves.

The collection of Arachnida does not in any essential differ from the collection of Insects or other small creatures, and the best methods are the usual ones of beating, sweeping and sifting. A common necessity for all these methods is some sheet-like surface, which may be merely a newspaper or the lid of a cardboard box or a white mackintosh sheet or an old umbrella. In beating, the leaves and branches of hedges and trees are vigorously beaten or shaken so that a shower of small creatures falls upon the sheet or into the inverted umbrella. As these crawl about they are covered with a glass tube, up which they will run and from which they are then shaken into a bottle of alcohol or, if required alive, into pill-boxes. Small animals may be easily and quickly picked up with a moistened forefinger. In sifting, handfuls of dead leaves or pine-needles or other débris are gathered into a sieve made of fine-meshed wire netting and shaken over the sheet, the produce being treated in the same way. Grass roots may be cut with a strong knife, including some of the earth, and treated in the same way. In sweeping, a stout canvas net is dragged through the undergrowth and its contents periodically turned out on to the sheet.

Arachnida can only be preserved in alcohol, the strength of which should not be less than 90 per cent., contained in specimen tubes. Some species will discolour the spirit when first put into it, so that it must later be changed. The brilliant colours of some species may disappear, but in the majority there is no change and the specimen may be kept in perfect condition certainly for two hundred years and probably for ever. For mere exhibition in a museum case, the hard specimens like Limulus and the Scorpions may be allowed to dry, but as this fixes all their limbs in immovable positions it is useless for any other purpose.

In laboratory investigation of the bodies of the Arachnida, three methods are possible. In ordinary circumstances the animal is most easily examined as it lies in alcohol in a clean white saucer. A bright direct illumination is an essential, when the one-inch objective will be found to provide sufficient magnification for all but exceptionally small specimens. Alternatively, the specimen may be allowed to dry and then examined in the same way, only without the alcohol. For some species this is found to be an advantage. A third method is unorthodox but most efficient. The specimen

is allowed to dry and is then picked up by one leg with the stage-forceps. The points of the forceps are first focused and then illuminated as strongly as possible with a standing lens. The specimen can now be turned and twisted about and viewed from all angles far more easily than in any other way. For this helpful method I am indebted to Mr. D. R. Pack-Beresford.

Laboratory examination of the Arachnida also includes dissection and microtomy. Ordinary naked-eye dissection is possible only with the larger species and calls for little comment: its fascination is immense, but it is an art which can be learnt only by practice. The only helpful advice which can be given in print is to emphasise that, more even than the familiar worms, frogs, cockroaches and rabbits, do the Arachnida demand that one's knives and scissors be really sharp.

Section cutting is more specialised work. The chitin with which Arthropoda are invested makes them slowly penetrable by fixatives and hard to embed and to cut. Among Spiders the difficulty is intensified by the fluid nature of the abdominal contents and the fact that the eggs harden considerably. In the study of ovaries, however, these organs may be dissected out and fixed separately. To a limited extent this is also true of the silk-glands, but to little else.

The trouble caused by the hardness of the exoskeleton has often been avoided by using animals which have only just moulted and whose exoskeleton is still soft. But the process of moulting is accompanied by various internal changes and moreover suitable animals are naturally much less easy to obtain.

Millot [62] has perfected a process in which these difficulties are lessened, and his procedure is as follows:

i. Dehydrate.
ii. Transfer to a mixture of equal parts of ethyl ether and absolute alcohol for 12 to 24 hours, according to size.
iii. To celloidine solution for 48 hours.
iv. To toluene, two changes.
v. Embed in paraffin in the usual way.

As a fixative solution Duboscq-Brazil's or Fleming's solutions may be used, but in general the best results are obtained by the use of the following, recommended by Petrunkevitch [66*a*]:

Alcohol, 60%	100 c.c.
Nitric acid, sp. gr. 1·42	3 c.c.
Ether	5 c.c.
Cupric nitrate crystals	2 grams
p-Nitrophenol crystals	5 grams

Specimens may be left in this fluid as long as desired without the tissues becoming any harder than they are in the living animal. The fixative is washed out of the tissues with three or four changes of 70 per cent. alcohol. The best stains to use are

Delafield's Hæmatoxylin, alone or counter-stained with tetrabrom-fluorescic acid, or the incomparable Mallory's triple stain.

Petrunkevitch also recommends the examination of entire Spiders which, after fixing, have been cleared in tetrahydronaphthalene. This renders visible the muscular and alimentary systems.

Complete knowledge of the Arachnida, however, cannot be obtained by examination of their dead bodies only. In this respect the Arachnida are often found to be excellent subjects, living with apparent contentment in captivity and reacting as normally to stimuli as they do in nature. Some species are harder to keep than others, or perhaps it is more accurate to say that the essential conditions necessary for their survival in cages are less easily discovered and maintained, but this is not the general rule. Most arachnologists have been able to observe one or more species very fully and have described their methods. Millot [62] gives very high praise to the Thomisidæ, which he describes as the ideal laboratory Spiders, capable of living in anything. Bonnet's [22] great work on Dolomedes is a model of its kind, unsurpassed in extent and fullness of detail, while in his study of the life-history of Nephilia the same author [22*a*] has succeeded in hastening the development of the females and retarding that of the males, so that members of the same cocoon reached maturity together, a striking modification of natural events.

In addition to this it is a fact that is far from being generally recognised that the Arachnida in general and perhaps Spiders in particular provide very suitable subjects for the study of animal behaviour, of reflex actions, of tropisms and of instinct. They are essentially animals of the " small-brained " type, richly endowed by heredity with instinctive modes of behaviour but without the power to learn possessed by " large-brained " creatures. It is so seldom necessary to postulate the existence of a thinking or conscious mind in interpreting their actions that the Arachnida might well be taken by mechanistic biologists as ideal examples of automata or organic machines.

It is probably for this reason that they are so ready to live an undisturbed life in our observation cages. On occasions in the past experiments on insect behaviour have been barren or have yielded untrustworthy results because the insect did not exhibit its natural reactions when in captivity. But the circumstances of experiment do not perturb the placid and amenable Arachnida ; their mechanical responses are called forth and their behaviour can be measured and often predicted as if one were working with a galvanometer or a spectroscope.

Excursus XIV

A Laboratory Course in Arachnology

There are probably few, if any, University courses in Practical Zoology in which the Arachnida can hope to occupy as much as the ten periods for which the work

outlined below is designed. The full course may, however, be used as a basis from which selections can be made, while a few specialists or others working privately may wish to follow it completely and to supplement it. In recognition of this, the work has been divided into two parts, general and special.

GENERAL COURSE.—This consists chiefly of examining and drawing the Demonstration Specimens provided, and the preparation of microscope slides of entire specimens of some of the smaller Arachnida. The part occupies five periods of about two hours each.

1. (i) *Limulus*, dorsal view.—Cephalothorax; abdomen; telson; compound eyes; simple eyes.
   (ii) Ventral view.—Cephalothoracic limbs 1–6, gnathobases on 2–6; digging process on last leg; genital operculum; abdominal limbs 1–5, with gill-books; anus; telson.
   (iii) Casts of fossil forms, such as *Eurypterus* and *Prestwichia*.
   (iv) *Scorpion*, dorsal view.—Cheliceræ; pedipalpi; carapace; median eyes; lateral eyes; mesosomatic segments 1–7; metasomatic segments 1–5; telson.
   (v) Ventral view.—Cheliceræ; pedipalpi; legs 1–4 with gnathobases on 1 and 2; genital operculum; pectines; four pairs of stigmata; telson.
2. *Araneæ*.—A moderate-sized Spider, preserved in 70 per cent. alcohol or freshly killed by dropping into boiling water, is gently boiled in dilute (10 per cent.) potassium hydroxide. The viscera are thus entirely dissolved and the exoskeleton which remains is rapidly upgraded to absolute alcohol, cleared and mounted in balsam under a large cover-slip. Under one-inch objective draw:
   (i) Dorsal view.—Cheliceræ; pedipalpi; legs 1–4; eyes; cephalothorax; abdomen.
   (ii) Ventral view.—Cheliceræ; pedipalpi with maxillary gnathobase; labium; sternum; legs; epigyne; lung-books; spinnerets.
   (iii) From a mature male Spider the pedipalpi are detached. One is dehydrated and mounted on its side in its normal state; the other is boiled in potash until the organ has expanded, when it is dehydrated and mounted.
3. *Opiliones*.—A Harvestman with its legs cut through the femora near the body is boiled in potash and mounted whole.
   (i) Dorsal view.—Cheliceræ; pedipalpi; eyes; orifices of odoriferous glands; cephalothorax and abdomen broadly joined; vitta.
   (ii) The characteristic penis of the male or the ovipositor of the female is made to extrude from the ventral surface by gently squeezing the body. These parts are then extracted and mounted.
   (iii) Permanent mounts of an isolated chelicera and of a single tarsus are also well worth making.
4. *Chelonethi*.—These should be studied by the method described by J. C. Chamberlin [2]. The cheliceræ and palpi and the legs of the first and fourth

pairs are removed from the body, dehydrated, cleared and mounted. The body is gently boiled in potash, washed, stained with magenta or fuchsin, cleared and mounted. All the characteristic features are well displayed by this method.

5. *Acari.*—Cheese-Mites, Tyroglyphus, and Red-Spiders, Tetranychus, are readily obtainable for mounting. A drawing is made from the ventral aspect, showing : thorax and abdomen broadly fused ; cheliceræ ; pedipalpi ; legs ; genital orifice ; anus. Various species of Mites are easily found by bringing a boxful of drifted leaves and similar vegetable débris into the laboratory and turning it out on to a sheet of paper. The Mites that crawl out are straightway drowned in spirit. Quite satisfactory preparations may often be made by merely allowing their bodies to dry and covering them with a drop of balsam and a cover-slip. But crude methods like this are not necessarily to be encouraged.

Special Course.—Owing to the small size of most of the Arachnida, and the difficulty of obtaining the largest species in Britain, this course is of necessity based on the Spider. Spiders, however, justify their choice since they are the most highly specialised order. This course also occupies five periods.

6. *Families of Spiders.*—(i) Examine and draw in outline the nine demonstration specimens selected as representatives of the chief European families. The following species are all readily obtainable and are suggested as suitable for the purpose.

Family.	Species.
1. Drassidæ	*Scotophœus blackwallii.*
2. Thomisidæ	*Xysticus cristatus.*
3. Salticidæ	*Salticus scenicus.*
4. Amaurobiidæ	*Amaurobius fenestralis.*
5. Agelenidæ	*Tegenaria derhamii.*
6. Lycosidæ	*Lycosa amentata.*
7. Theridiidæ	*Steatoda bipunctata.*
8. Linyphiidæ	*Linyphia triangularis.*
9. Argiopidæ	*Araneus diadematus.*

(ii) Examine examples of the Mygalomorphæ and Liphistiidæ, if available.

7. *External Structure.*—(i) After boiling in potash, the exoskeleton of a Spider is dissected and a set of slides made to illustrate all the chief external features. The following are suggested : 1. carapace, with eyes ; 2. maxillæ with palpi and labium ; 3. legs ; 4. spinnerets ; 5. sternum ; 6. cheliceræ.
(ii) A leg, parboiled in stronger potash, readily sheds its spines and setæ. If then mounted, the lyriform organs are more easily visible.

8. *Genitalia.*—(i) Female.—The genital area is cut away from the abdomen, cleaned by gentle digestion in dilute potash, dehydrated, cleared and mounted.

(ii) Male.—General treatment as in 2 (iii) above, but different species should be used. For further remarks on the treatment of palpal organs see T. H. Savory, *J. Queckett Micros. Club.* xv. 1927. pp. 252–4.

(iii) Spermatozoa.—A male Spider is chloroformed, the palp removed and crushed between two slides. This produces a smear of spermatozoa, together with some débris which is removed. The smear is fixed with Bouin's fluid, after being dried on the slide, and the Bouin then washed off with tap water. Ehrlich's hæmatoxylin is applied until the smear goes a deep red colour, when it is washed in tap water until it turns blue. It is then dehydrated, cleared and mounted in balsam.

9. *Internal Structure.*—(i) The dissection of the large House-Spider, *Tegenaria atrica*, is most interesting though not conspicuously easy. With but moderate skill, however, the following should be detectable: In the cephalothorax—poison-glands (stain and mount), pharynx (Fig. 1) endosternite (clean in very dilute potash). In the abdomen—heart, ovaries or testes (stain and mount), one or more kinds of silk-gland (double stain with hæmatoxylin and eosin). (ii) A Spider macerated in water until all the soft parts have rotted away is well worth examination. The pharynx and sucking stomach are more easily seen by this method than by any other and usually remain attached to the lip. Fig. 1 was drawn from a slide made from material obtained in this way in June 1927.
10. *Other Arachnida.*—A more detailed examination of such demonstration specimens as may be available—e.g. Galeodes, Mastigophorus or Thelyphonus and a small type-collection of Ticks.

XIX

HISTORICAL ARACHNOLOGY

The Ancients were well acquainted with the Arachnida, and, as is evident from the quotations chosen for the chapters in the principal part of this book, the classical authors make a number of references to them. Living, indeed, where they did, they could hardly fail to know these animals only too well.

Scorpions were so impressive that they earned a place in the Zodiac—the sign of Scorpio, October 21 to November 20—and the ubiquity of Spiders was of course responsible for the fact that the Orders now known as Opiliones and Solifugæ were not then distinguished from the Araneæ. The Itch-Mite, *Sarcoptes scabei*, was known to Aristotle, who also mentions the Book-Scorpion, *Cheiridium museorum*, but both these were at first regarded as insects. Thus five of the modern Orders of Arachnida can boast a respectable ancestry. In the seventeenth century the first certain description of one of the Pedipalpi, an Amblypyge from Surinam, was published by Stephen Blankaart.

Scientific Arachnology cannot, however, be said to have begun until the nineteenth century. The preceding century had indeed seen the publication of at least three works on Spiders, all of which are of some interest to those who concern themselves with the history of the subject. Eleazar Albin's *Natural History of Spiders and other Curious Insects* was published in London in 1736 and C. Clerck's *Svenska Spindlar* in 1757 gave an account of the Swedish species. An Englishman, Th. Martyn, had also produced in 1793 a synthetic work, *Aranei*, which contained the chief parts of the books of Albin and Clerck. The opening years of the nineteenth century produced two much more ambitious works. These were P. A. Latreille's *Genera Crustaceorum et Insectorum* and C. A. Walckenaer's *Histoire Naturelle des Araneides*, both of which began to appear in 1806. Apart from their intrinsic value, these books have an historical interest as they helped to turn the attention of Eugene Simon, while still a boy, towards the subject of Spiders. Then, in 1815, the Arachnida emerged, at the hands of Lamarck, as an independent Order and shook off their associations with insects and crustaceans.

The foundations of modern Arachnology were laid by Thorell in Upsala, Simon in Paris and Pickard-Cambridge in England, the last of whom was instructed and inspired by his friendship with Blackwall.

John Blackwall was born on 20 January 1790, and after some years in the Irish linen trade, settled in 1833 at Llanwrst, in North Wales. Fifteen of his first

twenty-five papers were ornithological, but he was soon attracted to Spiders and his first paper on this subject, to which he afterwards devoted himself, appeared in 1827. Later his writings were collected as *Researches in Zoology*, the first edition of which appeared in 1834 and the second, an almost entirely different work, in 1873. His study of the British Spiders, which he continued almost alone in England for many years, produced his great folio work, *A History of the Spiders of Great Britain and Ireland*, published by the Ray Society in 1861 and 1863. The manuscript of this was in the hands of the Society for ten years before it was printed. In addition, the artist died before his work of illustration was quite complete, and certain type specimens of species, amounting to about twenty-five in all, have been lost. Consequently there are some descriptions of which it is impossible to say what species they describe, but apart from this, the book will always remain as a monument of pioneer-work. Blackwall died at the age of 91 on 11 May 1881.

T. THORELL, like Clerck, Linné and de Geer, lived and worked in Sweden, where he was Professor of Zoology at the University of Upsala. He was a scholar renowned for his intimate acquaintance with nearly all European languages, as well as for his high authority of an Arachnologist. Besides taking a share in the task of determining the bounds of the natural Orders and describing their relationships, he was always alive to the necessity for precision and accuracy in nomenclature of species. One of his earliest papers, published in 1858, " Om Clercks original-spindelsamling," was a review of the actual collection of Spiders left by his predecessors, a work of great value in determination of the actual species described by Clerck, the first to apply the Linnean system of nomenclature to Spiders.

Soon after the publication of Blackwall's great work, he produced a comparative account of it and N. Westring's *Araneæ Suecicæ* of 1861, in which the general of European Spiders as then known were reviewed. This book, *On European Spiders*, appeared in 1869. In the preparation of it and his next work he was engaged in the considerable task of making a critical examination of types of many species of European Spiders. Pickard-Cambridge, Simon and others were of necessity called upon to collaborate in this, so that for years a continual interchange of species of Spiders was taking place between Bloxworth, Paris, Upsala and elsewhere. The outcome of this work is to be found in Thorell's extremely valuable book on *The Synonyma of European Spiders*, published in Upsala, London and Berlin in 1870–3.

EUGENE SIMON was born in Paris on 30 April 1848. He acquired from his father a love of natural history, and finding that Spiders were generally neglected, determined to devote his life to their study. In this he made so precocious a start that his first edition of the *Histoire Naturelle des Araignées* appeared when he was 16 years old. He was only 27 when he held the position of president of the Sociéte Entomologique de France.

For the purpose of collecting Arachnida he travelled all over France, and later visited South America, Ceylon and Africa. During these years he was constantly receiving collections made by both individuals and expeditions, from all parts of the

world, and all this material he studied personally, with the additional burden, which zoologists to-day seldom encounter, that as he did it, the whole of the classification had to be simultaneously constructed. This taxonomic work he included in his great *Histoire Naturelle des Araignées*, the second edition of which appeared in parts between 1892 and 1901. After its completion he returned to the study of the French Arachnida, in Volume VI of which he planned a revision—practically a second edition—of the work. This volume was completed after his death by Fage and Berland.

Simon worked also at other branches of zoology and was a very competent botanist. But he was first and foremost the world's greatest Arachnologist. He published several papers annually on Spiders and his collection grew until it reached the immense total of 26,000 tubes, many of which contained a large number of specimens. He died at the age of 76, on 16 November 1924.

Octavius Pickard-Cambridge was born at Bloxworth Rectory, Dorset, on 3 November 1828. At first he studied law, but in 1855 entered University College, Durham, with a view to ordination. In 1860 he returned to Bloxworth as his father's curate, in 1868 he succeeded him as rector, and he remained at Bloxworth until his death at the age of 88 on 9 March 1917.

He became acquainted with Blackwall about 1854, from which year his interest in Spiders grew until he rapidly became the greatest authority on Arachnida in Britain. His first papers on the subject appeared in 1859 and continued almost annually until 1914. He also wrote his invaluable *Spiders of Dorset*, as well as most useful accounts of the British Harvestmen and False-Scorpions and a large part of the Arachnida section of the *Biologia Centrale Americana*. He was elected F.R.S. in 1887.

The life of Pickard-Cambridge, as portrayed in the memoir by his son, presents a picture of great attractiveness. He is seen on the one hand living " the uneventful life of a country parson," carrying on the traditions of his father and ministering faithfully to the needs of village parishioners for so many years that it is no surprise to read that one of them said at his death, " There, it is the end of all things to we." All that is best in the quiet life of a scholar and a Christian, in a world now so remote, is found in this aspect of his work. On the other hand he is seen as one of the foremost scientists, in his own speciality, of his, or any other, age, exerting not a parochial but a universal influence, justly famous and honourably rewarded for his services to Zoology.

During these years at least two animals of more than usual interest had been discovered. One of these was the Spider *Liphistius desultor*, found in Penang in 1849. Very few Arachnida have inspired anything like the same amount of discussion. The other was *Cryptostemma westermanii*, found in Guinea in 1838, the first of the Ricinulei. Later, in 1885, came P. Grassi's discovery of *Kœnenia mirabilis*, the first of the Palpigradi, the youngest Order of the Arachnida. We may also note, in passing, the publication of N. Westring's *Araneæ Suecicæ* in 1861 and of A. Menge's *Preussische Spinnen* in 1866–9, for these books led to the production of Thorell's valuable *Synonyma of European Spiders* in 1870–3.

In the meanwhile Arachnology was making a beginning in the New World, where the first mygalomorph Spider had been caught, in Jamaica, a century earlier. The father of American Arachnology was NICHOLAS MARCELLUS HENTZ. Hentz was born in Versailles on 25 July 1797, the son of a lawyer and politician. He began to study medicine, but in 1816 after the downfall of Napoleon, of necessity accompanied his father to America. Here he lived as a teacher until his death on 4 November 1856. Throughout his life in America he devoted his leisure to the study of Spiders, his publications on which, between 1821 and 1850, were ultimately collected and edited by J. H. Emerton.

Hentz's work was carried on by Emerton and by Dr. G. W. Peckham and his wife. The latter, in particular, made some of the earliest investigations of spider courtship and were practically the pioneers in the scientific study of their behaviour under experimental conditions. In 1893 appeared one of the largest works on Spiders in existence, the three volumes of Dr. C. McCook's *American Spiders and their Spinning-work*. This book, which was published by the author, included a very full account of the habits and life-histories of American Spiders as far as they were then known, and much of its contents were due to the study and observations of the author himself. It was copiously illustrated, and dealt in a particularly valuable way with the form of the orb-web and its many variations.

The opening of the twentieth century was notable for the appearance of two arachnid volumes of the German *Tierreich*, compiled by Karl Kraepelin. These collected together the previously widely scattered descriptions of the four Orders Solifugæ, Scorpiones, Pedipalpi and Palpigradi. Yet the years before the War did not produce any particularly striking advance in the subject. In England, however, there began the appearance of the valuable papers by Dr. A. Randell Jackson, of Chester, on the species and genera of British Spiders, work which its author, now one of the foremost arachnologists of the world, has continued and extended, especially to Arctic fauna. The descriptive work of H. R. Hogg, who dealt with tropical Spiders, also deserves mention. In America, Professor J. H. Comstock's widely appreciated *Spider Book* was published in 1912.

Since the War, Arachnology has advanced in a conspicuous manner, especially during the last decade. This has shown itself partly in the greater number of papers on the Class which have been published in scientific journals, and even more conspicuously in the appearance of a set of authoritative books of immense value.

Of these the first that claims attention is the monograph on the Ixodidæ or Ticks by G. H. F. Nuttall, C. Warburton, W. F. Cooper and L. E. Robinson, a work in four parts which appeared in 1908, 1911, 1915 and 1926. Comparable to this are the three volumes on British Water-Mites, by C. D. Soar and W. Williamson, published by the Ray Society in 1925, 1927 and 1929. The intricate study of Mites, which present the united features of a microscopic size and a multiplicity of species, has made great progress, as the works of Berlese and Vitzthum on the Continent show.

To Spiders, as always, a large share of attention has been given. The efforts of A. Petrunkevitch to produce a finally acceptable system of classification have already been mentioned, and the descriptive work of C. R. Crosby and S. C. Bishop on American Spiders is also noteworthy. In Europe the study of Spider courtship has made great advances, owing to the work of U. Gerhardt in Germany and W. S. Bristowe and G. H. Locket in this country. At the present moment most of the work on Spiders is rightly of a specialist nature, and is concerned with particular problems. Among these the contributions of J. Millot on structure, P. Bonnet on regeneration, H. Wiehle on the orb-web and H. Peters on behaviour are conspicuous.

In 1923 C. F. Roewer's work on the Opiliones culminated in his great volume *Die Weberknechte der Erde*, which, together with almost annual supplementary papers on " Weitere Weberknechte " gives a review of all the Harvestmen in the World. Subsequently Roewer has dealt at almost equal length and in greater detail with the Order Solifugæ, a most comprehensive account of which is given in Bronn's *Klassen und Ordnungen des Tierreichs*.

The Chelonethi have received similar treatment from J. C. Chamberlin, of Ohio, whose monograph on the Order appeared in 1931. The study of False-Scorpions owes its foundations to H. J. Hansen and to C. With of Copenhagen : the group was also studied by E. Simon in France as well as in England by O. Pickard-Cambridge, whose work was continued by H. Wallis Kew. Chamberlin's work is the widest survey of the Order that has appeared.

Among the smaller groups, the paper by H. E. Ewing on the Ricinulei in 1929 is noteworthy as it summarised the existing knowledge of the Order and gave a promise of more, based on recently found specimens of these exceptionally rare Arachnida.

An approximate but extremely interesting survey of the recent rise in the study of Arachnology may be made by considering the number of publications listed in the annual issues of the *Zoological Record*. The view is only approximate because the Arachnida section of this indispensable production includes the Prototracheata as well as Trilobita and other groups here described as the Doubtful Arachnida, but this does not really affect the point. The numbers of titles during the last twenty-five years are as follows :

1909, 224	1914, 127	1919, 75	1924, 247	1929, 388
1910, 223	1915, 141	1920, 128	1925, 201	1930, 382
1911, 217	1916, 126	1921, 124	1926, 298	1931, 424
1912, 209	1917, 95	1922, 270	1927, 345	1932, 380
1913, 181	1918, 69	1923, 180	1928, 416	1933, 471

A comparatively slow recovery after the War is noticed, with the " golden age " beginning in 1927, so that the annual average is now double its pre-War value.

From this it is not surprising that a feeling seems to be manifest among Arachnologists that the time has come for the existing knowledge of the Class, for so long widely scattered in the zoological literature of the world, to be brought together for scrutiny,

extension and revision. Two works which promise to do this in a worthy manner are the contemporary German series, Bronn's *Klassen und Ordnungen des Tierreichs* and Kukenthal and Krumbach's monumental *Handbuch der Zoologie*, both of which are in the course of publication. The scale and the comprehensive nature of these are such that it is impossible to overpraise them—and difficult to live without them. To the German Arachnologists is due an expression of gratitude which every Zoologist must acknowledge.

XX

DISIECTA MEMBRA

On Diagnoses

Each Order of living Arachnida mentioned in the second part of this book is preceded by the customary summary of its essential features. By reading the diagnoses of its Classes or Orders a survey of a whole Phylum may be obtained more rapidly and easily than in any other way, and for purposes of comparison such diagnoses are invaluable. The practice of writing diagnoses has, however, been interpreted in various ways, which seems to indicate uncertainty both as to the purpose of a diagnosis and the best way of achieving it. Thus, in the *Cambridge Natural History*, some of the Orders of Arachnida are introduced by diagnoses which average about forty words in length. At the other extreme, Petrunkevitch gives a diagnosis of Araneæ running to four hundred and fifty words and Chamberlin a diagnosis of Chelonethi of four hundred and twenty words. What is the ideal ? A diagnosis should obviously be more than a definition. For example, the Solifugæ may with perfect accuracy be defined as " Arachnida with malleoli on the fourth legs," and the Araneæ as " Arachnida with opisthosomatic silk-producing organs," but such definitions are too condensed to be of much value. They have a place only in a dichotomic table. On the other hand, the very full diagnoses are so unwieldy that they sacrifice to completeness their chief virtue—that of being quickly and easily grasped.

The diagnoses in the second part of this book have been written with some care in an attempt to avoid these extremes. Each is about a hundred words long, and aims at providing a rapid résumé of the characteristics of an Order without overburdening details.

On Types

The International Rules of Nomenclature make clear the necessity for naming a type-species for each genus of animals. This has been extended by some recent Zoologists, not only by multiplying the varieties of " types " so that now there are genotypes, holotypes, allotypes and paratypes but also by naming types for families and Orders. The value of this is less apparent for the Orders of animals are now fairly well established although genera are still liable to considerable revision. Logically, the process might continue, types might be named for Classes and Phyla, and *Amœba proteus* or *Homo sapiens* compete for the position of " type " to the Animal Kingdom with the Scorpion, the Eagle or the Cow.

On Somites and Segments

Human Anatomy has provided much of the nomenclature of Zoology, but not always with wholly satisfying results. Among the invertebrates, the three words "somite," "segment" and "joint" are used almost indiscriminately in the descriptions of the bodies of the Arachnida—and indeed of the Arthropoda generally—and are applied indifferently either to the body or the limbs. It is clearly undesirable that this should be done, for a segment of the opisthosoma is not morphologically the same sort of thing as a segment of the pedipalpi or legs. A leg segment, like a femur or a tibia, is not a joint at all, a joint being the meeting-place of two segments, comparable to a knee or an elbow.

To avoid this looseness of terminology I have in this book uniformly adopted the rule that the elements of the body itself be called by the more scientific term of somite, and that the word segment be applied only to the parts of the limbs and other appendages. Joint is used only in its proper sense as junction.

It is, of course, still accurate to describe the Arthropoda as segmented or segmental animals, for their bodies are composed of sections or segments of which the proper name is somite.

On the Word Tarantula

Every traveller returns from abroad with stories of "tarantulas." This confusing word is, of course, taken from the town of Taranto in Apulia. In its arachnological sense it was first used by Hoby in 1561 in a translation of *Castiglione's Courtyer* and was there marginally described as a kind of Spider whose bite was dangerous. There is no reason to doubt the traditional belief that the Spider referred to was the species properly known as *Lycosa tarentula* (Rossi), a frequent synonym of which is *Tarentula apulia* (Walckenaer). The idea that its bite was poisonous and that a cure was only to be found in music and dancing was connected with it from the first and has been more fully dealt with by myself elsewhere (*Biology of Spiders*, pp. 126–8).

Later the word was applied to any large Spider, particularly the Mygalomorphæ of Central America, but even as early as 1598 was used to describe other poisonous animals, Florio in that year referring to a tarantula serpent and a tarantula fish. A genus of Lizards still bears the name Tarentola, while Tarantula is a genus of the Pedipalpi, the type of the Amblypygi or Tarantulidæ.

On Dichotomic Tables

Long and short diagnoses find a parallel in long and short dichotomic tables, and practice in writing out these tables varies a good deal. Some make the descriptions as full as possible, even to the extent of much repetition of widespread characters. Others give only one, two or three distinguishing features. In this book Dichotomic Tables have been compressed as severely as possible, partly to enable them to go (save for the Acari) as far as families. The next stage, to genera and species, usually means

much work at a Museum where a zoological library exists and a good collection is available for comparisons. My idea is that if an Arachnologist can by using this book place his specimens in their correct families, his work in other places should be simplified, and the book will have justified itself.

There are many different ways in which Dichotomic Tables are printed; the feature of the method used in this book is that every descriptive clause has a number of its own, and never an asterisk or a number shared with another clause. A number in brackets is the alternative to the number which precedes it.

APPENDIX

XXI

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III. Bibliographies

Since an even moderately representative bibliography of the general subject of Arachnology would run into several hundreds of titles, it is believed that the most useful course to adopt here is to indicate the whereabouts of some of the bibliographies already in existence.

General	in *The Zoological Record*, Division "Arachnida, etc."		Published annually by the Zoological Society of London.
	in Comstock, 3 *supra*, pp. 701–7.	146 titles.	
Acari	in Vitzthum, 81 *supra*, pp. 152–60.	240 titles.	
Araneæ	in Savory, 10 *supra*, pp. 349–69.	319 titles.	
Chelonethi	in Chamberlin, 2 *supra*, pp. 247–63.	311 titles.	
Linguatulidæ	in Hett, 43 *supra*, pp. 156–9.	103 titles.	
Liphistiidæ	in Bristowe, 24*c* *supra*, pp. 1017–22.	31 titles.	
Ricinulei	in Ewing, 33*a* *supra*, p. 597.	7 titles.	
Solifugæ	in Roewer, 70 *supra*, pp. 14–29.	374 titles.	

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