wounds and other injuries, that Mr. Holding thought the specimen exhibited was of some interest as indicating that organic disease might also be a factor in the degeneration of horns.

The following papers were read:

By H. H. Brindley, M.A., St. John’s College, Cambridge.

[Received September 13, 1897.]

In 1892 Mr. Bateson called my attention to the fact that specimens of the common Cockroach (Stylopyga orientalis) are not unfrequently found to exhibit an abnormal condition of the tarsus, or distal portion of one or more of the walking-legs. This abnormal condition is a numerical variation of the tarsal joints, only four being present instead of the normal number, five—the tarsus as a whole, however, presenting in other respects the features proper to the five-jointed or normal condition. Mr. Bateson suggested to me that it might be worth while to investigate in detail this instance of meristic variation.

The particular interest of the case was that the inspection of four-jointed tarsi in a few individuals seemed to point to the conclusion that the relative proportions of the several joints therein were constant. This abnormal tarsus seemed to possess a fixity or organic stability of structure such as is held usually to be the outcome of the continued operation of selection, an influence which can hardly be called upon to account for the condition of an occasional abnormality.

The investigation thus originated called attention to facts other than those bearing directly on the original question concerning which information was sought. The latter have been discussed by Mr. Bateson in his work on Variation 2. I postpone reference to his conclusions till an account has been given of the observations made before and after his book was published. The present paper is concerned chiefly with certain facts regarding the reproduction of lost or injured legs in the Blattidæ, and with some points in the post-embryonic development of Stylopyga orientalis.

The former of these two subjects cannot be considered apart from that of the reproduction of parts among other Insecta and the Arthropoda as a whole. It has therefore seemed more satisfactory to describe separately the results of the observations and experiments originally undertaken for a more circumscribed purpose, leaving the details of reproduction to a future communication.

The leg of the Cockroach resembles that of other Orthoptera, and consists of the following parts: a massive coxa, which is movably articulated with a small trochanter, to which latter is immovably fused a stout femur. The parts distal to the femur are the tibia and tarsus, all of whose articulations are movable.

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1 Communicated by W. Bateson, M.A., F.R.S., F.Z.S.
The femur very frequently, and the tibia always, have a conspicuous armature of spines. The tarsi in all the Blattidae is five-jointed. The proximal joint is the longest and stoutest, the next much smaller, and the succeeding two very much smaller, while the distal joint approaches the proximal in length and bears a pair of claws. Between the claws many species have a thin rounded projection, the arilium.

In other Orthoptera the number of tarsal joints is 3 in Forficulidae, Hemimeridae, and Acrididae, 2 or 3 in Gryllidae, 4 in Locustidae, and 5 in Mantidae and Phasmdae.

The occasional occurrence among Blattidae of tarsi possessing only four joints, but in other respects normal, has been noted by entomologists from time to time.

In the last century Geoffroy specially characterized the genus Blatta as having four joints in the tarsi of the posterior pair of legs and five in those of the other pairs, though, in spite of this statement, he figures both sexes with five-jointed tarsi on all the legs. His description was doubtless based on one or two abnormal individuals.

This error was corrected by Serville, who does not allude, however, to the occasional occurrence of abnormal tarsi.

A few years later Brisout de Barneville called attention to the occasional presence of four-jointed tarsi in several species of Blattidae. He gives the following table, in which, as elsewhere in this paper, I have followed the nomenclature of Brunner:

<table>
<thead>
<tr>
<th>Species</th>
<th>Total number of individuals examined</th>
<th>Number of individuals with one or more of the tarsi four-jointed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyctibora latipennis</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>N. sericea</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Epilampra cinerea</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Homalosilpha ustulata</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Periplaneta americana</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Leucopsea surinamensis</td>
<td>51</td>
<td>10</td>
</tr>
<tr>
<td>Monachoda grossa</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Blabera atropos</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Panesthia javanica</td>
<td>14</td>
<td>4</td>
</tr>
</tbody>
</table>

2 'Hist. abrégée des Insectes.' 1764, i. p. 379.
3 Hist. nat. des Insectes, 1839, p. 58.
Brunner\textsuperscript{1} quotes Serville's remarks, and states that he could add a large number of cases. He observes that the abnormal tarsus is usually unilateral and on the posterior legs (\textit{Nyctibora}, \textit{Epilampra}, \&c.).

The above-mentioned authors examined only small numbers of individuals, and it was therefore desirable to extend the inquiry as to the frequency of occurrence of abnormal tarsi through greater numbers. This has been done among certain easily obtained species, the total numbers examined being:

\begin{center}
\textbf{Table A.}
\end{center}

\begin{center}
\begin{tabular}{|l|c|c|c|}
\hline
 & Adult & Young & Total \\
\hline
\textit{Periplaneta americana} & 750 & 180 & 930 \\
\textit{P. australasiae} & 280 & 411 & 691 \\
\textit{Phyllodromia germanica} & 102 & 0 & 102 \\
\textit{Stylopyga orientalis} & 1635 & 1976 & 3611 \\
\hline
\end{tabular}
\end{center}

The specimens of \textit{P. americana} and \textit{P. germanica} were obtained from the Society's Gardens, those of \textit{P. australasiae} from the Botanic Garden, Cambridge (where the egg-cases of this species appear to have been introduced in packets of plants from Kew and South America), and those of \textit{S. orientalis} from Cambridge bakehouses, except 262 captured in a bakehouse at Poole, Dorset. The specimens of \textit{P. americana} and \textit{P. germanica} were caught by hand, and those of the other two species by traps. This probably explains the small number obtained of the young of the two former species, as the larger adults are more easily picked up.

It is possible that some of the young of \textit{P. germanica} were wrongly included as belonging to \textit{P. americana}, for both species occur in the same warm houses in the Society's Gardens.

An examination of these specimens showed the percentage frequency of occurrence of individuals with one or more tarsi four-jointed to be as follows:

\begin{center}
\textbf{Table B.}
\end{center}

\begin{center}
\begin{tabular}{|l|c|c|c|c|c|}
\hline
 & Adult males & Adult females & Total adults & Young & Total \\
\hline
\textit{P. americana} & 21.8 & 23.5 & 25.2 & 8.8 & 21.9 \\
\textit{P. australasiae} & 16.9 & 23.2 & 20.0 & 14.8 & 16.7 \\
\textit{P. germanica} & 14.9 & 16.4 & 15.7 & ... & 15.7 \\
\textit{S. orientalis} & 20.6 & 21.8 & 21.4 & 16.4 & 18.7 \\
\hline
\end{tabular}
\end{center}

\textsuperscript{1} Nouv. Syst. des Blattaires, p. 146.
The examination took no account of the sex of immature individuals, because of the very great difficulty or impossibility of rightly ascertaining it without making a dissection in each case.

In the great majority of cases only one of the six legs bore a four-jointed tarsus, though many individuals possessed the abnormality on more than one leg. This point was examined in detail in rather more than one thousand young and adult individuals of both sexes distributed among three species, with the following result:—

**Table C.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of four-jointed tarsi in single individuals.</th>
<th>Number of individuals examined.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
<td>2.</td>
</tr>
<tr>
<td><em>P. americana</em></td>
<td>155</td>
<td>36</td>
</tr>
<tr>
<td><em>P. australasia</em></td>
<td>92</td>
<td>19</td>
</tr>
<tr>
<td><em>S. orientalis</em></td>
<td>588</td>
<td>108</td>
</tr>
</tbody>
</table>

In all four species the posterior pair of legs was the most frequently affected. The following table gives the percentage incidence of four-jointed tarsi among the three pairs of legs:—

**Table D.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Pair.</th>
<th>Adult.</th>
<th>Young.</th>
<th>Total.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. americana</em></td>
<td>I.</td>
<td>20.3</td>
<td>11.1</td>
<td>19.7</td>
</tr>
<tr>
<td></td>
<td>II.</td>
<td>31.1</td>
<td>33.3</td>
<td>31.2</td>
</tr>
<tr>
<td></td>
<td>III.</td>
<td>48.6</td>
<td>55.5</td>
<td>49.1</td>
</tr>
<tr>
<td><em>P. australasia</em></td>
<td>I.</td>
<td>22.8</td>
<td>30.1</td>
<td>26.9</td>
</tr>
<tr>
<td></td>
<td>II.</td>
<td>21.1</td>
<td>28.8</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>III.</td>
<td>56.1</td>
<td>41.1</td>
<td>47.7</td>
</tr>
<tr>
<td><em>P. germanica</em></td>
<td>I.</td>
<td>6.2</td>
<td>......</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>II.</td>
<td>18.7</td>
<td>......</td>
<td>18.7</td>
</tr>
<tr>
<td></td>
<td>III.</td>
<td>75.0</td>
<td>......</td>
<td>75.0</td>
</tr>
<tr>
<td><em>S. orientalis</em></td>
<td>I.</td>
<td>26.9</td>
<td>15.7</td>
<td>21.4</td>
</tr>
<tr>
<td></td>
<td>II.</td>
<td>22.9</td>
<td>27.7</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>III.</td>
<td>50.2</td>
<td>56.4</td>
<td>53.2</td>
</tr>
</tbody>
</table>

The abnormal tarsi occurred indifferently on the right and left sides—thus, in 1329 cases in *S. orientalis*, 661 were on the right and 668 on the left side.

Having set forth the preliminary results obtained, it becomes
necessary to state that at first the frequent occurrence of the abnormal tarsus encouraged a belief that it was a congenital variation. This was supported by several features of the case besides the above. It happened by chance that individuals of *P. americana* were examined first. Among these there were several cases where one tarsus of a pair was normal, and the other abnormal; and in these cases the tarsi were of approximately equal dimensions and seemed symmetrical till closely examined. Moreover, as shown by Table B, the abnormality occurred with distinctly greater frequency among females than males.

Finally, the abnormal tarsus was found in three individuals of *S. orientalis* only 4 cm. in body-length, which is the average size of newly-hatched young.

These facts offer material for discussion, but they must be left for awhile, as the evidence they afford in favour of congenital origin of the four-jointed tarsus seems rebutted by that subsequently obtained—that the abnormality is the form assumed by the tarsus when it is a reproduction taking the place of a lost or injured tarsus.

Cockroaches, like other Orthoptera, attain sexual maturity after performing a series of ecdyses, which in some species probably extend over several years. The power of reproducing lost appendages is known to be possessed by members of several of the tribes of Orthoptera. Among the Blattidae the reproduction of the antennae of the Cockroach after amputation was first described by Heineken

The evidence given below appears to establish that the four-jointed tarsus arises in connection with the reproduction of the leg when any part thereof has been lost or severely injured during the immaturity of the animal.

(a) Absence of abnormal tarsi in newly-hatched individuals.

A number of egg-cases of *S. orientalis* were collected and artificially incubated, from which altogether 210 young were hatched. In a few cases limbs were found to have been broken off, but all the tarsi of entire limbs were normal.

(b) Relative infrequency of abnormal tarsi in very young individuals.

That there was a smaller proportion of abnormal tarsi in young than in adult individuals is shown by Table B. This led to an examination of young of different ages, with the following result:—

<table>
<thead>
<tr>
<th>Body-length</th>
<th>Percentage with abnormal tarsi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 1·05 cm.</td>
<td>10·7</td>
</tr>
<tr>
<td>1·05 to 2·0 cm.</td>
<td>20·0</td>
</tr>
<tr>
<td>2·05 to 3·0 cm.</td>
<td>25·0</td>
</tr>
</tbody>
</table>

(c) Evidence from amputation experiments.

In describing these it will be convenient to employ abbreviations, viz:—

R and L for right and left.
1, 2, and 3 to denote the respective pairs of legs.
\( t_1, t_2, \) and so on for the tarsal joints, starting with the proximal joint.

Altogether the legs of 833 immature individuals of *S. orientalis* of various ages were mutilated and the animals confined in cages till ecdysis occurred. The mutilations were easily performed under chloroform, but it was found that recovery did not occur unless fresh air was admitted immediately the Cockroaches fell on their backs and ceased to struggle. Of the total number operated on 103 were mutilated in one leg and 730 in two legs. In the tabular summary of these experiments given below, "reproduction" must be taken to imply that regrowth of the parts removed took place, and that the new tarsi were always in a *four*-jointed condition.

**Table E.**

<table>
<thead>
<tr>
<th>Nature of mutilation.</th>
<th>Leg mutilated.</th>
<th>Number of mutilations.</th>
<th>Number of reproductions observed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_2 ) torn away from ( t_1 ) ...</td>
<td>3 R</td>
<td>300</td>
<td>141</td>
</tr>
<tr>
<td>( t_1 ) divided with scissors.</td>
<td>2 L</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3 L</td>
<td>109</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>130</td>
<td>19</td>
</tr>
<tr>
<td>Tarsus torn away from tibia</td>
<td>2 R</td>
<td>300</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>3 R</td>
<td>89</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>389</td>
<td>189</td>
</tr>
<tr>
<td>Tibia divided with scissors</td>
<td>3 R</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3 L</td>
<td>300</td>
<td>122</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>314</td>
<td>124</td>
</tr>
<tr>
<td>Femur torn away from trochanter</td>
<td>1 L</td>
<td>300</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>2 R</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3 L</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>340</td>
<td>152</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1473</td>
<td>625</td>
</tr>
</tbody>
</table>

It will thus be seen that about \( \frac{5}{2} \) of the mutilations were followed by reproduction of the lost parts accompanied by the appearance of a *four*-jointed tarsus. The normal five-jointed condition never occurred in reproduction. In only two or three
cases were the reproduced parts at all malformed. These will be dealt with later on. The balance of 848 cases in which reproduction was not observed is accounted for by no reproduction occurring at ecdysis or by death before ecdysis. The recent observation by Bordage\(^1\) that the reproduced tarsus of certain Phasmids is invariably four-jointed is of much interest in connection with the above results.

(d) Liability to accidental injury in immature individuals.

The evidence already obtained that the occurrence of the four-jointed tarsus in a captured Cockroach indicates accidental injury in the part, was confirmed indirectly by the examination of 1106 young of \(S. \text{orientalis}\), when first caught, with the result that \(8\%\) were found to be imperfect as regards either the whole or portions of one or more legs. This is a considerably lower percentage than that for the occurrence of four-jointed tarsi recorded in Table B, but the importance of the frequent occurrence of imperfect individuals is increased by bearing in mind that reproduction of lost parts may take place at any of the several ecdyses and that, as has been ascertained by observation, when once a four-jointed tarsus has appeared it is perpetuated through the succeeding ecdysis and almost certainly though all subsequent ones up to their cessation on maturity being attained, which accounts for the higher percentage of such tarsi found in adult individuals.

From another point of view the relation of abnormal tarsi to accidental injury in captured individuals is emphasized by comparing Table D with the following results of examining newly captured \(S. \text{orientalis}\) for the distribution of imperfect legs:

<table>
<thead>
<tr>
<th>Pair.</th>
<th>92 young</th>
<th>131 adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>25 %</td>
<td>20·6 %</td>
</tr>
<tr>
<td>II.</td>
<td>32·6 %</td>
<td>19·1 %</td>
</tr>
<tr>
<td>III.</td>
<td>42·4 %</td>
<td>60·3 %</td>
</tr>
</tbody>
</table>

The long third pair of legs seems to suffer more from their exposed condition as compared with the less extended anterior pairs, and this was observed to be the case with individuals kept in confinement. The tarsi of these, if subsequently reproduced, were invariably four-jointed.

Newport\(^2\) has noticed a similar special liability to injury in the long posterior legs of \(Scolopendra\).

It is of course possible that the four-jointed form of tarsus may be occasionally of congenital origin, but the balance of evidence indicates clearly that in \(S. \text{orientalis}\), at all events, it is a result of the loss of the normal tarsus.

---


\(^2\) "On the Reproduction of Lost Parts in Myriapoda and Insecta," Phil. Trans. 1844.
Numerical variations in the joints of reproduced appendages have been described by several observers in other Orthoptera than the Blattidae and in certain other groups of the tracheate Arthropoda. As has been pointed out, the phenomena of reproduction of the legs and the special features of the peculiar form of tarsus associated therewith in the Cockroach must be considered with some reference to what is known of the reproduction of lost parts in the Arthropoda generally. The close connection between the phenomena of reproduction of appendages and ecdysis permits the insertion at this place of certain facts noticed during the mutilation experiments already briefly described.

Immediate effects of mutilation.—A drop of blood appeared on the cut or ruptured surface of the leg, but clotted in a minute or two, thus preventing further haemorrhage. The loss of part or the whole of the leg seemed to inflict mechanical inconvenience only, and an individual which had lost portions of three legs moved about on recovery from anaesthesia with fair activity and resumed its normal habits at once. It was noticed that in nearly all cases the remaining portions of a partially removed tarsus were very soon dropped off, the tibia then terminating the limb. The remaining half of a divided tibia was sometimes dropped and sometimes retained. These losses of parts proximal to the artificially injured region never occurred simultaneously with the inflicted injury. In considering this matter it is necessary to bear in mind the fact that Arthropods of several groups have the power of throwing off their appendages in response to stimuli of various kinds, a phenomenon to which the name autotomy has been given. In Cockroaches there seems to exist a very slight degree of autotomy. If thrown into boiling water they do not snap off their legs as is the case, for instance, with many Spiders. On the other hand, a Cockroach held by a leg not infrequently escapes by its separation from the body when no particularly strong pull is made by the forceps holding the limb, and with a suddenness suggestive of autotomy. Moreover, it was noticed that the break occurs, invariably, either at the tarso-tibial articulation or (and much more frequently) at the suture where femur and trochanter are fused. But if a certain degree of autotomy be admitted, it must be remembered that, in a Cockroach preserved in spirit, a break is effected easily at either of the above-mentioned places, while a strong pull with the forceps is necessary to separate femur and tibia. If the body be held and the tarsus pulled, the break occurs at the femoro-trochanteric suture, while if the femur be held instead, a pull on the tarsus is followed by its separation from the tibia.

I cannot find any record of observation on this point in the Blattidae, but in the case of the Phasmidae, Scudder¹ observed that in Diapheromera amputation of any portion of a leg distal to the femoro-trochanteric suture was followed by loss before the next

ecdyosis of the remaining parts up to the suture. Scudder does not speak of immediate loss suggesting autotomy as usually understood, but he states that the regrowth which replaced the lost parts necessarily always commenced from the above place. On the other hand, Bordage describes well-marked autotomy and subsequent reproduction in two other genera of Phasms as always occurring at the femoro-trochanteric suture. As in the case of the Blattidae, these observations on the Phasms were on individuals which had not performed their final ecdysis, after which reproduction of lost appendages ceases.

Bordage, who employed different kinds of stimuli for bringing about autotomy, found that the age of the individual, as well as the mode of stimulation, was a controlling factor in the readiness with which autotomy occurred. Heineken, early in this century, experimented on the autotomy of the posterior, or jumping, legs in genera of Gryllidae, Locustidae, and Acrididae; while more recently Frédéricq and Contejean have observed in detail the autotomy of the jumping-legs of Locusta viridissima. The experiments of these authors show that the autotomy of the jumping-legs takes place at the femoro-trochanteric suture. [The statement of the last-named that inasmuch as the trochanter is absent in Locusta viridissima, the autotomous break occurs between femur and coxa, appears to rest on the fact that in this species the trochanter is telescoped into the coxa in such a manner as to be visible only when the femur is removed. In a spirit-specimen a sharp pull on the femur always leaves the trochanter still attached to the coxa. In connection with this point, as well as with others in the present enquiry, I am indebted to Dr. David Sharp, F.R.S., for much kind advice and assistance.]

The above-mentioned authors, in addition to ascertaining that different methods of injury and stimulation caused autotomy after a shorter or longer latent period, demonstrated that the event is dependent on the integrity of the third pair of thoracic ganglia, and is as truly a reflex action as the autotomy exhibited by the appendages of Decapod Crustacea, or the tail in certain Lizards. In connection with these observations it must be noted that the power of reproducing lost legs is usually supposed to be absent in the Orthoptera Saltatoria. Graber has observed reproduction of the antennae in Gryllus and Locusta, but could not obtain reproduction of the tarsi. For further information the writings

of the above-mentioned authors and those of Durieu\textsuperscript{1}, Frédéricq\textsuperscript{2}, Peyerimhoff\textsuperscript{3}, and Werner\textsuperscript{4} may be referred to. More recently, however, Griffini\textsuperscript{5}, quoting the above in connection with cases he has observed of apparent reproduction of appendages in \textit{Gomphocerus}, \textit{Oedipoda}, and \textit{Pristes}, concludes that, as is the case in the Cursoria, reproduction may not improbably occur during the post-embryonic development of the Saltatoria also.

From these statements it appears that more extended observations would show that among the Orthoptera alone the more immediate effects of injury to a limb differ considerably in the several tribes of the order. While in some genera a slight stimulus may bring about immediate autotomy at a certain fixed place, in others little or no autotomy is observable even when strong means of stimulation, such as amputation of the more distal portions of a limb, are employed, the injury in such cases being followed sometimes by the eventual dropping away of certain portions of the remaining stump, and sometimes by the retention of the entire stump. Again, though the subject of autotomy necessarily bears a close relation to that of reproduction of lost parts, there seems to be no direct ratio between the degree of autotomy exhibited and the power of reproduction possessed in any particular case.

More or less parallel are the diverse results obtained from mutilation of the limbs in different genera of Arachnida recorded by Heineken\textsuperscript{6}, Blackwall\textsuperscript{7}, Parize\textsuperscript{8}, and Frédéricq\textsuperscript{9}, to whose work fuller reference will be made later on in connection with the phenomena of reproduction of the lost parts.

\textit{Mortality in confinement.---}About 25\% of the 833 mutilated individuals died before accomplishing an ecdysis. Apparently this mortality was not due to the injuries inflicted, for it was not excessive in the period immediately following mutilation, but occurred at a steady rate throughout the experiment. The animals were kept in three glass-fronted boxes $24 \times 8 \times 10$ inches in size, and provided with narrow dark shelters imitating the crevices haunted by Cockroaches when at large. The boxes remained throughout the experiment in a room kept at a temperature of $16^\circ$ C. It is very possible that these arrangements reproduced the natural habitats too imperfectly and that overcrowding, or want

\begin{enumerate}
\item \textit{"Notes sur quelques Orthoptères," Petites Nouv. Entomol. 1876, no. 158.}
\item \textit{Loc. cit.; also "La Latte pour l'existence chez les Animaux Marins" (Paris, 1889), p. 250.}
\item \textit{"Note sur l'atrophie des membres chez les Orthoptères," Miscellanea Entomologica, 1896, iv. p. 70.}
\item \textit{"Selbstverstümmelung bei Heuschrecken," Zool. Anziger, 1892, Jahrg. xv. p. 58.}
\item \textit{"Di un Pristes tuberosus anomalii," Boll. de Musei di Zool. ed Anat. Comp. Torino, 1896, xi. no. 234; also "Di due Acrididi anomalii," \textit{ibid.} xi. no. 256.}
\item \textit{Loc. cit.}
\item \textit{"L'amputation réflexe des pattes des Crustacés," Rev. Scientifique, 1886, ser. 3, xi. p. 379.}
\item \textit{Loc. cit.}
\end{enumerate}
of sufficient space for running about, was the chief cause of this degree of mortality. That it was abnormally high seems probable, especially in view of the facts which will be mentioned later on, concerning the hatching of the egg-cases. Moreover, though Cockroaches once established in a building may become extremely numerous, their slowness in spreading in the neighbourhood is well known, and it is probable that we by no means understand what conditions are most favourable to this imported species. I succeeded, however, in maintaining a few individuals in health for nearly two years and one lived for rather over that time, and eventually escaped from confinement. Bread and cake were always readily eaten, but the animals seemed to pay no attention to a moist sponge always kept in the cages. With large numbers in one cage it was impossible to observe how often any one individual made a meal, but Dr. Sharp ¹ has called attention to the very small amount of food that is required to maintain a Cockroach in good condition, and that many weeks of starvation seem to make little difference to the animal. In the case of my own Cockroaches, a weak individual was never attacked by his companions, but the soft parts of the dead were soon devoured, as were all cast skins not removed from the cages. These latter were certainly not always eaten by their owners, though occasionally they were.

Occurrence of the Ecdyses.—On this subject the monograph of Miall and Denny ² contains the following statement in quotation of Cornelius: ³ “The first change of skin occurs immediately after escape from the egg-capsule, the second four weeks later, the third at the end of the first year, and each succeeding moult after a year’s interval. At the sixth month the insect becomes a ‘pupa,’ and at the seventh (being now four years old) it assumes the form of the perfect insect. The changes of skin are annual and, like fertilization and oviposition, take place in the summer months only. These statements are partly based on observations of captive Cockroaches, and are the only ones accessible; but they require confirmation by independent observers, especially as they altogether differ from Hummel’s account of the life-history of *Blatta germanica*, and are at variance with the popular belief that new generations of the Cockroach are produced with great rapidity.”

The observation of Hummel ⁴ referred to is that *Phyllochromia germanica* performs six ecdyses between April and September, and becomes adult within seven months from hatching out of the egg-capsule. My own observations on the post-embryonic development of *S. orientalis* may now be described.

In the first place great difficulty was experienced in obtaining

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³ "Beiträge zur näheren Kenntniss von *Periplaneta orientalis*,’ Elberfeld, 1853.
⁴ "Quelques observations sur la Blatte germanique.” Essais Entomologiques. I. St. Pétersbourg, 1821.
undoubtedly newly hatched individuals. Between 500 and 600 egg-capsules were collected from bakehouses and kitchens in Cambridge, very many of them immediately after deposition by the females.

At first they were placed in an incubator in the Zoological Laboratory in a constant temperature of 38° C., but so little success attended this method that the capsules obtained later were left undisturbed, as nearly as possible in the exact spots where they had been deposited. But from the whole number of capsules observed, only 20 hatchings were obtained, the total number of young thus raised being 210, an average of 10·5 young from each capsule, which in this species normally contains 16 embryos.

If this observation may be regarded as resting on a fairly sufficient number of instances, it would seem that a large proportion of the egg-cases deposited do not hatch out, and also that some of the young in those that do hatch never appear. As all the cases that hatched did so within a few days after deposition, while the others examined long after were invariably found to be quite brittle and dried up inside, it seems unlikely that the non-hatching of the greater number observed was merely a result of allowing insufficient time for hatching to take place. If this view be accepted, it affords a partial explanation of the well-known tardiness with which this species spreads.

With regard to the time of year when ecdysis occurred, the following observations were made. The mutilated Cockroaches commenced living in captivity during the first three months of the year. The dates of 235 observed ecdyses were distributed thus:

March...... 4 ecdyses.
April....... 12 "
May......... 18 "
June....... 92 "
July....... 72 "
August..... 33 "
September... 4 "

That the number of ecdyses during the maximum period increased rather more rapidly than it declined, is apparent from the following:

May, 3rd week...... 4 ecdyses.
" 4th " .......... 8 "
June, 1st " ...... 12 "
" 2nd " .......... 42 "
" 3rd " .......... 21 "
" 4th " .......... 17 "
July, 1st " ...... 23 "
" 2nd " .......... 22 "
" 3rd " .......... 10 "
" 4th " .......... 17 "

[No. 30,
The dates when ecdysis occurred indicated no relation with either age or sex, and the final ecdyses at which the adult condition commenced were distributed over the whole period in the same ratio as those of still immature individuals.

The statement by Cornelius, that the post-embryonic development of S. orientalis extends over several years, received distinct confirmation from my observations, though to a very imperfect extent, as the purpose for which the immature individuals were kept in captivity was not primarily connected with their life-history, and consequently they were usually removed and placed in spirit when they had completed a single ecdysis. With regard to the statement that an ecdysis is performed immediately on leaving the egg-case, I failed to observe the actual emergence of the young therefrom, though in several cases I examined them within twenty-four hours of their hatching out. With these I could find no trace of cast cuticles, nor did any ecdysis occur for a week succeeding the examination. It is quite possible, however, that ecdysis did occur almost simultaneously with hatching, and that the cuticles shed were speedily devoured, as the young of this species commence to feed within a few hours of hatching. As already mentioned, the four-jointed form of tarsus was found in young only 4 cm. in body-length, which appears, from measurements I have made, to be the length of newly hatched individuals. Whether or not such very young individuals could have lived long enough to suffer loss of a tarsus, perform ecdysis, and reproduce the lost part it is not possible to decide.

As regards the statement that two further ecdyses are performed in the first year, I was able only to ascertain that individuals of less than half the adult size may cast their cuticle twice within five months. This observation was made on eleven individuals which performed an ecdysis in April or May. These were isolated from the others and were observed to again shed the cuticle on different dates between June 7th and August 21st. The body-length of these individuals ranged from 6 to 95 cm. after the second ecdysis noted (the mean length of an adult being 2.1 cm.). The shortest time between two ecdyses observed was forty-three days (April 25th to June 7th). More than two ecdyses were not observed in a single individual, even among the several which were kept in captivity for about two years. It is, however, quite possible that an ecdysis occurred occasionally without being detected, as during certain weeks the animals were looked at only every other day. So far as these observations go, it will be seen that they confirm the statement of Cornelius that the post-embryonic development of this species is relatively long.

The Act of Ecdysis.—The mode of shedding the cuticle is described and illustrated by Miall and Denny\(^1\), to whose account it may be added that the whole process usually lasts for two or three hours, though sometimes the crumpled mass of cast

\(^1\) Op. cit. p. 32.
cuticle remains adhering to the hinder end of the abdomen for more than a day after. Coloration of the new cuticle commences as blotches on the dorsal surface and extends gradually to the outlying parts, the extremities of the limbs becoming completely coloured by the end of the third day after ecdysis. The animal remains unusually still during this period and eats very little, apparently not at all during the first day.

Loss of Appendages during Ecdysis.—Five cases were observed in which normal, and apparently uninjured, tarsi were broken off during ecdysis. This may result from a struggle to free the leg during its sliding away from inside the old cuticle. As already pointed out, the region where a break in the leg occurs most easily is the suture between the femur and trochanter, so that these occurrences of a break at a normally stronger point may perhaps be accepted as an indirect argument that there is a certain degree of autotomy in the usual rupture between femur and trochanter.

Note on the Numerical Proportion of the Sexes.

Among the whole number of adult specimens collected for the purposes of the present enquiry, the actual and percentage distribution of the sexes were:

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. americana</em></td>
<td>371 49.5%</td>
<td>379 50.5%</td>
</tr>
<tr>
<td><em>P. australasia</em></td>
<td>118 51.3%</td>
<td>112 48.7%</td>
</tr>
<tr>
<td><em>P. germanica</em></td>
<td>47 46.1%</td>
<td>55 53.9%</td>
</tr>
<tr>
<td><em>S. orientalis</em></td>
<td>505 30.9%</td>
<td>1130 69.1%</td>
</tr>
</tbody>
</table>

As the habits of the two sexes are similar, the above is probably a fairly accurate indication of their usual numerical proportion, except possibly in the case of *Phyllodromia germanica*.

In a future communication I hope to give an account of the structure of the reproduced leg with special reference to the four-jointed tarsus, and also of certain cases in which apparently reproduced tarsi were found to be in a three-jointed condition.