CHILTON

THE SUBTERRANEAN CRUSTACEA OF NEW ZEALAND

2nd Ser. ZOOLOGY.] [VOL. VI. PART 2.

THE TRANSACTIONS OF THE LINNEAN SOCIETY OF LONDON.

THE SUBTERRANEAN CRUSTACEA OF NEW ZEALAND: WITH SOME GENERAL REMARKS ON THE FAUNA OF CAVES AND WELLS.

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LONDON:

PRINTED FOR THE LINNEAN SOCIETY

BY TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET.

SOLD AT THE SOCIETY'S APARTMENTS, BURLINGTON-HOUSE, PICCADILLY, W.,

AND BY LONGMANS, GREEN, AND CO., PATERNOSTER-ROW.

May 1894.

II. *The Subterranean Crustacea of New Zealand: with some general Remarks on the Fauna of Caves and Wells.* *By* CHARLES CHILTON, *M.A., D.Sc., F.L.S., Rector, District High School, Port Chalmers, New Zealand.*

Read 20th April, 1893.

(Plates XVI.-XXIII.)

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I. INTRODUCTION.

IN the following paper an attempt is made to give a fuller account than has yet been published of the Blind Crustacea found in the underground waters of the Canterbury Plains in the South Island of New Zealand. The existence of similar Crustacea in the caves and wells and in the deep waters of lakes in Europe and North America has long been known, and has attracted much attention, both because of the inherent interest of the subject, and because of the bearing that the facts have on some general questions of Biology connected with the Theory of Descent, particularly on the effects of use and disuse, and on the influence of the environment on the animals.

The existence of these animals in New Zealand was first recorded by me [22] about eleven years ago, but the original descriptions, though fairly accurate so far as they go, were very short and meagre, and the figures were rough and crude, and many points were left on which fuller and more complete information was much to be desired. Moreover, during the time that has elapsed since they were first discovered, much additional information has been gathered as to their occurrence and distribution, and no connected account of these has as yet been published. During the same time, too, some important works on the Blind Subterranean Crustacea of other parts of the world have appeared, particularly Packard's work on the Cave Fauna of North America [83], and Wrześniowski's very important memoir on "Three Subterranean Amphipoda" [124].

If we consider the peculiarities of the New-Zealand fauna and flora, and remember that New Zealand forms by itself a distinct zoological province, which has long been more or less perfectly isolated from other provinces, we should naturally expect that the Subterranean Crustacea of New Zealand would present us with some new interesting facts, and that they would differ largely from the similar Crustacea found elsewhere. This proves to be the case. The Subterranean Crustacean fauna is peculiarly rich, and much more varied than that of either Europe or North America; so far as at present known, it consists of six distinct species, three Amphipods and three Isopods, belonging to five different genera. Of these genera *Crangonyx* is already known from the subterranean waters of Europe and North America, but none of the others have been recorded from underground habitats elsewhere, though one, *Gammarus*, is more or less allied to the blind *Niphargus* of Europe, the species of which were indeed originally assigned to *Gammarus*, and are still so assigned by some writers. Two genera are new: one, *Cruregens*, belongs to a family, the *Anthuridæ*, no members of which were previously known to inhabit underground waters, and the other, *Phreatoicus*, which now contains three species (two from the subterranean waters of New Zealand, and one freshwater one from the top of the Mt. Kosciusko plateau in Australia), is so peculiar that it forms the type of a new and very remarkable family of the Isopoda.

In the following pages I give a full detailed description of the external anatomy of each of these six species, in addition to the brief specific diagnoses and, usually, a discussion on the characters of the genus. I have given what is known of their occurrence and distribution, of their habits, and of the peculiarities which they present in common with or in addition to other Subterranean Crustacea; their probable origin is discussed at some length. I have given also a short historical introduction showing the growth of our knowledge on the subject of Cave and Well Sessile-eyed Crustacea; and have concluded with some remarks on the bearing of the facts presented by them on the general questions of Biology.

For their kindness in providing me with material, I have to record my best thanks to Mr. R. M. Laing, of the Christchurch Boys' High School, Mr. E. Wilkinson, of the School of Agriculture, Lincoln, Messrs. J. B. Mayne and W. W. Smith of Ashburton, Mr. D. L. Inwood and Miss Young of Winchester. Mr. W. P. Hay of Irvington, Indiana, U.S.A., has kindly supplied me with specimens of some North-American Subterranean Crustacea. Mr. Smith, of Ashburton, has been particularly zealous and

unwearying in his efforts to obtain specimens for me, and I am much indebted to him for additional knowledge on their distribution and on the general question of the underground waters of the plains. My friend and fellow-worker, Mr. G. M. Thomson, Science Master of the Dunedin High Schools, has assisted me in many ways by his advice and criticism, and by his kindness in supplying me with works from his library that I could not otherwise have obtained. To many writers I am indebted for copies of their various papers, particularly to Professor A. S. Packard and to Dr. R. Moniez, who have sent me copies of important works by them on the subterranean fauna of their respective countries; while, in common with all other workers on the Amphipoda, I am greatly indebted to the Rev. T. R. R. Stebbing for the very full and valuable Bibliographical Introduction to his Report on the 'Challenger' Amphipoda. Situated as I am at the Antipodes, far from the chief biological libraries of Europe and America, to which one would have liked to have recourse, I can perhaps appreciate the full value of this introduction better than those who are more favourably circumstanced in this respect.

II. Historical Sketch.

The following historical sketch of the growth of our knowledge of the Sessile-eyed Crustacea inhabiting caves and wells is in many respects very imperfect, for I am unable to consult many of the original papers and works quoted; it contains, however, I trust, references to most of the more important works on the subject. In its compilation I have derived much assistance from Alois Humbert's paper on *Niphargus puteanus*, var. *Forelii* [62], Professor Packard's paper on the "Cave Fauna of North America" [83], from Wrześniowski's work on "Three Subterranean Amphipoda" [124], and from the bibliographical introduction to Stebbing's "Report on the 'Challenger' Amphipoda" [108]. I have endeavoured to include the Subterranean Isopoda as well as the Amphipoda, but the parts bearing on them are, I fear, much more incomplete than those on the Amphipoda, as there is no general bibliography on the Isopoda at all comparable to that which Stebbing has compiled with so much care and labour for the Amphipoda.

Franz von Paula Schrank, in his account of *Gammarus pulex* [98, p. 535] says, "*Habitat in aquis, rivis, fontibus; albissimus dum natat.*" From the words "*in fontibus; albissimus dum natat*" Stebbing [108, p. 31] thinks it is fair to infer that Schrank had seen one of the well-shrimps. If this be so it would appear that we have in this work of Schrank (1781) the first mention of Subterranean Crustacea.

W. E. Leach [72]. The first undoubted reference to "well-shrimps" appears to have been made by Leach. In the article "Crustaceology" in the 'Edinburgh Encyclopædia,' published probably in 1813–1814, after *Gammarus pulex* a species is mentioned [72, p. 403] which is not numbered but "which Mr. Leach considers to be different from *pulex*." It came from a well in London. "It differs principally from *Gammarus pulex* in having the upper process of the tail much longer. The colour, when alive, was cinereous, but so translucent that the eyes could not be distinguished. It stands in Mr. Leach's cabinet under the specific name *subterraneus*." It is evident from this brief description that the animal in question is not a true *Gammarus*, but is a subterranean species, probably a *Niphargus*. Stebbing [108, p. 84] thinks it is probably identical with *Niphargus aquilex*, Schiödte, and it is assigned to this species also by Spence Bate and Westwood [4, p. 316]. Wrześniowski [124, p. 602] thinks that the description given is scarcely sufficient to enable us to decide whether the animal belongs to *Niphargus aquilex*, Schiödte, or *Crangonyx compactus*, Spence Bate; but in the latter species the terminal uropoda are not very long, and, as Leach specially mentions that they are long in his specimen, it appears more likely that it is a *Niphargus*.

I. C. Zenker. From a remark made by Zenker in connection with *Gammarus pulex*, Leydig infers [73, p. 245], and according to Wrześniowski [124, p. 602] with good reason, that Zenker had met with *Niphargus puteanus* in Thuringia.

Paul Gervais, in 1835, in a paper [46] describing the freshwater Gammarids of Paris, after giving the two species *Gammarus pulex*, Fabr., and *G. Roeselii* (= *G. fluviatilis*, Roesel), says: "There is also found in the environs of Paris, but only in the water from wells, a third kind of shrimp, remarkable for its small size, which does not in fact exceed 3 or 4 mm." He considers this simply a "variété de séjour," and draws attention to its slender appearance—"est constamment étiolée"—and to the fact that its eyes are without pigment and not apparent. He names it *Gammarus pulex minutus* [46, p. 127]. This name he afterwards altered to *Gammarus lacteus*, but without giving any further description of any value [47, p. 488].

C. L. Koch [69]. About the same time Koch described a species under the name *Gammarus puteanus* from wells at Ratisbon ("Regensburg"), giving the following diagnosis: "G. diaphano-albus, lateribus subochraceis, testis caudæ inermibus; articulo penultimo pedum 4 anteriorum quadrato." He does not describe it as blind, but says "Die Augen sind gelb" [69, *h.* 5, *n.* 2]. Wrześniowski gives the species under the provisional name *Niphargus ratisbonensis*? [124, p. 673]. Later on Koch describes a variety found "in den Brunnen der Stadt Zweibrücken," differing from the specimens from Ratisbon in colour and in the shape of the hands of the gnathopoda [69, *h.* 36, *n.* 22]. Koch's work was issued in parts, and it appears to be very difficult to determine the exact date at which each part appeared. See Stebbing [108, p. 158].

H. Milne-Edwards, in 1840, describes *Gammarus pungens* [77, iii. p. 47], from "les eaux thermales du Mont Cassini en Italie," as having "le petit appendice terminal des dernières fausses pates tout-à-fait rudimentaire, et le grand appendice très-poilu et à peine épineux." Spence Bate [5, p. 217, & 4, p. 314] and Stebbing [108, p. 253] consider this a *Niphargus*. At the same time Milne-Edwards also describes another species, *Gammarus Ermannii* [77, iii. p. 49], from warm springs of Kamtschatka; Spence Bate, who saw the specimen preserved in the Museum of the Jardin des Plantes, afterwards placed this species under the genus *Crangonyx* [5, p. 179].

Theodor G. Tellkampf, in 1844, in describing some new species of Arthropoda from the Mammoth Cave of Kentucky, gives, under the head of "*Crustacea, Malacostraca*," the species *Triura cavernicola* [109, pp. 321, 322, pl. 18]. Schiödte and afterwards Boeck suggested that the species belonged to the Amphipoda, and Dana (Choristopoda, p. 306), in a note says:—"Genus *Triura*, Tellkampf, Rhoeæ forsan affinis." Stebbing [108, p. 208], after giving a portion of Tellkampf's description, gives also a copy of his figure, and says that it will suffice to show that the animal cannot belong to the Amphipoda. A. S. Packard, junr., had, moreover, already shown in 1871 that the animal is not a Crustacean at all, but belongs to the Thysanurous Neuroptera, and that it is probably the same as *Machilis variabilis*, Say: Tellkampf's erroneous reference of the animal to the Crustacea having been caused by his mistaking the labial and maxillary palpi for feet, and regarding the nine pairs of abdominal spines as feet [82, p. 14].

J. C. Schiödte, in 1847, briefly communicated to the Académie des Sciences de Copenhague the results of his researches on the fauna of the caves of Carniola and Istria, and gives a short diagnosis of *Gammarus stygius* [93, p. 81]. In a later work, published 1849–51, he minutely described the species, figured it, and formed for it the new genus *Niphargus* [94, pp. 26–28]. According to Humbert [62, p. 283] he did not notice the great resemblances between his species and *Gammarus puteanus*, Koch.

In the same paper, Schiödte also describes with great fulness, and figures, *Pherusa alba*, Koch, an isopod belonging to the Oniscidæ. As the name *Pherusa* was preoccupied, he renames the species *Titanethes albus*, placing it in "Ordo *Isopoda*—Familia *Onisci*—Tribus *Oniscini*." Owing to Koch's use of the name *Pherusa*, earlier employed among the Amphipoda, it appears that Schiödte's *Titanethes* has itself been spoken of as an Amphipod. With regard to this species, Spence Bate [4, ii. p. 440] gives the reference "'Herrich Schäffer, Contin. of Panzer,' fasc. 180, pl. 24," and this, together with the above quoted from Stebbing [108, p. 24], is all the information I can gather on this species.

Robert Caspary [19], in 1849, gave a full account with figures of *Gammarus puteanus*, Koch, from specimens found at Elberfeld. He was not able to discover eyes, although he examined more than 30 specimens. The small size of his specimens (4–6 mm.) and the absence of eggs from the brood-pouches of the females show, says Wrześniowski [124, p. 603], that he had to deal with very young specimens. He considers the mouth-parts, but, according to Wrześniowski [124, p. 603], gives an incorrect figure of the palp of the first maxillæ.

In his list [15] giving the synonymy of *Asellus sieboldii*, de Rougemont (=*A. cavaticus*, Schiödte), Bovallius gives a reference to this paper by Caspary, as follows :—"1849. . . . . Fuhlrott. (Caspary), in Verhandl. des naturh. Vereins der preuss. Rheinlande und Westfalens, Jahrg. 6, fig.;" thus without mentioning any name as used by Caspary. I am unable to consult Caspary's paper, and therefore cannot say what information, if any, he gives on *Asellus cavaticus*. According to Packard [83, p. 146], Caspary gives a "figure, without name, of *Asellus cavaticus*, Leydig." The next entry in Bovallius's list of synonyms is under the date 1871 [15, p. 11].

A. Hosius [61], in 1850, sets forth very fully the characters which separate the three species, *Gammarus pulex* from running waters, *Gammarus fluviatilis* (=*G. Röselii*, Gervais) from still or weakly flowing waters, and *Gammarus puteanus* from wells. He compares the three species as regards the maxillæ, and gives two drawings of the maxillæ of *G. puteanus*, taken from Caspary, and retaining the erroneous figuring of the palp. The incorrectness was also pointed out by Spence Bate and Westwood [4, i. p. 311].

A. Costa [32], in 1851, gives, among others in his list of Amphipoda, *Gammarus longicaudatus* from the drinking-water of Naples, and *G. montanus* from the Lago del Maltese. Afterwards he admitted that the two were the same, and the first as "*Gammarus longicaudata*," A. Costa, appears alone in his Catalogue [see Stebbing, 108, p. 249]. Wrześniowski gives the species under *Niphargus* [124, p. 696–7]. Spence Bate and Westwood, without comment, give it as a synonym of *Niphargus aquilex*, Schiödte [4, i. p. 316].

J. O. Westwood [120], in April 1853, communicated to the Linnean Society the discovery of a well-shrimp in a well near Maidenhead, England. This was at the time referred to *Niphargus stygius*, Schiödte, but was afterwards separated under the name *Niphargus aquilex* by Schiödte [95, pp. 349–351]. Bate and Westwood point out that Schiödte has been misled into describing it with "dorso carinato" by examining dried specimens, but they retain his name *Niphargus aquilex* on other grounds [4, i. p. 317].

In an anonymous paper on some Crustacea [57], quoted by Stebbing thus :—"Anonymous (? Halliday)," Latin diagnoses of the genus *Niphargus* and the two species *N. stygius* and *N. aquilex* are given. The full account of the former is given in English as applying equally well to the latter, except for the differences mentioned in the diagnoses. As these amounted to little more than applying a smooth back to *N. stygius*, and by mistake a keeled one to *N. aquilex*, Spence Bate was, he says, misled by this to assume the identity of the two species.

Adam White [121] in his 'Popular History of British Crustacea,' in 1857, omits the *Gammarus subterraneus*, Leach, which he had previously suggested might be "*Gammarus pulex*, var. jun. ?." He changes *Niphargus stygius*, Westwood, into *Niphargus aquilex*, Schiödte, and asks whether this may not be the *Gammarus subterraneus* of Leach [see 108, p. 305].

A. DE LA VALETTE ST. GEORGE [112], in 1857, published a very minute account of the external and internal anatomy of the well-shrimps found at Cologne and Munich. He calls the species examined by him *Gammarus puteanus*, but they are referred by Bate and Westwood to *Niphargus aquilex*, Schiödte [4, i. p. 315]. His work is illustrated by fine figures, and among other points he draws attention to the sense-organs found on the antennæ, remarking, however, that the calceoli increase in size towards the end of the antennæ, which, as Stebbing points out [108, p. 304], is certainly not the case in all Amphipoda.

C. CHYZER, in 1858 [28, p. 4], announces Tóth's finding *Gammarus puteanus* and *G. fossarum*, Koch, "im Orczy-Garten zu Pest."

C. SPENCE BATE [6] in 1859, in a paper on the genus *Niphargus*, Schiödte, establishes two new species, *N. fontanus* and *N. Kochianus*, and also describes a new genus, *Crangonyx*, with the species *C. subterraneus*. Some discussion on the genus *Crangonyx* will be found further on (pp. 215–226).

R. M. BRUZELIUS [17], in 1859, established the new genus *Eriopis*, with the species *E. elongata*, "habitat in locis profundis maris Bohusiæ." The genus *Eriopis* is evidently very close to *Niphargus*, Schiödte, with which it was identified by Boeck. Stebbing also accepts this view; Wrześniowski, however, retains it as a separate genus, but alters the name to *Eriopsis*, as *Eriopis* was preoccupied [124, p. 634].

A. R. HOGAN [59 and 60], in 1859, published a paper on the habits, food-supply, and habitat of the species described by Spence Bate, viz., *Niphargus Kochianus*, *N. fontanus*, and *Crangonyx subterraneus*. In his notice of this paper Stebbing mentions that specimens of *Niphargus aquilex*, from a well near Tunbridge Wells, lived in his (Stebbing's) room from January 1886 till March 3rd, 1886, when they all died at about the same time, perhaps from the coldness of the night. Although they were very active in walking about the bottom of their jar, Stebbing never saw them attempt to swim. Another set of about a dozen were placed in a small jar on June 15th, 1886. Two were females with eggs; these died within a couple of days, surrounded by some rapidly developed parasitic growth; the others lived on for a considerable time, the last not dying until November 24th, 1886 [108, p. 316]. Wrześniowski [124, p. 604] refers to these observations on the habits of *Niphargus aquilex* in captivity as though they had been made by Hogan—a mistake natural enough, considering the way in which they are incorporated with the notice of Hogan's paper. Hogan published another paper on the same subject in 1861 [60].

JOHANNES LACHMANN [71], in 1859, describes parasites found in the intestine of the well-shrimp (*Gammarus puteanus*), the name being, however, misspelt "*Grammarus*" throughout the paper. The parasites are said to belong to the puzzling group of the Gregarines. (Quoted from Stebbing [108, p. 317].)

JOSEPH SCHÖBL [92] in 1860 published an elaborate monograph, illustrated by 10 plates, on "Typhloniscus—eine neue blinde Gattung der Crustacea Isopoda," in which he describes the new species *Typhloniscus Steinii*. This species, which belongs to the Oniscidæ, is not an inhabitant of wells or caves, but lives, like *Platyarthrus*, in ants' nests. It, however, resembles cave-species in the want of eyes, colour of the body, &c., and has been often mentioned as a blind Isopod along with *Titanethes albus*. This species was afterwards referred to *Platyarthrus Hoffmannseggii* by Budde-Lund [18, p. 199].

VICTOR SILL [100], in 1861, repeats Koch's description of *Gammarus puteanus*, but without adding anything new.

SPENCE BATE, in the 'Catalogue of the Amphipoda in the British Museum,' published in 1862 [5], gives the following subterranean species, all of which have been already referred to:—*Niphargus stygius*, Schiödte, with which he combines *N. aquilex*, Schiödte (though on further examination this was retained as a separate species); *N. fontanus*, Spence Bate; *N. Kochianus*, Spence Bate; *N. puteanus*, Koch; *Crangonyx subterraneus*, Spence Bate; and *C. Ermannii* = *Gammarus Ermannii*, Milne-Edwards. He leaves *Gammarus pungens*, Milne-Edwards, under the genus *Gammarus*, but adds as a footnote, "This species appears closely to resemble a *Niphargus*" [5, p. 217].

Bate and Westwood [4]. The parts of the 'History of the British Sessile-eyed Crustacea,' by these authors, which contained the account of the subterranean forms, appeared in 1862 [Stebbing, 108, p. 340], though the titlepage of volume i. bears the date 1863. A fuller account of the species already mentioned is given, there is a short account of some of the previous works on the subject and of the habits of some of the species, and *Niphargus aquilex*, Schiödte, is reinstated as a separate species distinct from *N. stygius*, Schiödte. Under *N. fontanus*, the authors say :—" Professor Westwood thinks that this species may be identical with the *N. stygius* of Schiödte, since both agree in the more robust form of the animal and the shape of the hands; there are, however, other important differences ; as, for instance, the form of the second and third segments of the tail, which, together with the diversity of habitat, will probably prove to be of specific value" [4, i. p. 322]. Again, under *N. Kochianus* they say :— "We are inclined to think this species identical with the specimens captured at Bonn, described and figured by Caspary and Hosius, referred to in the synonyms under *N. aquilex*, but want of specimens from that locality prevents our determining this point" [4, i. p. 325].

In speaking of the three species *N. aquilex, N. fontanus*, and *N. Kochianus*, Alois Humbert very shrewdly remarks :—" A n'en juger que par les descriptions et par les figures intercalées dans le texte, ces trois espèces semblent être bien tranchées et faciles à distinguer, mais dans la pratique la détermination n'est pas facile" [62, p. 287].

De Rougemont has, indeed, united *N. fontanus* and *N. Kochianus*, as well as *Crangonyx subterraneus* with *Gammarus puteanus*, Koch; but, as will be seen from the remarks below, his identifications can hardly all be accepted. Stebbing says, in connection with this point that "the matter, perhaps, is not yet ripe for final determination" [108, p. 312].

It is strange that so little has been written on the Subterranean Crustacea of England : thus I know of no special work on them since the publication of the 'History of the British Sessile-eyed Crustacea;' this is the more peculiar when we remember that many points in connection with them were left uncertain (*Crangonyx subterraneus*, for instance, being described from a single specimen), and that they are widely distributed in England and Ireland, and probably abundant.

Camil Heller [58], in his list of the freshwater Amphipoda of South Europe, says that they all belong to the genus *Gammarus*, Fabric., of which he makes *Crangonyx* and *Niphargus* subgenera. He omits Costa's *G. longicaudatus*, and unites *Gammarus puteanus*, Caspary, *Niphargus stygius*, Schöidte, and *N. aquilex*, Schiödte, but, according to Wrześniowski, without giving good reasons for so doing [124, p. 604].

Among the freshwater Crustacea mentioned by Heller is *Crangonyx recurvus*, Grube, which had been found by Grube in 1861 in the Vrana lake in the Island of Cherso, on the Illyrian coast, and described under the name *Gammarus recurvus*, and was afterwards redescribed by him and placed under *Crangonyx*. I regret that I have been unable to get a description of this species, as it would have been interesting to see what relation it bears to the various Subterranean Crustacea of Europe.

Pratz [88], in 1867, described under the name *Gammarus Caspary* a new species from a well at Munich, and mentions several remarkable differences between the male and female. In view of the "caractères contradictoires" presented by this species, and the "polymorphisme" of the *Gammari* found in the same town by de Rougemont, Moniez thinks [78, p. 48] that it is very desirable that the *Gammari* of the wells at Munich should be re-studied.

W. Czerniavski [33], in 1868, described a new species of *Niphargus*, from the Black Sea, under the name *N. ponticus*. This species differs from the usual species of *Niphargus* in the presence of well-developed eyes, in the colour, the gnathopoda, &c.; and from the small size (2·1 millim.), and the small number of joints in the flagella of the antennæ, it is probable that the single specimen obtained was, as Wrześniowski points out [124, p. 605], a young specimen, and further information regarding the species is desirable.

F. Plateau [86], in his researches on the freshwater Amphipoda of Belgium, makes special mention of the well-shrimps which he had taken at Ghent, and which had also been collected by Professor Bellynck at Namur. He calls his specimens *Gammarus puteanus,* Koch, and states that they have triangular, pigmentless eyes. Plateau appears to have been acquainted only with Koch's work on *Niphargus,* and ignores the works of later writers.

GUSTAV JOSEPH [65], in 1868, recorded the finding of a new species of *Niphargus, N. orcinus,* in the brooks of the hill-grottoes of Carniola, "which probably from these reaches the lake of Zirlenitz [Zirknitz], where it can be freely gathered. It comes to the surface after sunset in calm weather."—See Stebbing [108, p. 384]. The full description of this species was not given till 1882.

F. A. FOREL [38], in 1869, indicated for the first time the existence of blind Gammarids from the deep waters of the Lake of Geneva. Afterwards, in 1873, similar animals were found in the Lake of Neuchâtel.

BOECK [14], in his work published in 1870, gives the genus *Niphargus,* Schiödte, for the single marine species *Eriopis elongatus,* Bruzelius.

PAUL GODET [48, p. 153], in 1871, described three specimens of a *Gammarus* found in a well at Neuchâtel, pointing out the characters by which they differ from *Gammarus fluviatilis,* and comparing them with *G. puteanus,* Koch, and *G. puteanus,* La Valette. Stebbing says that, judging by the figure, it cannot be far removed from *Niphargus aquilex,* Schiödte [108, p. 1630].

A notice of Godet's observations on these well-shrimps had been previously communicated to the Société des Sciences naturelles de Neuchâtel, by P. Coulon, in 1867. See Wrześniowski [124, p. 605].

S. I. SMITH [102], in 1871, among other Crustacea dredged from Lake Superior, in North America, describes *Crangonyx gracilis,* Smith, n. s., and says that it much resembles *C. recurvatus* [*recurvus*], Grube, "in the form of the antennulæ, antennæ, gnathopoda, &c., while it differs much in the ultimate pleopoda and in the form of the telson." It is important to note the occurrence of this species, though not blind, in connection with the question of the distribution and origin of the subterranean forms.

A. S. PACKARD, Jun. [81], 1871, in describing the Crustaceans and Insects of the Mammoth Cave, describes an Isopod as a new genus and species under the name *Cæcidotea stygia.* This species was described from imperfect specimens, and its structure and affinities were consequently completely misunderstood. In point of fact it has nothing whatever to do with *Idotea,* but comes very close to *Asellus,* with which it is indeed united by Forbes [41, p. 11]. It will be further noticed in the account of Packard's larger work on the 'Cave Fauna of North America' [83].

E. D. COPE [30, pp. 6 and 14], in 1872, found in a cave adjoining the Wyandotte Cave an Isopod which he refers to the genus *Cæcidotea,* previously established by Packard, but describes it as a new species, *C. microcephala.* He gives a description and figure of the species, but owing to imperfect specimens his account is even more unsuccessful than Packard's: thus he describes and figures the uropoda as "egg-pouches full of eggs." This is the species which had been referred to by Cope in a previous paper as an "unknown Crustacean with external egg-pouches" [29]. Packard has since united it with his *Cæcidotea stygia* [83, p. 29].

In the same paper [30, pp. 8 and 17] Cope also describes a blind Amphipod under the name *Stygobromus vitreus,* nov. gen. et sp. He says that his genus is nearer to the true *Gammarus* than to *Niphargus,* Schiödte; but his description is very unsatisfactory, and gives no assistance in the attempt to ascertain the true position of the animal. S. I. Smith afterwards referred this species to *Crangonyx* under the name *C. vitreus,* Cope, and it appears under this name in Packard's larger work [83, p. 34].

Although described in Cope's paper "On the Wyandotte Cave and its Fauna," this species is not from that cave, but from the Mammoth Cave, and had been referred to as a "Gammaroid Crustacean" in an earlier paper by Cope [29].

F. Leydig [74, p. 269] had, in 1871, recorded the existence of *Asellus cavaticus* in the Falkenstein Cave. This species is usually referred to as *Asellus cavaticus,* Schiödte, and consequently was, I presume, first mentioned under that name by Schiödte; but, unfortunately, the works at my disposal do not enable me to say where Schiödte mentions it, or what information, if any, he gives about it. Bovallius, in his "Notes on the Family Asellidæ," in his list of synonyms of the species, gives no reference to any paper on the subject by Schiödte, and says, "As Schiödte never has given a diagnosis of *A. cavaticus,* and none of the following authors, using that name, did describe the animal, the name *A. cavaticus* must be rejected, and substituted by *A. Sieboldii,* Ph. de Rougemont" [15, p. 11].

A. Frič [42, p. 246, fig. 95], in 1872, recorded the existence of *Gammarus puteanus* in wells at Prague, Bohemia; but, according to Wrześniowski [124, p. 605], his observations on the subject are of little value, the third uropods, for example, being represented as seven-jointed!

R. Wiedersheim [122] found in 1873, in a small lake in the Falkenstein Cave, about 600 ft. from the mouth, an eyeless Gammarid which he does not describe, but believes to be the same as *Gammarus puteanus* from wells at Tübingen.

Apparently also in the same paper he gives an account of the habits of *Asellus cavaticus.* See Packard [83, p. 149].

S. Fries [43], in 1874, also studied the fauna of the same cave, but found only one example of a blind Gammarid. He thinks this to be the descendant of the eyed *Gammarus pulex* living in the neighbourhood outside the cave, and strengthens his opinion by observations on *Gammarus fossarum* kept during the winter in the dark, which lost pigment and whose eyes paled; but, as Humbert points out, Fries does not appear to have been acquainted with the genus *Niphargus* and the characters by which it is distinguished from the true *Gammarus.* See Humbert [62, p. 289]. Fries also appears to have referred in his paper to *Asellus cavaticus,* Schiödte.

F. A. Forel, in a series of works on the deep-water fauna of the Lake of Geneva, repeatedly mentions an interesting crustacean under the name *Gammarus cæcus.* This, I presume, is the species afterwards fully described by Humbert under the name *Niphargus puteanus,* var. *Forelii* [62].

Eugène Simon [101], in 1875, enumerates and shortly describes several species of Crustacea living in caves, among them "*Niphargus subterraneus* (Leach)=*puteanus* (C. Koch), *aquilex,* and *stygius,* (Schiödte), Carniola, also in wells." (Dr. von Martens, 'Zoological Record' for 1875.)

Ph. de Rougemont [89], in 1875, published an exhaustive paper on *Gammarus puteanus,* Koch. He had found five different forms in a well at Munich and a sixth form at Neuchâtel, the last having been previously described by Godet. He fully describes the various sense-organs, recognizes the olfactory cylinders on the flagellum of the upper antennæ as organs of smell, and explains the fact that they are longer in the blind *Gammarus puteanus* and *Asellus* from wells than in *Gammarus pulex* and *Asellus aquaticus* as a natural compensation made to the former for their want of sight.

De Rougemont was astonished to find five different forms so nearly allied living together in a single well, and at not finding any small forms similar to the larger kinds; consequently he came to the conclusion that all these five kinds as well as the large one from Neuchâtel are simply different stages in the life-history of the one species, and he states that he has seen individuals pass at the moulting of the exoskeleton from the first form (*Crangonyx subterraneus*) to the second (*Niphargus Kochianus*), and that he has seen the transformation also from the fourth form into the fifth. He concludes therefore that the genera *Crangonyx* and *Niphargus* ought not to be separated, since they represent different states of the same species, and further he proposes to suppress the genus *Niphargus*, as he considers it only a modification of *Gammarus pulex*. To the single species *Gammarus puteanus*, Koch, he therefore refers all the following forms :—I. Form : *Gammarus minutus*, Gervais ; *Crangonyx subterraneus*, Spence Bate. II. Form : *Niphargus Kochianus*, Spence Bate. III. Form : *Gammarus puteanus*, Caspary : *Gammarus puteanus*, Hosius ; *Niphargus fontanus*, Spence Bate. IV. Form : *Gammarus puteanus*, Koch. V. Form : *Niphargus stygius*, Schiödte ; *Gammarus puteanus*, Koch, La Valette St. George, and Plateau. VI. Form : a colossal specimen, 33 millim. long, from Neuchâtel.

These conclusions arrived at by de Rougemont have been very fully criticized by Aloïs Humbert [62, pp. 294–296], Wrześniowski [124, pp. 687–694], and others, who have shown that, in addition to the inherent improbability of some of de Rougemont's assertions, there are so many inaccuracies, inconsistencies, and contradictions in his own work and such neglect to notice points of special importance, as, for example, the difference between the undivided telson of *Crangonyx* and the deeply-cleft telson of *Niphargus*, that de Rougemont's views cannot be seriously accepted. It is therefore unnecessary to discuss the subject further, and I need only say that I feel quite convinced of the justice and truth of the remarks made on the matter by Humbert and Wrześniowski. It is of course quite possible that some of the various subterranean species described under *Niphargus* (*Gammarus*) are not entitled to full specific rank, but should rather be looked upon as local varieties, which, indeed, we might naturally expect to arise owing to isolation ; but certainly we cannot admit that all the forms mentioned by de Rougemont are modifications *due to age*, and if *Crangonyx subterraneus*, Spence Bate, can change at a single moult into *Niphargus Kochianus*, Spence Bate, it will be useless to attempt to classify Amphipoda into genera and species at all. The existence of five different forms in the single well at Munich, if this really was the case, is not so strange or so unprecedented as de Rougemont seems to have thought it, for the space in which they live is of course not merely the well itself, but the subterranean waters connected therewith, which may be very extended ; and Spence Bate had previously recorded the three species *Niphargus fontanus*, *N. Kochianus*, and *Crangonyx subterraneus* from the same well at Ringwood, England, while Wrześniowski has since recorded the two species *Niphargus tatrensis* and *Boruta tenebrarum* living together in one well ; and I have taken from a single well at Eyreton the three Amphipods *Calliopius subterraneus*, *Gammarus fragilis*, and *Crangonyx compactus*, as well as the two Isopods *Cruregens fontanus* and *Phreatoicus typicus*.

A year later, in 1876, de Rougemont published a French translation of his paper on *Gammarus puteanus* under the title "Étude de la Faune des eaux privées de la lumière," and this contained in addition a description of the Isopod *Asellus Sieboldii*, which Bovallius identified with the *A. cavaticus*, Schiödte, of earlier writers, though he retains de Rougemont's name, as he was the first to describe the species [15, p. 11].

S. I. Smith, 1874, in a work on the Crustacea of the fresh waters of the United States [103], describes both sexes of *Crangonyx gracilis*, Smith, an eyed species that has been already mentioned. He also mentions *Crangonyx vitreus*, Packard, giving under protest *Stygobromus vitreus*, Cope, as a synonym ; Packard, however, in his last work keeps the two separate [83, p. 34].

Smith also describes *Crangonyx tenuis*, n. s., "a slender, elongated species with very low epimera, resembling more in form the species of *Niphargus* than the typical species of *Crangonyx*."

In 1875, S. I. Smith [104], in a paper on the Crustaceans of the Caves of Kentucky and Indiana, states that *Crangonyx* (*Stygobromus*) *vitreus*, Cope, is very different from *Crangonyx vitreus*, Packard, of which he had previously, as above stated, given it as a synonym under protest. The latter species is, he says, closely allied to *C. gracilis*, Smith, from Michigan, Lake Superior, &c., differing principally in the structure of the eyes. In his account of this paper, Stebbing adds, "Since Packard's species in any case must yield its specific name, one is led by Professor Smith's account to regard it as a synonym of *Crangonyx gracilis*" [108, p. 451]. Packard afterwards refers to the species as *C. Packardii*, Smith ; but I am unable to find when this name was assigned to it.

S. A. Forbes [41], in 1876, describes an Amphipod found in a well at Normal, Illinois, under the name *Crangonyx mucronatus*. This species is, he says, perhaps entitled to rank as the type of a new genus, but for want of material for a more general study of its relations it is left with its nearest allies in the genus *Crangonyx*. The differences between the sexes are given, the most remarkable being in connection with the telson, which is very largely developed in the male. (See below, pp. 218–219.)

Aloïs Humbert [62] published his description of *Niphargus puteanus*, var. *Forelii*, in 1876. Besides a very careful and minute description of this variety, and of another named *onesiensis*, this work contains much important information on the general subject of blind subterranean Crustacea. After some introductory remarks he gives an historical sketch of previous works on the subject, in the course of which he fully criticizes de Rougemont's views as already stated, and pointed out that his own observations do not at all correspond with those of de Rougemont: thus among the specimens handed to him by Professor Forel were some very small, only 2 millim. long, which should therefore correspond with de Rougemont's first form, and belong to *Crangonyx subterraneus*, Spence Bate; but these, Humbert says, already had the characters well marked, the two gnathopods already having the form of the adult and the telson being deeply cleft. Humbert then considers the characters of the genus *Niphargus*, and gives a new definition of it. He discusses the place in the genus of his own varieties, and compares them with the species previously described by other authors. He distinguishes two varieties, *Niphargus puteanus* var. *Forelii*, from the deep waters of the Lake of Geneva, and *N. puteanus* var. *onesiensis*, from a well at Onex near Geneva, and gives at length the minute differences between the two. In considering the origin of the *Niphargus* found in the Lake of Geneva, he gives good reasons for believing that it is not merely a modification of *Gammarus pulex*, and concludes that it is probably descended from an ancient genus now extinct; he is inclined to think the *Niphargi* of the lakes come from those in the subterranean waters. This point was afterwards fully considered by Professor Forel, who finally came to the same conclusion as Humbert, though he had previously thought otherwise [40, pp. 170–183].

In the detailed description of *Niphargus puteanus*, var. *Forelii*, that follows, Humbert pays special attention to the various organs of sense. On the head and on the first segments of the pereion, on the dorsal portion, are found "capsules sensitives," and on the upper antennæ "cylindres olfactifs," "bâtonnets hyalins," "soies auditives," and also "capsules sensitives" like those on the head, &c. The females are said to be distinguished from the males by their smaller size, the brood-plates, and the shorter length of the terminal uropoda.

P. Godet [49], in 1878, was induced by Humbert's criticism of de Rougemont's work to rectify his measurements of the large specimen from Neuchâtel, as his measurements previously given had not corresponded with those given by de Rougemont. In connection herewith de Rougemont stated that he still held to his opinions previously published.

J. D. Catta [20], in 1878, described a new species of Amphipod, *Gammarus rhipidiophorus*, found only in a well at La Ciotat (Bouches-du-Rhône, France), a hundred yards or so from the Mediterranean; the water in the well becomes brackish in summer. He considers that the genus *Niphargus* should be given up, as the various differences between them are more or less bridged over by different species. In connection with this question, however, Wrześniowski points out [124, p. 607] that Catta says nothing about the mouth-parts, in which are found some of the most prominent marks of distinction; and Stebbing also says:—"The discovery of transition-forms between two genera will always cause some difficulty, but as such forms have probably existed in innumerable cases where they have not been discovered, it is a question how far the discovery of them should be allowed to interfere with well-established distinctions either of genera or species. When *Niphargus aquilex* and *Gammarus pulex* are side by side, it is rather the difference of the *facies* than the likeness which attracts attention" [108, p. 475]. It may here be added, the differences originally laid down between *Niphargus* and *Crangonyx* have to some extent been bridged over in the same way by species subsequently described, but that still the differences between *Gammarus, Niphargus,* and *Crangonyx* are much greater than those between many other genera of the Amphipoda. The main interest in the discussion is its bearing on the question—Have all the species classed under, say, *Niphargus,* arisen from the parent genus, whatever it may be, by one common origin, or have some of them arisen independently in different localities in which they have been isolated ?

Franz Leydig [73], 1878, in his remarks on the anatomy &c. of Amphipoda and Isopoda makes a good many references to the subterranean forms. With regard to the plumose bristles called "capsules sensitives" by Humbert, he says that they may be sensitive, but they are not capsules, they are modified pores. "In view of the very varying statements of authors on the eye of *Gammarus puteanus,* he made investigations from which he determines that the optic ganglion is present, but not the eye, though pigment-spots mimicking the eye have led some observers to believe that an eye existed in fact" (quoted from Stebbing [108, p. 481]). In connection with this point I may add that I have occasionally observed similar pigment-spots in the New-Zealand species, in none of which can I find any external trace of eyes except in *Crangonyx compactus,* which has two or three imperfect lenses ; some of the cave-inhabiting species of *Crangonyx* from North America also have imperfect external eyes. It seems probable that there may be great differences in the amount of degeneration of the eyes in different species, and perhaps also in individuals of the same species from different localities.

In remarking on the distribution of and distinctions between *Gammarus pulex,* de Geer, *Gammarus fluviatilis,* Rösel, and *Gammarus* (*Niphargus*) *puteanus,* Koch, Leydig adopts the view of de Rougemont, that *Gammarus pulex minutus,* Gervais, is identical with Koch's *G. puteanus,* which may, of course, be correct enough, while de Rougemont's other observations are unreliable.

F. A. Forel [39], in 1878, in an account of the fauna of the Swiss Lakes, mentions *Gammarus puteanus,* var. *Forelii,* Humbert, as being found in "die *tiefe* Region" in the Lake of Geneva.

Gustav Joseph [66], in 1879, discovered *Niphargus puteanus* at Venice, and states that their introduction into these carefully-covered wells is best explained by the transport of water from the mainland to replenish these wells in the dry season.

S. Fries [43], in 1879, discusses the occurrence of Well-Shrimps in the slightly brackish wells of Heligoland, &c., and advocates the view that they must have existed in these localities before the islands were separated from the mainland. He examined specimens from these wells of Heligoland, from the Falkenstein Caves, from the springs running out of the caverns, from the Hilgerhäusen Caves, and from the depths of the Lake of Geneva, and finds no greater differences than would justify the naming of varieties. He therefore follows de Rougemont in uniting them all under the name *Gammarus puteanus.* From this it appears probable that at any rate some of the described species of *Niphargus* are to be looked upon merely as local varieties of one and the same species ; but this in no way justifies de Rougemont's inclusion of *Crangonyx subterraneus,* Spence Bate, with the others, and does not support his statement as to the elaborate series of metamorphoses passed through by the specimens examined by him.

In the same paper Fries also discusses the blind Isopod, *Asellus cavaticus,* Schiödte. He had uniformly found this in company with *Gammarus puteanus,* which, according to de Rougemont, is its mortal foe. He agrees with de Rougemont that *Asellus cavaticus* is related to *A. aquaticus,* very much as *Gammarus puteanus* is to *G. pulex.* Judging, however, from the scanty descriptions of *Asellus cavaticus* that I have been able to consult, the connection between the first two appears much closer than that between the last two.

Fries's remarks lead de Rougemont to repeat that he is still of the same opinion [90].

Professor Giebel [50], in 1879, mentions the finding of *Niphargus puteanus* in Halle-a.-S.

Oscar Grimm [51], in 1880, described a new species of *Niphargus*—*N. caspius*—found in the Caspian

Sea at a depth of 35 to 90 fathoms. The species may, he says, be identical with *N. ponticus*, Czerniavski, but he is not able rightly to determine this species, as Czerniavski's description appears to be very defective. He points out that "*N. caspius* differs in many respects from the other species of *Niphargus*, and, indeed, from *N. puteanus*, as in its shorter antennæ, the differently formed hand of the last pair of limbs, &c.; so that our species may perhaps be regarded as the representative of a new genus between *Niphargus* and *Gammarus*." He also remarks that *N. caspius* is very probably the "extinct Gammarid" from which the other species of *Niphargus* have arisen.

Professor Asper [1], in 1880, met in some of the Swiss Lakes a Gammarid which strikingly reminded him of the common *Gammarus pulex*. "The lake-form, however, was smaller and of a glassy transparency. Specimens from depths of 140 and of 60 metres possessed beautiful organs of vision, with clearly observed crystal-cones. At Wädensweil, at a depth of 40 metres, along with seeing forms, were found blind specimens agreeing in the smallest detail with '*Niphargus Forelii*' from the Lake of Geneva. Specimens from Oberrieden Dr. Aspen regards as intermediate forms between *Gammarus pulex* and the '*Forelii*' variety of *Niphargus*." (See Stebbing [108, p. 508].) Forel, however, though admitting that these are modified so far as the colour and the eyes are concerned, states that they are not "des *Niphargus* avec des yeux, des *Niphargus* incomplètement modifiés," that the hands of the gnathopods and the third uropods are not modified, so that "ils ont le type *Gammarus* et non le type *Niphargus*" [40, p. 180].

C. Parona [85], in 1880, discovered blind "Shrimps" in the cave of Monte Fenere, Val Sesia, Piedmont. He considers his form to come very close to *Niphargus puteanus*, var. *Forelii*, Humbert. He gives a general history of the species, strongly supporting de Rougemont's views. One female specimen with short terminal uropoda specially attracted his attention as showing relation to *Crangonyx*. Moniez has, however, shown that the specimen in question was mutilated, having lost the third uropods, as frequently happens with *Niphargus* [78, p. 43]. In this paper Parona also describes a new species of *Titanethes*, viz. *T. feneriensis*.

Max Weber, in 1879, published a paper "Ueber *Asellus cavaticus*, Schiödte" [116].

H. Blanc [11], in 1880, described a new species of the same genus, *Asellus Forelii*, from the deep waters of the Lake of Geneva, pointing out the differences between it and *A. cavaticus*, Schiödte, to which it appears to be closely related.

Both of these species appear to have been referred to by Max Weber [117] in a paper published in 1881, but I am unable to say what information he gives on the subject.

Max Weber [118], (apparently in 1880), "examined histologically and chemically, and described, the so-called liver of terrestrial, freshwater, subterraneous, littoral, and truly marine species of different orders" of Crustacea. The blind and subterranean forms examined were *Typhloniscus Steinii*, *Asellus cavaticus*, and *Gammarus puteanus*. (See Stebbing [108, p. 525].)

According to Ludwig [75], 1881, *Gammarus puteanus* has been found "in einen Brunnen zu Greiz."

Packard and Cope [31], in 1881, investigated the fauna of the Nickajack Cave in Tennessee. They describe a new species of the genus *Cæcidotea*, viz. *C. nickajackensis*, Packard, in which the body is longer, narrower, and slenderer than in *C. stygia*, Packard, from the Mammoth and Wyandotte Caves. The authors add:—"This species forms, in the antennæ and slightly purplish colour and the proportions of the leg-joints, perhaps a nearer approach to the genus *Asellus* than that of the Mammoth and Wyandotte Caves; on the other hand, *C. stygia* approaches *Asellus* more in its shorter, broader body, with its shorter, broader abdomen. It seems quite evident that the two species must have descended from different species of *Asellus*. Thus far we know of but one species of *Asellus*, *A. communis* of Say, from the Middle and Northern States; whether there is an additional species in the Gulf States, from which the present species may have been derived, remains to be seen.

"The genus *Cecidotœa* differs from *Asellus* in the larger and much longer head, the longer claw of the first pair of feet, the much longer telson, and in the rami of the caudal appendages being of nearly equal size, while in *Asellus* one is minute; it is also eyeless. The *Asellus Forelii* of the Swiss Lakes belongs to *Cecidotœa*" [31, p. 880]. The statement that one of the rami of the caudal appendages of *Asellus* is minute is, of course, erroneous, and must have been based on some misunderstanding or erroneous observation. This statement is repeated on p. 19 (evidently copied from above) in Packard's larger paper, but is omitted in the fuller account on p. 29, where the differences between *Cæcidotea* and *Asellus* are given in considerably different terms, and it is stated the *Asellus Forelii*, Blanc, does not belong to *Cæcidotea* [83, p. 30]. Forbes united *Cæcidotea* with *Asellus*, as a detailed comparison of *C. stygia* "with undoubted *Asellus*, especially with the admirable plates of *A. aquaticus* in the 'Crustacés d'eau douce de Norvège,' has failed to reveal any structural peculiarities which could positively serve as the characters of a distinct genus" [41, p. 11]. In 1886, however, Packard still retained the genus *Cæcidotea* on "taxonomic grounds" [83, p. 30].

In the paper now under consideration, Packard and Cope write the name of the genus throughout as *Cecidotœa*, though in establishing the genus Packard had originally spelt it *Cæcidotea*; in his larger work again he spells it *Cæcidotœa*. Bovallius writes it *Cæcidothea* [15, p. 13]. Whether these varied spellings are intentional or accidental it would no doubt be better to adhere to the original spelling, as suggested by Stebbing [108, p. xx].

In the same paper [31, p. 880] a new species, *Crangonyx antennatus*, Packard, is described and figured. This species is said to be very different from *C. vitreus*, Cope, and from *C. Packardii*, Smith, but to present various resemblances to *C. gracilis*, Smith, from Lake Superior.

Chas. Chilton [22], in 1881, recorded the occurrence of subterranean Crustacea at Eyreton, North Canterbury, New Zealand. He briefly described and figured three Amphipods, *Calliopius subterraneus*, *Gammarus fragilis*, and *Crangonyx compactus*, and one Isopod, *Cruregens fontanus*, all the species being new. The genus *Cruregens* is also new, though apparently somewhat nearly allied to *Paranthura*. A short notice of this paper by Aloïs Humbert, appeared in the Arch. Sci. Nat. viii. (Sept. 1882) p. 265. A year later Chilton [23] gave a few additional facts on the occurrence and distribution of these species and also described another Isopod, *Phreatoicus typicus*, nov. gen. et sp., obtained from the same well at Eyreton. These Crustacea have since been obtained at various localities in the Canterbury Plains, and are fully discussed in the paper below, in which an additional species, *Phreatoicus assimilis*, sp. nov., is described from Winchester. Another species of the same genus, *Phreatoicus australis*, was obtained in 1889 in freshwater streams near the top of Mt. Kosciusko in Australia, and has been fully described by Chilton [26]. It of course possesses eyes, while the subterranean species are blind.

O. P. Hay [56], in 1882, described a new species of *Crangonyx*, *C. lucifugus*, from a well in Abingdon, Knox county, Illinois. It appears to resemble *C. tenuis*, Smith, but in the third uropod the two rami are both absent, and the peduncle itself is much reduced. He also describes *Crangonyx bifurcus*, sp. nov., found in a rivulet at Macon, Mississippi. He says: "The three species, *C. gracilis*, *C. bifurcus*, and *C. lucifugus*, present an interesting gradation in the form of the posterior caudal stylets." Attention has been directed to this point further on (see p. 218).

Professor Vejdovsky [113], in his work on the fauna of the wells of Prague, mentions *Niphargus puteanus*, but does not closely describe it. The species seems to be widely spread at Prague. Vejdovsky shares de Rougement's opinion as to the identity of the various species of Well-Shrimps.

Gustav Joseph [67], in 1882, gives very minutely his observations on the cave-fauna of Carniola, and describes a species, *Niphargus orcinus*, previously named by him. He mentions the following species as found in Carniola:—*Niphargus stygius*, Schiödte; *N. puteanus*, de la Valette St. George; *N. puteanus*, var. *Forelii*, A. Humbert; and *N. orcinus*, sp. nov.

Two species of *Titanethes* and one of *Typhloniscus* also appear to have been described by Joseph in this paper. They are *Titanethes fracticornis*, Joseph, *T. brevicornis*, Joseph, from Carniola, and *Typhloniscus stygius*, Joseph, from Italy. They are mentioned by Packard in his list of the cave-animals of Europe [83, p. 86].

F. A. Forel [40, p. 134] could not find *Niphargus* in the Savoy lakes, in Lake Bourget, and Lake Annecy, but *Niphargus puteanus*, Koch, was found in a well at Annecy.

O. E. Imhof [64] also was unable to find *Niphargus* in these lakes, though in Lake Bourget *Asellus Forelii*, Blanc, was found.

According to Eugène Daday [34] *Niphargus stygius* is found in Transylvania, at Kis-Nyires and Ugra.

Ed. van Beneden [10] also records the occurrence of *Niphargus puteanus* at Liége.

F. A. Forel [40], in 1885, published his very exhaustive and comprehensive work on "La Faune profonde des Lacs suisses," in which many references are made to the blind *Niphargus* and *Asellus*. In the fauna of the deep water he mentions *Gammarus pulex*, Deg. (which appears to descend to considerable depths, although the author says that the forms he has seen differ little from those of the littoral region), *Niphargus puteanus*, var. *Forelii*, Humbert, and *Asellus Forelii*, Blanc. He is inclined to raise Humbert's variety of *Niphargus* to the rank of a species, and mentions that it is nearer to the *Niphargus* of wells than to the *Gammarus pulex* of the littoral region of the lake. He afterwards calls it *Niphargus Forelii*. *Asellus Forelii*, Blanc, is abundant at various depths; two specimens found at depths of 200 mètres and 300 mètres had rudiments of eyes; all the others, even the young from the pouch of the female, showed no trace of eyes. The species is intermediate between *Asellus aquaticus* and *A. cavaticus*, Schiödte, but is nearer the latter. The author records *Niphargus Forelii* from the following lakes:—Geneva, Neuchâtel, Lucerne, Walenstadt, Zurich, Como; and *Asellus Forelii* from Bourget, Annecy, Geneva, Lucerne.

After an elaborate argument the author comes to the conclusion that the two species *Niphargus Forelii* and *Asellus Forelii* are not derived from the fauna of the littoral region, but from the underground waters of the surrounding country, which must therefore have more or less free communication with the deep waters of the lakes.

G. Budde-Lund [18] in his 'Crustacea Isopoda Terrestria,' published in 1885, identifies *Typhloniscus Steinii*, Schöbl, and *Itea crassicornis*, Koch, with *Platyarthrus Hoffmannseggii*, Brandt, a species found in ants' nests throughout Europe; he also gives another species, *P. Schöblii*, from Algeria [18, p. 201]. In the appendix [18, p. 306] he gives *Typhloniscus stygius*, Joseph, under the name *Platyarthrus stygius*, but does not say where it is found, or whether in ants' nests or in caverns. Packard, in his list of European cave-animals, gives it as from Italy [83, p. 86]. Under the genus *Titanethes* Budde-Lund gives a short description of *Titanethes albus* (= *Pherusa alba*, Koch), and merely mentions *T. alpicola*, Heller, *T. graniger*, Frivaldsky, *T. feneriensis*, Parona, *T. fracticornis*, Joseph, and *T. brevicornis*, Joseph [18, p. 254].

G. du Plessis-Gouret [87] deals with the same subject as that handled by Forel. He found *Niphargus Forelii* opposite Ouchy in the Lake of Geneva, where Forel had not found it, and states that it occurs also in the Lake of Lucerne. He says, without hesitation, that the lake *Niphargus* is descended from the underground *Niphargus*.

G. Asper [2], in 1885, refers to his former work on this subject, but does not mention the forms supposed to be intermediate between *Gammarus pulex* and *Niphargus Forelii*. He is of opinion that the *Niphargus* gets into the lakes from wells.

R. Schneider [96], 1855, described from the mines at Clausthal a variety of *Gammarus pulex,* under the name *G. pulex* var. *subterraneus,* which differs from the normal specimens of the species in its loss of colour, the partial degeneration of the eyes, the possession of two joints only in the secondary flagellum of the upper antennæ as in *Niphargus puteanus,* &c. Schneider appears to consider it to some extent intermediate between *Gammarus pulex* and *Niphargus puteanus.* In connection with it Stebbing says: "The special interest of the form lies in its occurrence in the waters of mines of which the age can be more or less definitely ascertained" [108, p. 573]. It is discussed by Moniez, who has found a somewhat similar form at Emmerin [78, p. 39].

Karl Bovallius [15], in 1886, in his 'Notes on the Family Asellidæ,' mentions and gives brief descriptions of *Asellus Forelii,* Blanc, *A. Sieboldii,* de Rougemont (=*A. cavaticus,* Schiödte), and *Cæcidotæa stygia,* Packard. He omits *Cæcidotæa nickajackensis,* Packard, the account of which he had evidently not seen. In the introduction [15, p. 3] he says:—"*Cæcidotæa* seems to be closely connected with *Asellus Forelii* and *A. cavaticus,* but without any knowledge of the form of its pleopoda it is impossible to say whether it ought to be united with *Asellus* or not."

R. Schneider [97], in 1887, described a new variety *freibergensis,* Schn., of *Asellus aquaticus,* found in the water of the mines of Freiburg. It bears to *A. aquaticus* much the same relation as *Gammarus pulex* var. *subterraneus,* Schn., does to the normal *G. pulex.* It is smaller, quite colourless, the eyes persistent, but presenting the same example of degradation as in *G. pulex* var. *subterraneus.*

A. E. Jurinac [68] found in the caves of Croatia a species which he first named *Eriopis croatica* and afterwards *Niphargus croaticus.* According to Moniez, it is characterized by the antennæ, which are longer than the body, and contain 73 joints, the last six segments of the pleon are furnished with a thick row of forked spines, the hand is almost square in the female and oval in the male [78, p. 49].

A. S. Packard's [83] paper on "The Cave Fauna of North America" was read in November 1886, but I am unable to find out exactly when it was published. It contains a very full and comprehensive account of the various caves, with the fauna of each, and a discussion on some of the points of general importance presented thereby. The cave Isopoda given are *Cæcidotæa stygia,* Packard, and *C. nickajackensis,* Packard. A fuller account than had previously been published is given of the genus *Cæcidotæa,* which is retained as distinct from *Asellus* "on taxonomic grounds" *, and, as it is pointed out, it presents constant differences from the blind Isopods of European caves and wells and from the depths of the Swiss lakes, which, though exposed to similar conditions, have developed in a different direction. The two species *C. stygia* and *C. nickajackensis* are described in some detail and compared with the surface species *Asellus communis,* and the author says: "It seems quite evident that the two species have descended from different species of *Asellus.* Whether there is an additional species in the Southern States from which the present species [*C. nickajackensis*] may have been derived remains to be seen" [83, p. 33]. Two species, *A. intermedius* and *A. brevicauda,* described by Forbes from Southern Illinois, are mentioned, but it is stated that neither has been found in central or northern Illinois, "although the most varied situations were carefully searched" [83, p. 33]. The Amphipoda given are *Crangonyx vitreus,* Smith (=*Stygobromus vitreus,* Cope), *C. Packardii,* Smith (=*C. vitreus,* Packard), *C. antennatus,* Packard, *C. mucronatus,* Forbes, and *C. lucifugus,* Hay. Of the three last mentioned, the original descriptions given by their authors are simply reproduced, the other two are described and figured by Professor S. I. Smith. Of the first species, *C. vitreus,* he says:—"I know of no species with which this is closely enough allied to make its affinities of any value on the question of

* Since this was written I have, through the kindness of Mr. W. P. Hay, received specimens of *Cæcidotæa stygia* from wells in Irvington, Indiana, and they differ so much in the proportions of the body and in other points from *Asellus communis,* of which Mr. Hay has also sent me specimens, that I fully agree with Packard that *Cæcidotæa* should rank as a distinct genus separate from *Asellus.*

the origin of the cave-fauna" [83, p. 35]. This species does not possess even rudimentary eyes, but in *C. Packardii* an imperfect eye is present. The latter species is very close to *C. gracilis*, Smith, and the "differences are all such as very naturally lead to the supposition that this subterranean form has been derived from the *C. gracilis* at no very remote period" [83, p. 36].

The brain of the eyeless *Cæcidotæa* is described and compared with that of *Asellus*, from which it appears "that the eyeless *Cæcidotæa* differs from *Asellus*, as regards its brain and organs of sight, in the complete loss of the optic ganglion, the optic nerve, and the almost and sometimes quite total loss of the pigment-cells and lenses" [83, p. 109]. *Cæcidotæa* does not appear to be always totally eyeless. In specimens from a well at Normal, Illinois, the eye was represented by a black speck, varying in distinctness; no trace of eyes could, however, be detected in most of the Mammoth Cave specimens. The brains of eyed and eyeless species of *Crangonyx* were also examined and compared, and the result thus stated: "we see very slight differences between the brains of the eyed and the eyeless *Crangonyx*. The optic ganglia have about the same proportions as do the other lobes and the arrangement of the ganglion-cells. Perhaps striking differences should not be expected, as the eyes of the eyed species of *Crangonyx* are small compared with those of *Gammarus*."

Numerous references to these cave Crustacea are made in the course of the author's remarks on the general question of the peculiarities of the cave-fauna.

Thos. R. R. Stebbing [108] in his "Report on the 'Challenger' Amphipoda," published in 1888, notices in his biographical introduction previous writings on the blind Amphipoda found in caves, wells, and the deep waters of lakes, with occasional remarks and criticisms of his own, most of which have been already incorporated above.

R. Moniez [78], in 1889, gave a full account of the fauna of the "Département du Nord," and particularly of the town of Lille, and besides giving the Crustacea found in this locality he mentions also those recorded from other places by previous observers. He describes under the name *Gammarus fluviatilis*, var. *d'Emmerin*, a single specimen from the reservoirs of Emmerin, which seems to differ from the *Gammari* found at the surface in much the same way as the *G. pulex*, var. *subterraneus*, described by Schneider does; but as the last segments of the pleon bear groups of strong spines, it approaches more nearly to *G. fluviatilis*. Moniez says that it forms in some manner a connecting-link between the surface type and the variety described by Schneider. The number of joints in the flagella of the antennæ are rather numerous, the secondary appendage of the upper antenna containing *five* joints, a point to which Moniez attaches some importance. The importance of this is, however, somewhat lessened when we remember that the single specimen examined was of large size, viz. 22 millim. in length, for the numbers of joints in the flagella of the antennæ, and also in the secondary appendage, appear to increase with the size of the animal; thus I have a large specimen of *Gammarus fragilis*, 14 millim. long, which has the secondary appendage composed of *nine* joints, whilst in another only 7 millim. long there are only *six* joints, and I have seen specimens with even fewer joints than this. Of course, in species where the normal number of joints is very small, the variation will not be so great, but the same reasoning will apply to a modified degree.

Moniez does not accept the genus *Niphargus*, and under the name *Gammarus puteanus*, Koch, he describes two forms; the first, "*G. puteanus* à main triangulaire," corresponds to *Niphargus aquilex*, Spence Bate, and to *N. puteanus*, var. *onesiensis*, Humbert, and this is the species which should, he considers, be looked upon as the true type of *Niphargus puteanus*. The other form, "*Gammarus puteanus* à main ovale," differs in the form of the hand of the gnathopods, and particularly in the last uropoda, which are short and bear only one branch consisting of a single joint, thus resembling *Crangonyx*, though the telson is double and not simple as in that genus. This form Moniez constantly found associated with *Niphargus puteanus* (à main triangulaire), but in much fewer numbers; and as he cannot identify it with any of the previously described species and is not inclined to see a new species in it, he suggests that it may be a second form of the male of *Niphargus puteanus*.

Wrześniowski, however, makes this form a separate species under the provisional name *Niphargus Moniezi*, considering it a connecting-form between *Niphargus* and *Crangonyx* [124, p. 672].

Moniez did not find *Asellus cavaticus* along with *Niphargus puteanus* at Lille, although these two species are frequently found associated. He accounts for this by suggesting that owing to the habits of the animal it is not so likely to be drawn up the pumps as the Amphipods are. He gives, however, brief notices of the various Isopods found by other authors in wells, caves, &c., as he has already done a few pages previously for the Amphipods found in similar situations.

August Wrześniowski [123], in 1888, published an elaborate paper in the Polish language under the title "De tribus Crustaceis Amphipodis subterraneis." In 1890 there appeared a translation, apparently with some additions and alterations, in German [124]. This exceedingly careful and conscientious work will be quite indispensable to all future students of the subterranean Crustacea, and it will therefore be sufficient to indicate here briefly the contents of the paper. Some of the more general questions raised are considered elsewhere.

The paper commences with a full historical sketch of the subject, which I have freely made use of in drawing up the present account. Wrześniowski, however, deals only with the Amphipoda. Then follows a discussion on the genera *Gammarus*, *Niphargus*, *Eriopis*, *Crangonyx*, *Goplana*, and *Boruta*, the genus *Eriopis*, Bruzelius, being retained under the altered form *Eriopsis*, and a new genus *Boruta* being established apparently nearly related to *Goplana*, Wrześniowski, but differing in some details of the mouth-parts. The three new Amphipods described are *Niphargus tatrensis*, sp. nov., *Niphargus puteanus*, var. *Vejdovskyi*, var. nov., and *Boruta tenebrarum*, nov. gen. et sp. These species are described at great length and compared with previously described species, the mouth-parts in particular receiving special attention and being figured with great care. There is a discussion on the multiplicity of species of *Niphargus*, with an elaborate criticism of the views of de Rougemont, an account of the geographical distribution of the subterranean Gammarids and of their probable origin, a bibliographical list of works relating to the subject, and tables of measurements of the different species.

I regret exceedingly that my imperfect knowledge of German has prevented me from making as full use of this paper as I should like to have done.

III. The History, Distribution, and Occurrence of the New Zealand Subterranean Crustacea.

The occurrence of blind Crustacea in the underground waters of Canterbury, New Zealand, was first recorded by me in a paper read before the Philosophical Institute of Canterbury, on the 3rd November, 1881 [22]. This paper contained descriptions illustrated with figures of four new species,—one Isopod, *Cruregens fontanus*, and three Amphipods, *Crangonyx compactus*, *Calliope subterranea*, and *Gammarus fragilis*,—and was subsequently published in the 'Transactions of the New Zealand Institute.'

In 1882, in a second paper read before the same Institute on the 5th October [23], I made a few additions and corrections to the first paper, giving a few facts as to the occurrence of the different species, and also described another Isopod, *Phreatoicus typicus*, a new species and genus for which I have since made a separate family, the Phreatoicidæ [26, p. 151].

The five species mentioned above had all been obtained from a well at East Eyreton, about 13 or 14 miles from Christchurch, and most of them were subsequently obtained from other wells in the immediate neighbourhood. Nothing further of importance regarding these Crustacea was ascertained until towards the end of 1883, when Mr. D. L. Inwood, of Winchester, near Temuka, South Canterbury, wrote to me stating that he had taken similar blind Crustacea from a pump at Winchester. He afterwards very kindly forwarded me some specimens, which proved to belong to *Gammarus fragilis*, *Calliope subterranea*, *Cruregens fontanus*, and to a species of *Phreatoicus*. A short note recording the occurrence of these species at Winchester was published in the 'New Zealand Journal of Science' for March, 1884 [24], in which also the generic name *Calliope* was altered to *Calliopius*, as the former name was preoccupied, and it was pointed out that the specimens referred to *Phreatoicus typicus* differed to some extent from the Eyreton specimens, though whether they were entitled to rank as a new variety or not was at the time left an open question; in the present paper they have been placed under the new species *Phreatoicus assimilis*.

In 1889, Mr. G. M. Thomson [110, p. 262], recorded the existence of *Calliopius subterraneus* in wells at Ashburton from specimens forwarded to him by Mr. W. W. Smith. I have since received numerous specimens of this species from various wells in that locality, both from Mr. Smith, and also from Mr. J. B. Mayne, Head Master of the Ashburton Public School.

In 1891, Mr. R. M. Laing, of the Christchurch Boys' High School, sent me several specimens of *Gammarus fragilis* from wells at Leeston, about 27 miles from Christchurch in a southerly direction. He has since sent me specimens of *Crangonyx compactus* and *Cruregens fontanus* also from the same well.

In the year 1892 Mr. E. Wilkinson, of the School of Agriculture, Lincoln, sent me a large number of specimens of *Calliopius subterraneus* from wells at that place, about 12 miles from Christchurch.

These are all the localities from which I have seen specimens of these Crustacea up to the present time, though from various correspondents I learn that they have been seen in other localities on the Canterbury Plains. Mr. Smith wrote me (Aug. 1892) that he had heard of them from as far north as Leithfield, and also from Alford Forest, only a few miles from the base of the ranges, in a well 46 feet deep.

About the end of 1889 I received from the Trustees of the Australian Museum, Sydney, a small collection of terrestrial and freshwater Crustacea, collected for the Museum by Mr. R. Helms, while on an expedition to the Mt. Kosciusko plateau. Among these I at once saw that there was one belonging to the genus *Phreatoicus*, which had been established for the blind form from the wells at Eyreton. The occurrence of a species of this genus inhabiting the surface-waters on the top of the Mt. Kosciusko plateau, at a height of nearly 6000 feet above sea-level, was first published in the small 'Handbook of Christchurch,' prepared for the Meeting of the Australian Association for the Advancement of Science, at Christchurch, in January 1891 [63, p. 19]. The species was afterwards fully described in the 'Records of the Australian Museum' under the name *Phreatoicus australis* [26]. In the present paper I have compared it with the two subterranean species *P. typicus* and *P. assimilis*.

Subterranean Crustacea have now been actually obtained from the following localities in the Canterbury Plains:—

1. *East Eyreton*, about 15 miles north of Christchurch, altitude about 120 feet above sea-level *.

2. *Lincoln*, about 12 miles south of Christchurch, altitude about 28 feet above sea-level.

3. *Leeston*, about 27 miles south of Christchurch, altitude about 60 feet above sea-level.

4. *Ashburton*, about 50 miles south-west of Christchurch, altitude about 323 feet above sea-level.

5. *Winchester*, about 85 miles south-west of Christchurch, altitude about 136 feet above sea-level.

I have also heard of Crustacea being seen from wells at several other localities in addition to those given above; but leaving these out of consideration, the localities given, from all of which I have actual specimens, are sufficient to show that these Crustacea are widely distributed in Canterbury, so far as distance north and south is concerned; the distribution from east to west, so far as at present known, appears to be much more restricted, and it is perhaps worthy of notice that all the places mentioned are within short distances of the sea, none of them being more than 10 or 12 miles from it.

No doubt further research will demonstrate the occurrence of these Crustacea at many other places; at the same time it is to be remarked that they do not occur in the artesian waters of Christchurch. The area in which artesian wells can be sunk with success is a narrow belt parallel to the sea, extending from Flaxton, north of the Waimakariri, to Lake Ellesmere, the inland boundary being the contour of about 50 feet above the sea. The depth below the surface of the first water-bearing stratum varies from about 55 feet at Riccarton to 136 at New Brighton, on the sea-coast, and there is a second water-bearing stratum at about double the depth of the first in each locality. Crustacea appear to be absent from both of these water-bearing strata; I have frequently sought for them in vain in water from wells to the first stratum, and others have been equally unsuccessful; moreover, as the water of these wells is used throughout the whole district for drinking-purposes without previous filtering, the animals would certainly have been noticed had they been present. With regard to the wells reaching to the second stratum, Mr. R. M. Laing tells me that he endeavoured to collect Crustacea from a well of this kind at the Christchurch Boys' High School, Bath, by fixing a muslin bag over the mouth of the pipe for some hours, but that no trace of any Crustacea was obtained. Of course, this evidence, though very satisfactory so far as it goes, is by no means conclusive, and it would be well to repeat the experiment in other wells and at different times, in order to confirm or disprove the results of the single trial already made.

In the above-mentioned 'Handbook of Christchurch' [63, p. 33] it is pointed out that although it is commonly thought that the main source of the water-supply of the artesian wells is the leakage of the bed of the Waimakariri, the few careful observations that have

* This height has been obtained from the Survey Department through the kindness of Mr. C. W. Adams, Chief Surveyor, Dunedin. The other heights are taken from the figures given in the time-tables published by the New Zealand Railway Commissioners.

been made do not confirm this hypothesis at all, as floods in the river never affect the height of the water in the wells, while heavy rain makes them rise, and a continuance of dry weather makes them fall. The absence of subterranean Crustacea appears to confirm the opinion that the water of the artesian wells is not derived from the leakage of the Waimakariri, for the water in which they are found at Eyreton is almost certainly derived, partly at any rate, from the Waimakariri, and if they exist there we might reasonably expect to find them distributed all over the water affected by leakage from that river.

All the subterranean Crustacea hitherto collected from the underground waters of the Canterbury Plains have been obtained by means of the ordinary suction-pumps with which the wells are usually fitted. In the same way similar Crustacea have been obtained in England by Spence Bate and others, in France by Moniez, in various parts of Europe by numerous observers, and in North America by Hay, Forbes, and others. In Europe and North America these Crustacea have also been procured from underground streams in caves and from the deep waters of lakes, but none have as yet been obtained in this way in New Zealand. These situations have not yet been properly searched, and it is quite possible that the blind Crustacea may yet be obtained by exploring the caves in different parts of the colony, and by dredging in the deep alpine lakes of Otago.

The pumps referred to are mostly ordinary suction-pumps, and consequently do not go down to a depth of much more than 30 feet. In some cases, however, owing to a continuance of dry weather for several years, the pipes have had to be driven deeper, and fitted with a cylinder-pump, and Crustacea have still been occasionally taken from them; but it would be obviously rather more difficult to bring up Crustacea from greater depths in this way than from less depths by an ordinary suction-pump, even although they were equally numerous in the waters underground in the two cases. In some cases there is an actual well, the soil having been excavated to a depth of 25 feet or so, and a hole thus formed in which the water can accumulate; in the majority of cases, however, the suction-pipe has been simply driven into the ground like that of an ordinary artesian well. The Crustacea are obtained quite as freely from wells of the one description as of the other. I have myself noticed that the Crustacea are often brought up most abundantly when pumping is first commenced, and that jerking the handle of the pump somewhat violently is often more successful than pumping at the ordinary rate. Mr. J. B. Mayne has noticed the same thing in connection with pumps at Ashburton, and Mr. E. Wilkinson, of Lincoln, states that the Crustacea come up most abundantly after the pump has been left for a time, especially in the early morning. Of course, these facts can be easily accounted for if we consider the character of the small animals with which we have to deal, for a sudden upward flow of the water would be more likely to carry them with it than a more gradual flow, and they would be more likely to be found in the neighbourhood of the pipe, or indeed in the pipe itself, when the waters had been for some time undisturbed by pumping.

In order to collect them I have generally taken a small hand-bowl, pumped it full by a few vigorous or jerking motions of the handle, then examined it to see if any Crustacea have been brought up, catching any that there may be with a dipping-tube, and pumping the bowl full again after the lapse of a few minutes; and where the Crustacea have been fairly numerous I have found this intermittent method of pumping more successful than continuous pumping. In other wells where the Crustacea were found only sparingly, Mr. Smith of Ashburton found it better to collect them by tying a muslin net over the spout of the pump; and in order to prevent the animals being injured he floats the net in a bucketful of water, the bucket being raised so that the level of the water in it is higher than the spout of the pump.

Mr. Smith reports from Ashburton that all the subterranean animals appear to have been brought up by the pumps most abundantly some eighteen months or two years ago, when, owing to the continued drought, the water in the wells was sinking; but that since the wells were sunk deeper, and up to the present time when the water is now rising again in most wells, the animals have been much rarer. Thus in one of his letters he says:—"I generally enquire wherever I go if any animals come up in the water, the answer being that there were plenty twelve months ago but none lately." In another he says that one gentleman informs him "that they frequently saw minute 'pale shells with white slugs in them' before the pump went dry eighteen months ago; since sinking the pump 15 feet more, they have not detected any animals in the water." In another letter, dated 29th June, 1892, Mr. Smith says Mr. Dolman, a practical well-sinker of the district, informed him "that he had not seen a single animal in well-water for some months. There is, however, not much well-sinking going on, as the water is almost up to its usual height."

My own experience tends to strengthen the conclusion that the animals are brought up most abundantly while the level of the water is sinking, for I found them very abundant at Eyreton from 1881 up to about 1886, during the whole of which time the water was sinking, and the wells had to be deepened several times. I have had few opportunities of collecting at Eyreton since, but I am told that very few animals have been seen during the last two or three years. In 1891 Mr. R. M. Laing sent me quite a number of subterranean Crustacea from one of the wells at Leeston, and he states in a later letter that the well has since become dry.

From the one well at EYRETON in which I first noticed the Crustacea I have collected the following five species:—*Gammarus fragilis*, *Crangonyx compactus*, *Calliopius subterraneus*, *Cruregens fontanus*, and *Phreatoicus typicus*. Of these *Calliopius subterraneus*, the female, has always been much more abundant than any of the others; for two or three years from 1881 I seldom had to pump for more than 10 or 15 minutes without obtaining some specimens of this species. After the well was deepened it was less abundant, and did not preponderate over the others so much as before. The male of this species is very rare; I have seen only about half a dozen specimens altogether. Whether this species is really so much more abundant than the others in the underground waters is, perhaps, a little doubtful, as from its smaller size it would naturally be drawn up the pipe more easily than the larger forms. Of the other species, *Gammarus fragilis* and *Crangonyx compactus* have been about equally abundant on the whole, but sometimes one form has preponderated and sometimes the other; *Cruregens fontanus*, though somewhat numerous, has not been so commonly obtained as the others; this may perhaps be accounted for by its habit of creeping instead of swimming like the Amphipods. Moniez notes the same thing with regard to *Asellus caraticus*, Schiödte, which is frequently found along with *Gammarus puteanus*, but has not been met with from the district of Lille nor from Prague, although the latter species is found at both places; he accounts for this by stating that, owing to the habits of the animal, it would rarely be brought up by the pumps [78, p. 51].

The occurrence of *Phreatoicus typicus* has been somewhat peculiar. Although the Crustacea coming up the pump were pretty carefully watched and collected from January 1881, no specimen of *Phreatoicus* was observed until the beginning of September 1882, while in a month from that date some six or seven other specimens, all females, were obtained. I have not taken it again since then; but in the year 1892 a single specimen, also a female, was taken at Ashburton by Mr. Smith. This species is represented at Winchester by a closely allied species, described in this paper as *Phreatoicus assimilis*, and of this I have three specimens only, two males and one female.

From LEESTON the following species are so far known—*Gammarus fragilis*, *Crangonyx compactus*, and *Cruregens fontanus*; from LINCOLN, *Calliopius subterraneus*; from ASHBURTON, *Calliopius subterraneus*, *Gammarus fragilis*, *Cruregens fontanus*, and *Phreatoicus typicus*; from WINCHESTER, *Calliopius subterraneus*, *Gammarus fragilis*, *Cruregens fontanus*, and the representative species *Phreatoicus assimilis*.

IV. DETAILED DESCRIPTIONS OF THE NEW ZEALAND SUBTERRANEAN CRUSTACEA.

ISOPODA.

Family PHREATOICIDÆ.

Genus PHREATOICUS, Chilton.

(Transactions New Zealand Institute, vol. xv. p. 89.)

The following are the characters that I originally assigned to this genus in 1882, when I had only one species, *Phreatoicus typicus*, before me. They apply, with the slight limitations given below, to the three species of the genus now known, and may therefore still stand in the form in which they were originally put:—

"Body long, subcylindrical, laterally compressed. Upper antenna short, lower long, with flagellum. Mandible with an appendage. First pair of legs subchelate, others simple; first *four* pairs articulated to body at the anterior ends of their segments and directed forward; last *three* articulated at posterior ends of their segments and directed backward. Abdomen long, of six distinct segments, last joined to telson. Sixth pair of pleopoda biramous, styliform. Telson large, subconical."

On this description I may make the following remarks:—

1. The lateral compression of the body is not great and is seen chiefly in the pleon, where the pleura of the segments are produced downward.

2. With regard to the legs, the first pair is subchelate in both sexes, but is larger in the male than in the female, and the fourth pair in the male is slightly modified so as to

be almost subchelate; in the female the fourth pair is simple like the preceding. The statement that the first four are attached to the body at the anterior ends of their segments and the last three at the posterior ends, although true enough of the typical species, required some modification in the case of *P. australis*, for the last three pairs in this species are attached to the centres of their segments, the epimera occupying almost all the inferior margins, and this is also true in a modified degree of the other species. The point that I wished to bring out would be better expressed by saying that the legs are divided into an anterior series of four and a posterior series of three, and this would apply equally well to the three species.

3. "Abdomen long" should perhaps read "pleon long" in order to be consistent with the term "pleopoda" used afterwards. The term "uropoda" is again a very convenient one to use in place of "sixth pair of pleopoda."

4. The peculiarities of the pleopoda, as shown in the descriptions given below, are, no doubt, quite worthy of being mentioned among the characters of the genus, but they cannot be observed without dissection, and so long as the genus can be sufficiently distinguished by other points more easily observed, there is no necessity to introduce them. Perhaps some of them, such as the possession of an "epipodite," will prove to be characters of the family and not merely of the genus.

PHREATOICUS ASSIMILIS, sp. nov. (Plates XVI. & XVII.)

Phreatoicus typicus, Chilton, New Zealand Journal of Science, ii. p. 89 (March 1884).

Phreatoicus typicus (pars), Thomson and Chilton, Transactions New Zealand Institute, vol. xviii. p. 151.

Specific diagnosis. Body somewhat stout. Pleura of the second, third, fourth, and fifth segments of the pleon very largely developed, much deeper than their respective segments; the inferior margins somewhat sparsely fringed with small spinules. The projection at the extremity of the telson not much produced, broader than long; upper angle of its extremity sharp and tipped with a few setæ; lower angle rounded. Lower antennæ about half as long as the body; peduncle with the fifth joint only about half as long again as the fourth; flagellum much longer than the peduncle. Legs stoutish, with the joints somewhat expanded, all the pairs well supplied with setæ. Lower lip with each half ovate, with the extremity well rounded. Inner lobe of the first maxilla rather narrow and with only four plumose setæ at its extremity.

Colour. Translucent.

Length. About half an inch (10 to 12 mm.).

Habitat. Winchester, South Canterbury, in wells (*D. L. Inwood*).

Detailed Description.

The following detailed description is mainly taken from a male specimen that was dissected for the purpose. A few points regarding the surface of the body &c. have been taken from a female specimen that was mounted dry on a slide.

Body (Pl. XVI. fig. 1). The female specimen has the body 10·5 mm. long, and the peræon about 1·5 mm. deep. The body is of uniform breadth throughout its whole length. In the peræon the depth is about equal to the breadth, the ventral surface being more or less flat, so that here the body is semi-cylindrical; in the pleon the segments (except the first and sixth) have the pleura much produced below into smooth, flat, thin plates protecting the pleopoda on either side.

The surface of the body is smooth throughout, with a few setæ scattered here and there either singly or in small tufts, chiefly on the dorsal surface.

Head (Pl. XVI. fig. 1). The dorsal surface is convex, curving downward in front, making the outline of the head in lateral view roughly subtriangular. The anterior margin, as seen from above, is concave behind the bases of the antennæ. A depressed line on the side of the head toward the posterior end runs down more or less parallel with the posterior margin and runs out into the inferior margin; it does not extend over the dorsal surface of the head. Behind the base of the lower antennæ there is a slight cleft in the front margin, and behind this a slight depression on the surface which extends backward a little distance and then turns downward. The inferior margin of the head is nearly straight. In the dried specimen there is no trace of the eyes, the exoskeleton being apparently continuous over the place where the eyes would be situated if they were present.

Peræon (Pl. XVI. fig. 1). The first segment is only half as long as the second; it widens a little inferiorly and has the antero-inferior angle somewhat produced, so that the front margin slopes forward and brings the lower part of the segment very close up to the head. The inferior margin is slightly convex and not hollowed for the reception of the epimeron, which appears to be ankylosed to the segment, the suture being indistinct. The second, third, and fourth segments are all similar and subequal, and of the same length at the inferior margin as on the dorsal surface. The inferior margin is nearly straight, but slightly concave anteriorly for the reception of the shallow epimeron; the anterior angle produced into a rounded knob, tipped with a few setæ; the posterior angle rounded, with a few setæ in the third and fourth segments. The fifth segment is somewhat shorter than the fourth; the anterior angle of the inferior margin is rounded and bears a few setæ, while the rest of the inferior margin is deeply emarginate to receive the triangular epimeron; the sixth and seventh segments are similar to the fifth, but each is shorter than the preceding one.

Pleon (Pl. XVI. fig. 1). The first segment is shorter than the last segment of the peræon, but of nearly the same depth; the inferior margin is rounded off at both angles and bears about 6 to 8 minute spinules scattered along the margin. The second, third, and fourth segments are subequal and somewhat longer than the first; they have their pleura produced inferiorly into large, thin plates, considerably deeper than the respective segments. The pleuron of each segment has the anterior angle of the inferior margin rounded; posteriorly the pleuron is slightly produced so as to overlap that of the succeeding segment; that of the second segment is also produced anteriorly as far as the anterior margin of the first segment, fitting in below its small pleuron; the posterior angles are slightly produced and usually bear a few minute spinules. The fifth segment is nearly as long as the three preceding; its pleuron has the posterior angle well rounded, the posterior margin and part of the inferior margin being sparingly supplied with spinules.

The sixth segment is completely coalesced with the telson, forming a somewhat conical tail-piece, which ends posteriorly in a small projection broader than long, its upper angle at the extremity sharp and tipped with a few small setæ, the lower angle being rounded and free from setæ. Below this projection the inferior margin on each side is slightly irregular, more or less dentate, and is fringed with spinules. The posterior margin in front of the articulation of the uropoda is convex and bears four stout spiniform setæ.

The *upper antennæ* (Pl. XVI. fig. 2) consist of about 9 or 10 joints, of which the three at the base may be considered the peduncle, although there is little or nothing to distinguish them from the succeeding joints. The first and second joints are subequal and somewhat larger than the third; all three bear several small setæ at the distal end; the first three joints of the flagellum are subequal and a little shorter than the last joint of the peduncle; the remaining joints are longer and thicker, being usually considerably swollen, especially towards the distal end, the swelling being chiefly due to a thickening of the chitinous integument; the penultimate joint is usually the thickest, the terminal one being small. The joints of the flagellum bear a few minute spinules distally, and the last four joints have in addition one or two small "olfactory cylinders."

The number of the joints in the antennæ and their relative sizes are subject to considerable variation. The one drawn (Pl. XVI. fig. 2) has the terminal joints less swollen than usual; the penultimate joint is slightly constricted at the middle and bears two groups of "olfactory cylinders;" hence it probably represents two joints, and in that case this antenna would contain altogether ten joints. The other antenna of the same specimen was more normal; it also contained ten joints, and those toward the end were more swollen, the antepenultimate being the largest.

he *lower antennæ* (Pl. XVI. fig. 3) are about half as long as the body. The peduncle is somewhat longer than the upper antennæ. The first two joints are short and subequal; the third is about as long as the first and second together, curving slightly upward, the upper margin being concave and the lower convex, while there are two small groups of setæ on the lower margin and one on the upper margin at the extremity; the fourth joint is half as long again as the third, having a few spinules along each margin and a tuft at the extremity in the middle; the fifth joint is considerably longer than the fourth, bearing three or four small tufts of setæ along each margin and tufts of longer setæ at the extremity. The flagellum contains about 30 joints, each bearing at the extremity a circlet of setæ about half as long as the joint from which they spring; some are placed singly, others in small tufts. At the base of the flagellum each joint is as broad as long, but they gradually become longer and narrower until at the end each joint is about four times as long as broad.

The *upper lip* (Pl. XVI. fig. 4) is rather large and strong, being thick and chitinous. It is broader than long, rounded distally, the middle of the distal margin very slightly produced; the extremity is covered very densely with fine short setæ, directed chiefly towards the centre and forming a thick fur.

The *mandibles* (Pl. XVI. figs. 5, 6) are very similar in general structure to those of *Phreatoicus australis* [26, pp. 156, 157, pl. xxiii. figs. 5 and 5 *a*]. In a lateral view of the head the large basal joint is seen extending along the anterior portion of the lower margin of the head, which, however, is nearly straight and is not hollowed out for the reception of the mandible as described by Sars [91, p. 94] in *Asellus aquaticus*. Below the base of the lower antennæ arises the 3-jointed palp, which extends forward beneath the antennæ, its third joint being usually bent sharply inward, nearly at right angles to the second. From this point the basal joint extends downward and curves forward and inward to form the cutting-edge. The molar tubercle arises from the concave inner surface of the basal joint and extends inwards to meet its fellow on the other side, at a point above and somewhat posterior to the cutting-edge; it is large and strong, but not so stout as in *Phreatoicus australis*. A view of the outer convex surface of the mandible with the palp attached is shown in fig. 5; in this the molar tubercle is of course completely hidden from view; it will be seen that there are a few setæ at the base of the palp on the side toward the base of the mandible, a small row of fine hairs on the other side of the palp, and another on the inferior edge of the basal portion of the mandible. The figure that I originally gave of the mandible of *Phreatoicus typicus* [23, pl. iv. fig. 5] is almost the reverse of the one now referred to, and shows it from the inner side as it rests on its rounded outer surface—its most natural position when dissected out; the molar tubercle then projects directly upward and only its extremity is shown.

As usual, the two mandibles differ slightly in the cutting-edge. In the right mandible there is only the one cutting-edge formed by the extremity of the basal joint itself; this appears usually to consist of three teeth only. In the left mandible (fig. 6) the corresponding part is formed of four teeth, two long ones of equal length and the other two shorter; in addition to this there is the secondary cutting-edge, composed of three teeth on a process which arises inside and extends parallel to the outer cutting-edge almost as far as its extremity. At the base of this and between it and the molar tubercle is another projection nearly as broad as long, having its extremity rounded and bordered by a double row of stout setæ; the outermost of these are short, stout, and denticulated; the inner ones, nearer the molar tubercle, become gradually longer, more slender, and plumose instead of denticulate. This process is the same in both mandibles.

The mandibular palp (see fig. 5) is the same in both mandibles; the first joint is short, only half as long as the second, and bears several long setæ at its extremity; the second joint is oblong and bears three tufts of setæ on its lower margin toward the end and another tuft at the extremity; the third joint is fully as long as the second, and is usually bent upward and inward at right angles to it. Its anterior margin is slightly concave toward the distal end, and bears two regular rows of slightly curved, coarsely plumose setæ; those at the basal end of the row are very short, but the others gradually lengthen distally till the terminal one is about as long as the portion of the joint bearing the row.

The *lower lip* (fig. 7) consists of two lobes narrowed at the base, ovate in shape, with the extremity rounded; the inner margins are fringed with long setæ projecting radially inward, those toward the extremity being the longest. On the outer margins about the middle is a thick tuft of finer setæ, and nearer the base another group of shorter setæ forming a sort of fur, which extends on to the surface of the lip. The two lobes are quite divided almost to the base, where they appear to be connected with a soft membrane;

each has fine setæ arranged on the surface near the base of the inner margin. The outer margins appear thick and chitinous, but the rest of the lip is thin and delicate.

The *first maxilla* (fig. 8) consists of two lobes, which appear somewhat indistinctly articulated to a basal portion, which may perhaps represent the combined basos and ischium, the two lobes representing the internal and external *laciniæ* arising from the basos and ischium respectively. See Boas [13, pp. 495–8] and Parker [84, p. 22].

There is a tuft of fine setæ on the outer margin of the base near the articulation of the outer lobe, and another on the inner margin at the base of the inner lobe. The outer lobe is long, its articulation with the base very oblique; the distal portion curves slightly inward, having the margins parallel and both fringed with numerous fine setæ; the end, which is oblique, is crowned with numerous short spiniform setæ, the innermost of which are more or less denticulate. The inner lobe is narrow at the base, but expands somewhat toward the distal end; it has both margins and a portion of the outer (posterior) surface covered with rather long but very fine setæ. At the rounded extremity there are four long setæ, rather distant from each other; they appear segmented, and are densely plumose and somewhat denticulated toward the extremity; at the base of each of the two innermost is a single simple seta.

Bands of muscles can be seen attached to the bases of each of the lobes, but no muscles extend into the lobes themselves, a fact which, without further evidence, would be almost sufficient to show that the two lobes cannot represent the exopodite and endopodite of the typical crustacean limb, as some authors have held.

The *second maxilla* (fig. 9) is of the usual shape, and consists of a broad, somewhat rectangular basal portion, having two lobes articulated to its distal end, and being produced distally on the inner side so as to form a third lobe, which, however, is not divided off from the basal portion. The outer margin of the base is straight, and is fringed almost throughout with numerous fine, stiff setæ; the inner margin is slightly concave, and is fringed with two rows of setæ. The outer (posterior) row consists of about 15 setæ, not very closely packed, and denticulate at the ends; at the distal end of this row succeeds a number of finer stiff setæ, forming at first a kind of continuation of the row and then spreading out so as to cover the surface of the end of the inner lobe. The inner (anterior) row consists of a much greater number of setæ, apparently simple, with thickened bases, the setæ being so closely packed that the bases almost adjoin; towards the proximal end of the row the thickened base of each seta is rather long, but in the others it gradually decreases till in the setæ at the distal end of the row the base is quite short. This row of setæ is situated along the edge of the inner margin; but at the distal end, when it has reached about halfway along the inner lobe, it leaves the margin and is continued for a short distance along the inner (anterior) surface of the lobe; beyond the end of the row is a single simple seta.

The inner lobe curves slightly inward; its extremity is truncate, with the corners rounded off, and it bears about 12 long setæ, the outermost being the longest and simply plumose, while the inner ones are shorter and in addition to the plumes bear denticulations toward the ends, the denticulations increasing in distinctness and strength as they proceed inward.

The two articulated lobes are similar and subequal; they are oblong, with the extremities rounded. Each bears at the end and along the distal portion of the inner margin a large number of long pectinated setæ, which curve somewhat inward. On the outermost setæ, which are the longest, the pectinations which project at right angles to the setæ are very fine, but they become much coarser on the inner shorter setæ.

Various portions of the second maxilla bear very fine but rather long straight setæ, like those on the first maxilla. Those on the outer surface have already been described. On the inner surface there is a large tuft on the basal portion toward the inner edge, and two other tufts near the base of the outer articulated lobe; the inner margin of the inner articulated lobe is also fringed with fine setæ.

The *maxillipedes* (figs. 10, 11) are large and appear more perfectly developed than in most other genera of the Isopoda. In general structure they closely resemble those of *Phreatoicus australis* as well as those of *P. typicus*, but my original description and figure [23, pl. iv. fig. 9] of the maxillipedes of the latter species are imperfect and based on a partial misconception of the appendage.

The first joint, the *coxa*, is irregular in outline, appearing more or less circular when seen from the anterior side; from it arises the large *basos* and, on the outer side, the *epipodite*. This is a large flat plate reaching beyond the end of the ischium, irregularly elliptical in outline, slightly emarginate at the distal end, the margins being entire; along the inner edge, where it impinges against the basos, the margin itself and the neighbouring portion of the outer surface are covered with very fine setæ. The *basos*, when seen from the outside, is quadrangular, about twice as long as broad, the outer margin fringed with fine delicate setæ like those on the neighbouring portion of the epipodite; besides the portion of the basos thus seen, another portion almost at right angles to it projects inward, and this is produced distally beyond the basos proper into a large concave plate, reaching beyond the inner extremity of the meros and having its convex surface turned inward toward the median line. The inner margin of this plate up to the end of the basos proper is thickly fringed with fine delicate setæ; beyond this the whole margin of the distal portion of the concave plate is thickly fringed with large plumose setæ, those at the extremity being shorter than the others and more or less pectinate instead of plumose. Many other setæ, similar to these at the extremity, are scattered over the distal end of the convex side of the plate. These setæ probably form straining apparatus of some kind.

Near the base of the plate, a little beyond the extremity of the basos proper, are two long "coupling-spines," slightly hooked at the extremity, very similar to those of *Asellus aquaticus*, as described and figured by Sars [91, pl. ix. fig. 5″].

The *ischium* is short, transverse, with one or two setæ at the extremity on the inner edge. The *meros* is subtriangular, produced at the outer side about halfway along the carpus, and is somewhat hollowed distally to receive the carpus; there are a few rather stout setæ on the outer margin at the extremity, and the inner margin is convex and fringed with rather long setæ. The *carpus* is somewhat sunk in the meros, slightly narrowed at the base, the outer margin slightly sinuous and with a small tuft of setæ at the extremity, the inner margin convex and densely fringed with long setæ.

The *propodos* is oblong; outer margin slightly convex, with one or two setæ at the extremity only; inner margin slightly convex and densely fringed with setæ, except at the base. The *dactylos* is similar to the propodos, but much shorter and narrower; it bears setæ arranged as in the propodos, two or three of those at the extremity being very long and robust.

First appendage of peræon (Pl. XVII. figs. 1, 2, 3). *In the male* these form large well-developed subchelate gnathopoda, very similar in general appearance to those found in many Amphipoda. In the female they are similar, but much smaller. Unfortunately, the only female specimen that I have of this species has been mounted dry on a slide, and I am, therefore, unable to give a full detailed description of its gnathopods, but so far as I can see they are very like those of *Phreatoicus typicus* as described later on [see p. 199, Pl. XVIII. figs. 7, 8], except that they are stouter and rather better supplied with setæ. The following description therefore applies to the male only.

The *coxa* (epimeron) is small, attached to the anterior portion of its segment, and is more or less ankylosed to it; it is free from setæ, and is emarginate below to receive the basos. The *basos* is longer than the ischium; it is constricted at the base and has three small tufts of setæ on the posterior margin. The *ischium* is similar to and nearly as long as the basos; it has two or three tufts of setæ on the posterior margin and two stout setæ at the middle of the anterior margin, where it is slightly convex. The *meros* has a small tuft of setæ at the extremity of the posterior margin, which is straight: this joint is expanded distally, produced anteriorly and inward, and is hollowed out at the end to receive the rounded end of the large propodos; the inner margin of the cup-shaped socket thus formed is very densely fringed with long straight setæ projecting radially inward (Pl. XVII. fig. 3). The *carpus* is small, sub-oblong, the posterior margin with a tuft of setæ towards the extremity and one or two separate setæ placed more proximally, the anterior margin completely covered by the propodos and meros. The *propodos* is very large, forming much the largest portion of the whole limb; it is produced backwards beyond the carpus into a rounded lobe which rests back on to the meros; the whole joint is oval in outline, the anterior margin very convex and without setæ, with the exception of a small tuft at the extremity; the posterior margin slightly sinuous, fringed with short setæ; the palm oblique and well defined, armed with a rounded lobe near the base of the dactylos, followed by four very short triangular spines placed on slightly rounded lobes: these spines decrease in size as they recede from the dactylos; between the base of the dactylos and the rounded lobe is a row of 7 to 8 setæ, and from the lobe toward the end of the palm is a row of simple setæ, each with a distinctly enlarged base, and near this row a few scattered setæ on the surface of the propodos. The *dactylos* is strong, as long as the palm, both margins fringed with a few minute spinules, the extremity forming a distinct nail, with a small secondary nail on the inner margin at its base.

The second appendage of the peræon (Pl. XVII. fig. 4).—The *coxa* is similar to that of the first appendage, but is slightly larger and is distinctly marked off from its segment. The *basos* is narrow at the base, but widens out at the middle, where the breadth is nearly half the length, and it narrows slightly again toward the distal end; the anterior margin is fringed throughout its whole length with short, stout setæ; the posterior margin bears one or two similar setæ about the middle and a tuft of finer setæ at the extremity. The *ischium* is about three-fourths as long as the basos: it is narrow at the base but considerably expanded distally; the anterior margin is convex, slightly irregular, and bears five spiniform setæ, followed by a series of three or four finer setæ towards the extremity; the posterior margin is nearly straight, bearing five or six small tufts of one or two setæ each, and a larger tuft of longer setæ at the extremity. The *meros* is about three-fourths as long as the ischium, subtriangular, and produced at the antero-distal angle; the anterior margin is strongly convex, bearing five spiniform setæ, with a row of six or seven along the distal end; the posterior margin straight and fringed with numerous setæ. The *carpus* is somewhat smaller than the meros, similar in shape, but not produced at the antero-distal angle; the anterior margin convex, with setæ towards the extremity only; posterior margin straight and fringed externally with spiniform setæ. The *propodos* is oblong, slightly longer than the carpus and a little narrowed distally; the anterior margin is slightly convex and bears a few fine setæ, chiefly toward the extremity; the posterior margin straight, bordered with five spiniform setæ and a number of finer hairs: at its extremity the propodos is produced alongside the base of the dactylos into a small triangular projection (Pl. XVII. fig. 5) similar to that described by Sars [91, p. 100] in *Asellus aquaticus.* The *dactylos* is slender: the end forms a distinct nail with three or four setæ on the surface of the dactylos at its base: on the inner margin is a small secondary nail at the base of the large one, with a seta arising in the angle between the two.

The third appendage of the peræon is almost exactly the same as the second in all respects, and fig. 4, drawn from the second, will equally well delineate the third.

The fourth appendage of the peræon (figs. 6, 7) is like the second and third in the female, but it is slightly modified *in the male* to form a grasping-organ, instead of being merely adapted for walking. The whole leg is somewhat shorter than the preceding; the *basos* is the same; the *ischium* also the same, except that it is shorter than in the preceding legs; the *meros* and *carpus* are much shorter, but otherwise similar, and with the same general arrangement of setæ; the *propodos* has the anterior margin very convex, the posterior margin being developed into a slightly concave palm, distinctly defined by a small group of three or four very stout spiniform setæ, and occupying nearly three-fourths of the whole margin; the *dactylos* is rather short, and is considerably curved.

The first four pairs of appendages to the peræon form an anterior series, differing very considerably in structure from the last three pairs, forming the posterior series. In the anterior series the dactylos is directed backward, while in the posterior pair it is directed forward, as in the majority of the Amphipoda.

The fifth, sixth, and seventh appendages of the peræon (figs. 8, 9) are similar to each other, but differ in size, the sixth being larger than the fifth, and the seventh as much larger than the sixth. I shall describe the sixth pair only, and it must be understood that this pair represents the mean between the fifth and seventh pairs, not in size only, but also in the number and size of the setæ found on the various joints.

The *coxa* is subtriangular in outline, and fits into a triangular emargination in the segment, the lower margin of the coxa being straight or somewhat concave. In the fifth segment the coxa occupies only the posterior half of the lower margin of the segment, but in the sixth and seventh segments, which are considerably shorter, the coxa occupies nearly the whole of the lower margin. The *basos* is oblong, about twice as long as broad, its slightly convex anterior margin supplied with eight or nine short but rather stout setæ and a tuft of finer hairs at the extremity; the posterior margin produced somewhat backward, as in the Amphipoda, irregularly serrate, and armed, except towards the extremity, with about a dozen strong spiniform setæ. The *ischium* is as long as the basos, its anterior margin straight, obscurely serrate, and with five small tufts of setæ marking the serrations, and a transverse row along the distal margin; the posterior margin is convex, with five serrations, each of the first four bearing a strong spiniform seta, and the last a row of about four or five. The *meros* is rather more than half as long as the ischium, the anterior margin straight and bearing three groups of stout setæ, the distal one being the largest; the posterior margin bears two or three spiniform setæ, and a row of three or four along the distal margin at the posterior angle, which is somewhat produced. The *carpus* is as long as the *propodos,* but broader: both are oblong, slightly expanding distally, with groups of stout setæ along both margins, but more especially along the anterior margin, and a row along the end at each angle. The *dactylos* is about as long as the setæ at the end of the propodos, similar to the dactylos of the second pair of legs, but more slender.

The *pleopoda* of *Phreatoicus* are large and well developed, and present such peculiarities that they are well worthy of careful examination and description. The five pairs all appear to be branchial in function, and though the first pair differ in shape from the others, they appear to be the same in minute structure, probably fulfil the same function, and do not act as an "imperfect operculum" to the others as I originally stated [23, p. 91]. All the pleopoda hang vertically from the ventral surface of their segments, and are protected laterally by the greatly developed pleura.

The *first pair of pleopoda* (Pl. XVII. fig. 10) have the basal joint or *protopodite* subrectangular, with one seta at the extremity on the outer margin, and several similarly placed on the inner margin. From the protopodite arise two rami, both long and narrow; the inner one, *endopodite,* is narrow-elliptical, about five times as long as broad, with the margins quite entire and without setæ, and the extremity subacute; the outer ramus, *exopodite,*is oblong, longer than the endopodite, the inner margin nearly straight, outer margin irregularly curved at each end; the whole of the inner margin and the extremity fringed with rather long setæ; on the outer margin the setæ are long at the end, but they become smaller toward the base and disappear altogether before the base is quite reached. All the setæ on the inner margin are simple, those at the extremity and on the neighbouring portion of the outer margin are plumose; the others on the outer margin become gradually less plumose as they approach the base, until at about the middle of the joint they are quite simple.

The *second pair of pleopoda* (fig. 11) differ in the two sexes, being specially modified in the male so as to serve as an accessory copulatory organ. It will be convenient to describe that of the male first. The *protopodite* has the same general shape as in the first pair, and bears a few setæ at its extremity on the inner margin; the *endopodite* is similar to that of the first pair, but bears on the inner side a long, narrow, curved appendage, the "penial filament," which does not reach so far as the end of the endopodite; it appears to be semi-cylindrical, being concave on the outer side, and bears four or five short setæ at its extremity. The portion of the endopodite between its base and the base of the "penial filament" is about one-fourth the length of the whole endopodite; it is slightly enlarged, and bears toward the inner margin a powerful muscle attached to the base of the "penial filament."

It will be seen from fig. 11 that the "penial filament" of *Phreatoicus assimilis,* as drawn, is much shorter than in *P. australis* [26, pl. xxvi. fig. 2]; it is, however, quite probable that, like other secondary sexual characters, it may vary very greatly in development at different seasons. The *exopodite* is large, and consists of two joints; on the outer side it is produced backward at the base into a rounded lobe which lies alongside of the protopodite; the outer margin of the first joint is fringed rather sparingly with short simple setæ, its inner margin is straight and more thickly fringed with similar setæ; the second joint is triangular, articulated to the first joint by a very narrow base; the inner margin is straight, and, like that of the first joint, is fringed with simple setæ, but these are much longer than on the first joint; the extremity, which is oblique, is bordered on the outer margin by about 10 long delicately plumose setæ.

The endopodite does not hang by the side of the exopodite, but overlaps it, and the exopodite is curved so as to receive it; a raised ridge runs from the outer extremity of the protopodite toward the outer margin of the first joint of the exopodite, meeting it at about the middle, and thus bordering the depression within which the exopodite lies. The endopodite usually overlaps the exopodite to a greater extent than is shown in fig. 11, where it was purposely somewhat separated from the exopodite to allow the form of the latter to be more clearly seen. The more natural position of the two is shown in fig. 12, which represents the third pair of pleopoda.

I have had no opportunity of examining the pleopoda of a female specimen of *Phreatoicus assimilis,* but from the analogy of *P. australis* and *P. typicus* I have no doubt that the second pleopoda would resemble that of the male, as above described, except that there would be no penial filament.

The third pair of pleopoda (fig. 12) are similar to the second, but the *endopodite* is rather smaller in proportion to the *exopodite*, and does not reach beyond the base of the second joint of the latter. From the outer margin of the protopodite arises a subtriangular lobe projecting nearly at right angles to the protopodite, and apparently representing the *epipodite*; its margins bear long simple setæ, widely separated from each other, and its integument, though apparently thicker than that of the rest of the pleopod, is more or less membranaceous, so that this epipodite is perhaps also branchial in function.

The significance of the occurrence of an epipodite in the pleopoda of *Phreatoicus* is considered later on (see p. 244).

The fourth and fifth pairs of pleopoda contain precisely the same parts as the third pair, but each is much shorter and broader than the preceding.

The *uropoda* (fig. 13) are long, the peduncle as long as the inner ramus, and reaching considerably beyond the end of the telson. Its lower margin is straight and bears three tufts of setæ on the proximal portion and another tuft at the extremity; the upper surface is flat or slightly concave, the outer margin with a few small setæ scattered along the whole length; the inner margin with few setæ, except towards the end, where it is somewhat raised and bears two stout spiniform setæ on the projection. The outer ramus is considerably shorter than the inner, but of the same shape; each is lanceolate, a little constricted at the base, and bears numerous tufts of one or two stout setæ and many fine hairs; the extremities narrow somewhat abruptly and are free from setæ.

Male reproductive organs. I came across the male reproductive organs in the specimen from which I was dissecting out the appendages. They seem to have the same general shape as in *Asellus aquaticus* [91, pl. x. fig. 7], but there appears to be a great number of the oval *cul-de-sacs*, apparently five or six. The vas deferens was quite crammed with spermatozoa, which resemble those of *Asellus.*

I have been unable to find an external male organ in either of the two specimens I possess.

PHREATOICUS TYPICUS, Chilton. (Pl. XVIII. figs. 1–12.)

Phreatoicus typicus, Chilton, New Zealand Journal of Science, vol. i. p. 279 (Nov. 1882); id. Transactions New Zealand Institute, vol. xv. p. 89, plate iv.; Thomson & Chilton, Transactions New Zealand Institute, vol. xviii. p. 151; T. R. R. Stebbing, Report on the 'Challenger' Amphipoda, pp. 513, 587; R. Moniez, "Faune des eaux souterraines du département du Nord &c.," extrait de la Revue Biologique du Nord de la France, tome i. (1888–1889), p. 53.

Specific diagnosis. Body somewhat slender. Pleura of the second, third, fourth, and fifth segments of the pleon moderately produced, not deeper than their respective segments; their inferior margins well supplied with setæ, especially in the fifth segment. Extremity of the telson forming a narrow projection much longer than broad, narrowing distally, the truncate extremity tipped with rather long setæ. Lower antennæ about three-fourths as long as the body; flagellum much longer than the peduncle, which is slender and has the fifth joint twice as long as the fourth. Legs slender; joints scarcely expanded, the first four pairs not very abundantly supplied with setæ. Lower lip with each half subtriangular, with the inner distal angle somewhat acute. Inner lobe of the first maxilla broad, expanded distally, and bearing about nine long plumose setæ.

Colour. Translucent.

Length. Rather more than half an inch (15 mm.).

Habitat. Eyreton (*Chilton*) and Ashburton (*W. W. Smith*), in wells.

Detailed Description.

Unfortunately I have no male specimen of this species, all the few specimens I have seen, about ten altogether, being females. The following detailed description applies therefore to the female only, though doubtless it will apply equally well to the male, except as regards the first and fourth appendages of the peræon and the second pleopoda, which are specially modified in the male.

I described this species pretty fully in my original paper [23], and in the present paper I have given a full detailed description of the new species *P. assimilis*, and I shall therefore give only such further details of *P. typicus* as are necessary to exhibit clearly the differences between the two species.

Body (Pl. XVIII. fig. 1). It will be seen, from a comparison of Pl. XVI. fig. 1 and Pl. XVIII. fig. 1, that the body is much more slender than in *P. assimilis*; thus in one specimen that I have mounted dry on a slide, and from which fig. 1, Pl. XVIII. is taken, the body is fully 15 mm. long, yet the depth is only 1·5 mm., the same as the depth of a specimen of *P. assimilis* that was only 10·5 mm. long.

The surface of the whole body is smooth, and though there are a few fine setæ scattered over it, chiefly in the pleon, they are not so numerous nor so distinctly arranged in small tufts as in *P. assimilis*.

Peræon (Pl. XVIII. fig. 1). The first segment is very short, not half so long as the succeeding; it widens inferiorly, and has the inferior angle somewhat produced and brought close up to the head, so that the first pair of appendages of the peræon seem almost to arise from the head. The next three segments are subequal and rather longer than deep; they are quite rectangular in outline, the inferior margin being almost straight and scarcely hollowed, except slightly in the first segment for the reception of the coxa of the appendage, which is small and placed well to the anterior end of each segment. The next three segments are similar, but each is shorter than the preceding segment; the inferior margin of each is emarginated towards the posterior end for the triangular coxa.

Pleon (figs. 1, 11). In the pleon this species resembles *P. assimilis* as above described, but the pleural portions are not so largely developed, being somewhat shallower than their respective segments, and their inferior margins are more abundantly supplied with setæ. In each segment there is a slight ridge where the pleural portion leaves the body-ring proper, but the integument is quite continuous, and there is no suture or line of division of any kind.

The projection at the end of the telson (fig. 12) is narrow, longer than broad, projects slightly upwards, and has the truncate extremity tipped with a few setæ; there is a stout seta below at its base; the inferior margin of the telson on each side from this projection to the articulation of the uropoda is irregular and fringed with very fine setæ.

The *upper antenna* (fig. 2) extends a little beyond the extremity of the third joint of the peduncle of the lower antennæ; it usually contains eight joints, but is not distinctly divided into peduncle and flagellum. The first three joints are similar, but each smaller than the preceding, oblong, about twice as long as broad, with a few setæ at the distal end; the fourth joint is like the third, but shorter; the fifth shorter still, but somewhat expanded distally; the sixth and seventh are subequal to each other and to the first joint and are considerably swollen; the eighth joint is usually small, but swollen; the last three bear at the extremity one or two small "olfactory cylinders" of the usual shape in addition to a few simple setæ.

The *lower antennæ* (fig. 2) are about three-fourths as long as the body, the flagellum being much longer than the peduncle. The first two joints are subequal, short, as broad as long, without setæ; the third is as long as the first and second together, its upper margin slightly convex, lower margin straight, one or two small setæ on the lower margin at the distal end; the fourth is about half as long again as the third, but slightly narrower, sides straight and parallel, one or two small setæ on the margins, and tufts of longer setæ above and below at the extremity; the fifth joint is similar to the fourth but about twice as long, each margin bears about four small setæ and there are tufts of longer setæ at the end; the first joint of the flagellum is about twice as long as the second, which is about as broad as long; the remaining joints (about 35 altogether) gradually become longer and narrower till at the end each is about six times as long as broad, each bears one or two small setæ at the distal end, but toward the extremity of the flagellum these become very small.

The *upper lip* does not differ in any important respect from that of *P. assimilis.*

The *mandibles* (fig. 3) also appear to resemble those of *P. assimilis*, but the left mandible has only three teeth on the terminal cutting-edge, with three also on the secondary cutting-edge. In the specimen from which I have taken the drawing (fig. 3), these teeth are much sharper and more acute than those shown in the figure of *P. assimilis* (Pl. XVI. fig. 6), but this is probably due to the fact that they belong to a younger specimen. In the figure they are flattened out so as to be seen full in front, while those of *P. assimilis* are seen in profile.

The *lower lip* (Pl. XVIII. fig. 4) differs considerably in shape from that of *P. assimilis.* Each lobe is triangular, inner margin straight, outer margin very convex, especially toward the base, the extremity being more or less acute, not rounded, and there is a small projection on the inner margin at some little distance from the extremity. The extremity is densely covered with long setæ; the inner margins and the distal portions of the outer margins are fringed with fine setæ.

The *first maxilla* (fig. 5) bears a general resemblance to that of *P. assimilis*, but the inner lobe is much broader, especially toward the extremity, which is rounded and bears about 9 or 10 long plumose setæ, about twice as many as in *P. assimilis.* The two simple setæ also present at the extremity are situated near the base of the third and fourth setæ respectively from the outer margin of the lobe. In *P. assimilis* they are situated at the base of the two inner setæ.

The *second maxillæ* (fig. 6) differ from those of *P. assimilis* in the following points:— The inner margin of the basal portion is more convex, and bears a very distinct row of long plumose setæ, which have thickened bases; those at the distal end have the base quite short, but toward the proximal end of the row the bases become gradually longer. At the lower end of the row on the surface of the base is another somewhat imperfect row of simple setæ. The inner (fixed) lobe is longer than in *P. assimilis* and has the end more rounded, and the long plumose setæ, instead of being confined to the extremity, extend for some distance along the inner margin toward the base.

The *maxillipedes* are practically identical with those of *P. assimilis*, but the "grappling setæ" are slightly different, being long curved setæ slightly hooked at the end; they thus resemble those of *P. australis*, but are more slender. In the specimen dissected there are two on one side and three on the other. *P. assimilis* has two on each side, and they are straight, with hooks at the end.

The *first pair of legs* of the female (Pl. XVIII. figs. 7, 8) are much more slender than in *P. assimilis*. The *coxa* is small, shallow, partly cleft below and ankylosed to the body-segment. The *basos* is narrow oblong, about three times as long as broad, and is almost free from setæ except a small tuft at the extremity on the posterior margin. The *ischium* is nearly as broad as the basos; posterior margin straight, with three or four minute spinules; anterior margin slightly produced in the centre and bearing a stout seta at this point. The *meros* is subtriangular, and has the posterior margin straight, with a few setæ at the extremity; the anterior margin is convex and produced distally into a rounded lobe extending about halfway along the carpus, the edge of this lobe next the carpus being fringed with stout setæ. The *carpus* is suboblong, its junction with the meros being oblique; on the posterior margin there is a small seta near the base and a small tuft of larger setæ toward the extremity. The *propodos* is subtriangular, expanding distally, longer than the meros; the anterior margin convex, especially toward the base, and bearing one or two minute setæ and a small tuft at the base of the dactylos; the posterior margin is straight, produced at the extremity to define the palm, the postero-distal angle being thickly covered with setæ. The palm is oblique, concave, and bears five or six very acute setæ with expanded bases, those nearest the base of the dactylos being the best marked, the others gradually becoming more slender until they are indistinguishable from the ordinary stout setæ at the postero-distal angle; in addition to these the palms bear a few simple setæ. The *dactylos* is somewhat stout, longer than the palm, both margins bearing a few spinules, the extremity being separated off as a distinct tooth.

The peculiar setæ on the palm are of the same kind as those described in the male of *Phreatoicus australis* [26, pl. xxiv. fig. 5 *a*], but they are not so stout and well marked. The female of that species has the first pair of legs very like those described above, but shorter and stouter and more spiniform, and the palm more oblique and not concave.

The *second pair of legs* (fig. 9) is rather longer than the first pair; the *coxa*, *basos*, and *ischium* are similar to the corresponding joints of the first pair; the *meros* is subtriangular, about three-fourths as long as the ischium, posterior margin straight and fringed with a few setæ, the anterior margin slightly convex, and with the antero-distal angle slightly produced, a few setæ on the margin and at the extremity; the *carpus* is oblong, not so long as the meros, posterior margin straight and with a few setæ, anterior margin nearly straight, and with setæ at the extremity only; *propodos* similar to the carpus but usually a little longer, the extremity produced into a small triangular lobe at the side of the dactylos; *dactylos* nearly half as long as the propodos, extremity forming a distinct nail, with a small tooth at its base.

The *third* and *fourth pairs of legs* are similar to the second and of the same size.

The *fifth*, *sixth*, and *seventh pairs of legs* (see fig. 10) are similar to each other, but each is larger than the preceding. The *coxa* is deeper than in the first four pair of legs and is triangular, fitting into a triangular emargination in the inferior margin of the segment; in the fifth segment this is at the posterior end, but in the sixth and seventh it approaches nearer the centre, though still in the posterior half of the margin. The *basos* is only slightly expanded, being oblong, about three times as long as broad, both margins somewhat scantily supplied with setæ. The *ischium* is very long, being considerably longer than the basos, narrow oblong; front margin straight, with five or six setæ; posterior margin a little convex, with a few spiniform setæ. The *meros* not half so long as the ischium; postero-distal angle a little produced; both margins with spiniform setæ, those at the extremity being very strong. The *carpus* and *propodos* similar, the carpus usually longer than the propodos; both oblong, and both margins supplied with spiniform setæ arranged in tufts, those on the anterior margin being larger than those on the posterior. The *dactylos* as in the preceding legs, but longer and more slender.

The above description applies to the fifth, sixth, and seventh pairs of legs, but it is to be remembered that the spines as described above are larger and more numerous in the sixth than in the fifth, and in the seventh than in the sixth.

The *pleopoda* appear to be similar to those of *P. assimilis*, but are rather more slender; the fifth pleopoda are very short and small.

The *uropoda* (fig. 12) differ from those of *P. assimilis* only in being longer and more slender, and in having the setæ on the inferior margin of the peduncle smaller and not arranged in distinct tufts, but evenly distributed along the whole margin.

In one of the females examined, brood-plates were beginning to appear at the bases of the appendages of the peræon; one of these is shown in the drawing of the second pair of legs (fig. 9).

Comparison of the three known Species of Phreatoicus.

When I first received the specimens of the *Phreatoicus* from Winchester along with the other species which were known from Eyreton (i. e. *Calliopius subterraneus*, *Gammarus fragilis*, and *Crurегens fontanus*), I naturally thought that they would belong to the Eyreton species *Phreatoicus typicus*; and though at the time I noticed that there were a few variations, I thought that these might prove to be due to differences of age or sex. I was therefore somewhat surprised to find on a close examination that this was not the case, but that the differences were quite sufficient to warrant the creation of another species, viz. *P. assimilis*. Besides being found at Eyreton *Phreatoicus typicus* is also known from Ashburton, only about 30 miles from Winchester, where *Phreatoicus assimilis* is found; and the existence of two subterranean species of the same genus being so near each other is a fact of considerable importance, and it would be interesting to know whether the species have differentiated since adopting a subterranean life, or whether they have descended from two different surface species. It is therefore desirable that the differences between them should be clearly set forth, and that they should be compared not only with each other but also with the species *Phreatoicus australis* [26], found on the top of the Mt. Kosciusko plateau in Australia, and at a height of nearly 6000 feet above the sea.

It is quite possible that on an examination of a greater number of specimens from various localities the differences between *P. typicus* and *P. assimilis* may partially or wholly break down; but, so far as my observations at present go, the Ashburton specimen of *P. typicus* is practically identical with those from Eyreton and differs from *P. assimilis* in the following points:—

(1) The body and the appendages are much more slender than in *P. assimilis.* This character is of course only a relative one and therefore difficult to estimate with accuracy, but in my specimens the differences, especially in the legs and the lower antennæ, are very marked.

(2) The pleura of the second to fifth pleon-segments, inclusive, are not so greatly developed and have all the inferior margins regularly supplied with moderately stout setæ. In *P. assimilis* the pleura are considerably deeper than their respective segments and have the inferior margins only sparsely fringed with spinules.

(3) The shape of the projection at the end of the telson is quite different in the two species.

(4) The shape of the lobes of the lower lip also differs to some extent.

(5) The inner lobe of the first maxilla is broader distally and bears fully twice as many long plumose setæ as in *P. assimilis.*

(6) There are slight differences in the second maxillæ; thus the long plumose setæ on the innermost lobe extend some distance along the inner margin, while in *P. assimilis* they are pretty well confined to the extremity; the rows of setæ along the inner margin of the basal portion also differ in character.

(7) The grappling-setæ of the maxillipedes also differ slightly.

The differences in the mouth-parts are somewhat peculiar, and were quite unsuspected when I had from other reasons already perceived that there were two species. The differences in the inner lobe of the first maxillæ are very noticeable.

Of the two, *P. assimilis* approaches more nearly to *P. australis* than *P. typicus* does, and I am inclined to think that, leaving out of account the special characters which are due to their subterranean life, *P. assimilis* is more closely related to *P. australis* than it is to *P. typicus.* The two former agree with each other and differ from *P. typicus* in the following points:—

(1) The stouter body and appendages.

(2) The shape of the lobes of the lower lip.

(3) The inner lobe of the first maxilla bears only 4 or 5 plumose setæ.

(4) The pleura of the pleon-segments are almost equally well developed in both.

On the other hand, *P. australis* has the projection at the end of the telson rather more like that of *P. typicus*, and in the second maxillæ and the maxillipedes it is also quite as close to *P. typicus* as to *P. assimilis*, if not closer; but in the last two points the differences of all three species are very trivial.

Phreatoicus australis differs from both the subterranean species in the following points, in addition to those which are evidently due to the different modes of life:—

(1) The body and especially the legs and pleura of the pleon are more abundantly supplied with setæ.

(2) The telson proper is much shorter and rounder.

(3) The inferior margin of the sixth segment of the pleon bears about 15 setæ instead of only 4 in front of the articulation of the uropoda.

(4) The first pair of legs in both sexes differ slightly in the shape of the propodos and in the armature of the palm.

(5) There are also slight differences in the maxillipedes.

(6) The body is much stouter than in either of the subterranean species.

Without a much fuller knowledge of the habits of each species than we possess, it is difficult to see the reason for the differences between them; and until we are able to do this, to some extent, it will be almost impossible to assign its true importance to each difference and thus to discover the true relationships of the species. The abundant setæ on *P. australis* are perhaps protective; and, if so, we can see why they should be less abundant in the subterranean forms, though even in these species they are pretty numerous, especially on the last three pairs of legs. The slender body and appendages of *P. typicus* may also be an adaptation to a subterranean mode of life, and, if so, it would appear that *P. typicus* has been longer underground than *P. assimilis*; but in the present state of our knowledge all speculations of this kind must be received with the greatest caution. The questions suggested may perhaps be some day solved by the discovery of species of *Phreatoicus* still living above ground in the mountain-streams of the Southern Alps, places where very little search of the kind required has hitherto been made.

It is worthy of notice that the species of *Phreatoicus* do not show the increase in the number of sensory setæ, &c., in compensation for the loss of eyes that has been observed in some other subterranean species. (See p. 262.)

Special points in the Structure of Phreatoicus.

In many respects *Phreatoicus* appears to be a very generalized type of the Isopoda, possessing all the segments of the body and their appendages in a more perfect form than any other Isopod I know. Thus in the body all the segments both of the peræon and the pleon are well developed and separate, except of course that the telson is joined to the sixth segment of the pleon as in nearly all Isopoda. The antennæ, though well developed, do not present any peculiarity, and the lower antenna does not possess the rudimentary exopodite found in some genera of the Aselliðæ, such as *Janira, Ianthe, Stenetrium* [9, p. 9]. The mouth-parts are all particularly well developed, no parts usual in the Isopoda being absent or coalesced; the maxillipedes especially have all the joints perfect and separate. The legs of the peræon all have the coxæ more or less separate from the segment, showing, I think, clearly that they are really the first joints of the legs, and not outgrowths of the body-ring ("epimera"). This view was first advanced by Spence Bate in 1855 [7], and has, I believe, since been pretty generally adopted, though, as Stebbing says, "It is a disputed question whether we have at the base of the leg an outgrowth of the body-ring carrying the more or less obsolescent first joint of the leg soldered to it, or whether the side-plate is itself a protective expansion of the first joint" [108, p. 1730]. In quoting Spence Bate's arguments to show that the so-called "epimera" are really the coxæ of the legs, Stebbing [108, p. 289] appears rather to favour the first view. Against this I may call attention to the fact that, in *Phreatoicus*, in the segments of the pleon the pleural portion of the body-ring has grown out to form a protection to the pleopoda, the coxal portion of which is present, but is in no way attached to this outgrowth of the body-ring, and the outgrowth is quite continuous with the body-ring, not being marked off by any suture or line of division. The same thing is of course true of the pleon of most Amphipoda. Thus these true outgrowths of the body-ring appear clearly marked off from the "epimera," which are either quite separate from the body-ring, or have a suture clearly showing the line of division, a fact that can be easily accounted for if the "epimera" are formed solely from the coxæ of the legs.

In the pleopoda of *Phreatoicus* we find several peculiarities which will probably be useful in helping us to trace out the homologies of the pleopoda of other Isopods. All the pleopoda have the basal portion, the "protopodite," present and of moderate size, and in the third, fourth, and fifth pleopoda this bears a fair-sized "epipodite." The existence of this epipodite is a point of considerable interest. I am not aware of any other case where the epipodite is present in any of the pleopoda of Isopods. In the 'Journal of the Royal Microscopical Society' for October 1891 (p. 593), in an abstract of a paper by Dr. J. Nusbaum [80] on "The Morphology of Isopodan Feet," it is stated that, according to the author, the epipodite of the thoracic legs has fused with the ventral wall of the body-segments. If this should be so in the peræon it certainly does not appear to be the case with the posterior pleopoda of *Phreatoicus*. There is no trace of the epipodite in the first and second pairs of pleopoda, nor can I suggest any reason for its absence.

Both the exopodite and the endopodite are present in all the pleopoda, both being large flat plates, apparently branchial in function. In all the pleopoda, except the first pair, the exopodite consists of two joints. This character is also possessed by some of the pleopoda of *Ianthe* [16], *Munna* [27, p. 11], and some allied genera, but the more general rule among the Isopoda is that the exopodite consists of one joint only. In the second pleopoda of the male, although there is a "penial filament," the whole pleopod has been very little modified, and it is quite easy to recognize the various parts, and to see that the penial filament is only a specialized portion of the endopodite. In *Ianthe* [16], *Munna* [27, p. 10], *Ichnosoma*, and *Acanthomunna* [9, p. 46] much further modification of the pleopod has taken place, and it is not so easy to see the homologies of the various parts. Thus both Bovallius and Beddard consider the large triangular portion which forms the main part of the pleopod to be the protopodite, and Beddard considers the penial filament to be the endopodite, and the exopodite to be represented by a small membranous portion at its base. Whether this is really so, or whether this view will require modification, is a question that must be left for future determination; but this interpretation of the various parts does not appear to harmonize well with what we find in *Phreatoicus*.

Affinities of Phreatoicus.

Phreatoicus presents so many peculiarities that it is difficult to determine its exact systematic position, and its affinities must therefore be discussed at some length. The following account is partly reproduced from my paper on *Phreatoicus australis* [26], but it has been revised and to some extent made more complete.

When I originally described the genus *Phreatoicus* in 1882 [23], I placed it in the Isopoda, and pointed out various separate resemblances to the Idoteidæ, the Anthuridæ, and the Tanaidæ, and also drew attention to the several resemblances to the Amphipoda; but after doing this I left the exact position of the genus among the other Isopoda an open question for the time. When preparing the "Critical List of the Crustacea Malacostraca of New Zealand" [111, p. 151] Mr. Thomson, judging from the general appearance (he had not had an opportunity of examining specimens), was inclined to place it under the Amphipoda, and, as I did not agree with this opinion, it was arranged that the genus should be placed between the Amphipoda and the Isopoda under a separate heading with the following note:—"The systematic position of this singular Crustacean is doubtful. In general appearance I was inclined to place it among the Amphipoda, but from the fact of the first five pairs of *pleopoda* acting as branchial organs, and from the absence of any such organs attached to the *pereion*, Mr. Chilton places it among the Isopoda.—G. M. T." [111, p. 151].

Unfortunately, however, the separate heading was omitted by some error, probably on the part of the printer, and the genus therefore appears under the last family of the Amphipoda, viz. the Platyscelidæ, as though it belonged to that family. It is no wonder, therefore, that the Rev. T. R. R. Stebbing, in his notice of the "Critical List," says, in speaking of *Phreatoicus*, "I do not know what are the special reasons for classing it among the Platyscelidæ." He also says, "The list [*i.e.* our 'Critical List'] continues with 'Suborder II. Isopoda. Tribe I. Anisopoda. Fam. I. Tanaidæ;' and probably the affinities of *Phreatoicus* will eventually prove to be rather with the Tanaidæ than with the Hyperina" [108, p. 587]. In another reference to the species *Phreatoicus typicus*, Mr. Stebbing calls it "a singular well-shrimp of a new genus and species, which appears to be an Isopod with some remarkable Amphipodan affinities" [108, p. 543].

At first sight *Phreatoicus* certainly does look very like an Amphipod, but on examination this is found to be due to superficial resemblances only, and not to any real affinity to that group. These resemblances appear to be as follows:—

(1) The body, especially in the pleon, is more or less laterally compressed.

(2) The pleura of the segments of the pleon are produced downwards, so as to protect the pleopoda on either side, just as in the Amphipoda.

(3) The legs of the peræon consist of an anterior series of *four* and a posterior series of *three*.

(4) The general appearance of the legs and of the uropoda is not unlike that common among the Amphipoda.

(5) The pleon is formed of six separate segments, and is better developed than in most Isopoda.

I think these are all the points in which *Phreatoicus* specially resembles the Amphipoda, and an examination of them shows that none is of any particular importance in its bearing on the systematic position of the genus. I will take the points one by one under their appropriate numbers as given above.

(1) Most of the Isopoda are, it is true, more or less dorso-ventrally compressed, and I do not know of any one in which there is any lateral compression as in *Phreatoicus*; but here the lateral compression is not great, and is chiefly confined to the pleon, where the downward prolongation of the pleura is no doubt a special adaptation for the protection of the pleopoda, and may very well have arisen quite independently of the similar adaptation in the Amphipoda. The peræon of *Phreatoicus* is subcylindrical, and thus resembles *Anthura* and *Paranthura*, and other genera of the Anthuridæ [106], and some species of *Idotea*, such as *Idotea elongata* [24, p. 198], in which there is no dorso-ventral compression. On the other hand, lateral compression is by no means universal among the Amphipoda; there are many genera where the body is more or less cylindrical, as in *Caprella* &c., *Corophium*, *Haplocheira*, and many others, while there are also some, such as *Icilius*, *Iphigenia*, and *Cyamus*, in which the body is much flattened, as in most Isopoda.

(2) This point has practically already been disposed of in the consideration of (1), and I need only add that *Phreatoicus* has the pleura of the first *five* segments of the pleon produced downwards, while in the Amphipoda it is only in the first *three* segments that the pleura are so produced.

(3) The division of the appendages of the peræon into an anterior series of four and a posterior series of three has been used by Dana in separating the Anisopoda from the typical Isopoda, and it is by no means a special Amphipodan character. It is, moreover, probably of little importance from a systematic point of view, seeing that it is found in such widely different genera as *Phreatoicus*, *Stenetrium*, *Munnopsis*, *Tanais*, and *Arcturus*, and its adoption as the chief bond of connection between a number of forms results, as Professor Haswell has pointed out, in "an extremely artificial arrangement" [55, p. 10].

(4) The appendages of the peræon appear at first sight undoubtedly Amphipodan, but here, again, a closer examination shows that the resemblance is merely superficial, for in all the legs we find that the *ischium* is fairly long, often as long or even longer than the preceding joint, the *basos*, while in almost all the Amphipoda the ischium is quite short, often transverse. In the possession of moderately long ischia, *Phreatoicus* agrees with most other Isopoda. I am not aware that anyone but myself has drawn attention to this difference between the Isopoda and the Amphipoda; but it appears to be one of very general application, though, of course, there are some exceptions to it as to every other rule in Natural Science. Thus, in the Apseudidæ and the Tanaidæ [106], the ischium is usually short, while in a few cases in the Amphipoda it is long, as in the second gnathopoda of the Lysianassidæ, and also in the second gnathopoda of *Seba* [108, p. 783], and perhaps in a few others. But in all these cases that I know of in the Amphipoda the long ischium is found in one pair of legs only, and I know of no Amphipod that has the ischium in each pair of legs long as in the Isopoda; so that, while the possession of short

ischia would not necessarily prove that the animal is not an Isopod (unless, indeed, we remove the Apseudidæ and the Tanaidæ to the Amphipoda, and this, notwithstanding Gerstaecker's opinion, does not seem to be desirable), the fact that it possesses long ischia in all the appendages of the peræon is a pretty clear indication that it is not an Amphipod.

It may also be pointed out that although the first appendage of the peræon of *Phreatoicus* is subchelate, as in the Amphipoda, the second appendage resembles the third in being quite simple, while in the Amphipoda the second appendage is usually subchelate like the first, or, if not actually subchelate, it shows a greater tendency to resemble the first leg than the third.

(5) In the possession of a long pleon of six separate segments, *Phreatoicus* certainly resembles the Amphipoda, and differs from most Isopods, but the same character is also possessed by the Apseudidæ and the Tanaidæ, and by the genus *Hyssura* [106, p. 128] in the Anthuridæ; and in many other Isopods, such as *Limnoria* and many of the Cymothoidæ, Oniscidæ, &c., the pleon, though not long, is composed of more or less separate segments.

The reasons given above will, I think, be quite sufficient to prove that there are no good grounds for classing *Phreatoicus* with the Amphipoda; for positive evidence that it is an Isopod it will be sufficient to take the following :—

(1) The first five pairs of pleopoda are branchial, and there are no branchial plates attached to the appendages of the peræon. The pleopoda themselves are quite different in form from those of the Amphipoda.

(2) The whole of the mouth-parts are distinctly Isopodan in character, and quite different from those of the Amphipoda.

(3) As shown above, the legs are really Isopodan, though at first sight they may appear to be Amphipodan.

(4) The telson is joined to the sixth segment of the pleon, as is usually the case with the Isopoda, but not with the Amphipoda. It is quite true, as Stebbing [108, p. 549] has pointed out, that this is also the case with certain Amphipoda, the *Hyperina* for example; but this is exceptional, and since *Phreatoicus* is certainly not one of the *Hyperina*, it does not affect the present argument. The large size and the form of the telson itself also clearly mark it off from the Amphipoda.

It will be noticed that, in considering the differences between the Isopoda and Amphipoda, I have confined myself to external characters. Other important differences in the internal anatomy have been pointed out by Blanc [12], but the material at my disposal did not permit of my testing *Phreatoicus* by these points, even if I had possessed the necessary skill to do so.

We have now to compare *Phreatoicus* with the other Isopoda to see what place it should take among them. It will be sufficient if we compare it with the Tanaidæ, Anthuridæ, Idoteidæ, and the Asellidæ.

It agrees with the Tanaidæ in the cylindrical form of the body, in the direction of the legs, and in the possession of a pleon formed of six separate segments. All these characters are, however, separately shared by other groups, and the differences in other respects are very considerable, and we may safely conclude that *Phreatoicus* has no very close affinity with the Tanaidæ.

The Apseudidæ, which rank close to the Tanaidæ, do not seem to present any greater affinity to *Phreatoicus*.

The resemblance of the Anthuridæ is, however, somewhat greater. There is a fairly good general resemblance in the shape of the body and in the legs, and though the pleon is usually short in the Anthuridæ, it is often composed of separate segments, and these may be of fair length, as in the genus *Hyssura*, Norman and Stebbing [106, p. 128]. The mouth-parts are very different, being specially modified in the Anthuridæ for the purpose of suction, and this, combined with differences in the pleopoda, uropoda, &c., is sufficient to make a pretty wide difference between the two.

With the Idoteidæ, *Phreatoicus* agrees in the shape of the body, in the antennæ, and to some extent in the mouth-parts. In the Idoteidæ these are more modified than in *Phreatoicus*, though formed on the same plan, and the mandible has no palp. It is probable, however, that the presence or absence of a mandibular palp is not a point of great systematic importance, for in the Amphipoda we have genera, in other respects closely similar, differing in this point; thus the old genus *Montagua*, Spence Bate, has been divided into *Stenothoë*, in which the mandible has no palp, and *Metopa*, in which the palp is present [108, p. 293]. A much more important difference is found in the structure of the pleon and the uropoda. In the Idoteidæ the segments of the pleon, except the last, are usually very short and more or less coalesced and the uropoda form flat plates covering up the pleopoda. There are, however, sufficient signs that the pleon of Idoteidæ has been derived from a pleon formed of separate segments, and that the uropoda, though now very different, are simply a modified form of the typical uropoda consisting of a peduncle and two rami; and it is quite probable that the special modifications of the Idoteidæ in these respects are of comparative recent date, and that their ancestors presented a much closer resemblance to *Phreatoicus* than the present Idoteidæ do.

The Arcturidæ, again, might be compared with *Phreatoicus* in much the same way, but they present a further resemblance in the legs, which, though very different in form, are very distinctly divided into an anterior series of four and a posterior series of three.

When we come to compare *Phreatoicus* with the Asellidæ we at once see a very great difference in the form of the body, but on closer examination the resemblances are seen to be much more numerous and much closer than might at first sight be expected. The head, antennæ, mouth-parts, and the legs are all in pretty close agreement; the resemblance in the mouth-parts is indeed somewhat striking, and although the legs of the last three pairs are more Amphipodan and flattened, there is a general resemblance in the relative lengths of the different joints to those of *Asellus*. In describing *Phreatoicus australis* I took Sars's description of *Asellus aquaticus* [91, pp. 96–100] as my guide, and was able to follow it pretty closely. The uropoda, again, are not very unlike those of *Asellus*, and the pleopoda of *Phreatoicus* appear to present more resemblances to those of the Asellidæ than to those of any other Isopods that I know. Besides differing very greatly in the shape of the body, *Phreatoicus* differs greatly from the Asellidæ, as from the Idoteidæ, in the structure of the pleon. In the Asellidæ this is short, usually composed of a single flattened piece, and the pleopoda lie horizontally under it, and are protected by a more or less perfect operculum formed of the first pair. In *Phreatoicus* the segments of the pleon are all separate, and the pleopoda hang vertically down, and are not protected below; indeed the shape of the pleon renders protection of the pleopoda below unnecessary.

These differences are pretty considerable and quite enough to show that *Phreatoicus* cannot be placed under the Asellidæ, but they are of such a nature that they do not prevent us from considering that the affinities of *Phreatoicus* are with the Asellidæ. For it is quite clear that the latter must have arisen from ancestors possessing a pleon formed of six separate segments, and that these have gradually coalesced to form a single plate; just as we see the same process going on at the present time in the Idoteidæ, where some species have the pleon formed of four or five segments, others of only two or three, and others, again, like *Idotea elongata*, Miers, with the pleon formed of a single piece [241, p. 198]. The horizontal position of the pleopoda and the development of an operculum from the first pair would naturally follow from the flattening of the body in the Asellidæ, which would otherwise leave the pleopoda much exposed below. Thus *Phreatoicus* appears to differ from the Asellidæ chiefly in having preserved the fully-developed pleon which must have been possessed by the ancestors of the Asellide, while in the latter this has been specially modified in accordance with the general flattening of the body, which would render a long-jointed pleon unsuitable and a source of danger to the animal, especially by the exposure to which it would subject the pleopoda. The flattening of the body in the Asellidæ would naturally follow as the result of their adopting a creeping mode of life; *Phreatoicus* walks erect or swims much in the same way as the Amphipoda.

There is one genus, *Limnoria*, formerly classed with the Asellidæ, which differs from them and resembles *Phreatoicus* in having the pleon composed of six separate segments with the pleopoda unprotected. *Limnoria*, however, resembles the normal Asellidæ in the flat depressed body, and the segments of the pleon, though separate, are short, and it may perhaps be looked upon as an approach toward the ancestral form of the Asellidæ, though its structure has been modified to some extent to suit its mode of life; thus the antennæ are very short, and the legs are short and perhaps little used for walking, and the mouth-parts are somewhat modified. Unfortunately, I do not know sufficient of the pleopoda of *Limnoria* to compare them with those of *Asellus* and *Phreatoicus*, but from the other resemblances we may with good reason look upon *Limnoria* as an intermediate link, to some extent connecting *Phreatoicus* with the Asellidæ. The very great difference in appearance between the two latter is due to the fact that the body of the Asellidæ is flat, depressed, and the animals are therefore represented as seen from above, while, owing to its body being somewhat laterally compressed, *Phreatoicus* is usually seen in side view. This difference in the form of the body is, however, probably not of much importance from a systematic point of view, for we have great differences in this respect in species of *Idotea* and in some of the Cymothoidæ, and, on the whole, I think we must place *Phreatoicus* somewhere near to the Asellidæ, but forming a separate family, the Phreatoicidæ, which bears to the Asellidæ somewhat the same relation that the Caprellidæ do to the Cyamidæ in the Amphipoda. *Limnoria* may perhaps be placed, as is done by many authors, in a separate family, the Limnoriidæ, possessing some of the ancestral characters of the Asellidæ, and thus approaching nearer to the Phreatoicidæ. Gerstaecker puts *Limnoria* under the Sphæronidæ, but forming a separate section, the *Limnorina* [45, p. 220].

From what has been already said it will be seen that *Phreatoicus* occupies a fairly central position among the Isopoda, retaining to a greater extent than any others the typical characters of the Isopoda.

The following are the characters which I have provisionally advanced for the new family Phreatoicidæ. These are simply given for the sake of comparison, and will no doubt require revision when other forms allied to *Phreatoicus* are discovered :—

Family PHREATOICIDÆ.

"Body subcylindrical, more or less laterally compressed. Mandibles with a well-developed appendage. Legs distinctly divided into an anterior series of four and a posterior series of three. Pleopoda broad and foliaceous and branchial in function, but not protected by an operculum. Pleon* large, of six distinct segments. Uropoda styliform." [26, p. 151.]

Family ANTHURIDÆ.

Genus Cruregens, Chilton.

(Transactions New Zealand Institute, vol. xiv. p. 175.)

The following characters were assigned to this genus when I originally described it :—
"Body subcylindrical. Head small. First six thoracic segments subequal, the seventh *small and without appendages.* Antennæ subequal, neither having a flagellum. First pair of thoracic legs large and subchelate, the second and third subchelate but smaller; the three posterior pairs simple. First pair of abdominal appendages forming an operculum enclosing the branchial plates, last pair biramous. Telson squamiform."

It is scarcely necessary to explain that the above description was drawn up by a tyro in the study of the Crustacea, and that though modelled on the descriptions given by others of allied genera, it contains much that is unnecessary and little that is essential.

The genus appears to fall under Norman and Stebbing's [106] "Section B," though the mouth-parts are even more modified than in the species assigned to this section by these authors. The following generic diagnosis may be given for the sake of comparison

* I have substituted "pleon" for "abdomen," which I had inadvertently put in my original diagnosis.

with Norman and Stebbing's descriptions; but even this must be considered merely provisional, as only the one species is known, and nothing is known of the distinctive characters of the two sexes:—

Eyes wanting. Segments of the pleon separate (in both sexes?). Both pairs of antennæ without distinct flagella (in adults ?). Mandibles without palp. Maxillipedes not divided into separate joints. Last segment of the peræon small and without appendages (in adults ?).

All the specimens that I have seen, many scores in number, agree in having the seventh segment of the peræon small and without appendages; but as I have never seen a specimen that I could be certain was sexually mature, I am doubtful whether this character would hold in the adult also or not. My specimens have been obtained from several wells in different localities, and were collected at different times during a period of about ten years, and it seems scarcely likely that all the specimens should be immature, and that during the whole time not a single mature specimen should be obtained, unless, indeed, the adult differs from the immature form in habits in such a way as to prevent it being liable to be drawn up by the pump. I have one specimen that has the integument of the under surface of the peræon much expanded, somewhat in the same way as shown by Stebbing in his figure of the "gravid female" of *Paranthura nigro-punctata* [106, pl. xxvi. fig. ii. D, ♀]; but in my specimen I can discover no trace of eggs or young, and it appears to be the integument itself that is distended, and not a pouch formed by brood-plates attached to the bases of the legs in the usual way; so that I am uncertain whether this specimen is really an adult female or is abnormal in some way, owing perhaps to half-completed ecdysis or some similar cause.

All this uncertainty makes comparison of *Cruregens* with other genera of the Anthuridæ a very difficult task, but it appears to approach to *Paranthura* more nearly than to any other. It resembles this genus generally in the antennæ (leaving out of consideration the special brush-like antenna of the adult male in *Paranthura*), in the peræon and its appendages, and in the pleon and the pleopoda, though the uropoda are much more slender in *Cruregens*. It differs, however, in the mouth-parts, for the mandibles have no palp and the maxillipedes have lost all trace of separate joints. If the absence of the seventh pair of legs is a character that holds in adults, this would form another difference between the two genera.

It is to be noted that the seventh pair of legs appears to be developed at a later period of the life-history in the Anthuridæ than in other Isopoda, for specimens without them, but apparently mature in other respects, are not infrequently met with. Besides *Cruregens* we have the following examples:—*Hyssura producta* is founded on a single specimen about a quarter of an inch long, of which Stebbing and Norman say "the last segment of the peræon in the type specimen has no legs, nor can we see any sign of scars where they would have been attached, and the specimen was otherwise quite perfect" [106, p. 128]; *Paranthura neglecta*, Beddard, is said to have the seventh segment of the peræon absent, the specimen is 6 millim. long, and from the absence of the last pair of legs Beddard considers it to be immature, though he does not mention any other point of immaturity about it [9, p. 114]; I have also a small specimen of an Anthurid from Port

Jackson, probably *Paranthura australis*, Haswell, which has only six pairs of legs, the seventh segment of the peræon being small and without appendages, as in *Cruregens*; my specimen is, however, only 3·5 millim. long, and is evidently immature.

Cruregens fontanus, Chilton. (Pl. XIX. figs. 1–22.)

Cruregens fontanus, Chilton, New Zealand Journal of Science, vol. i. p. 44 (January 1882); id. Transactions New Zealand Institute, vol. xiv. p. 175, pl. x. figs. 1–12; id. ibid. vol. xv. p. 88; Humbert, Archives des Sciences physiques et naturelles, t. viii. p. 256 (September 1882); Chilton, New Zealand Journal of Science, ii. p. 89 (March 1884); Thomson & Chilton, Transactions New Zealand Institute, vol. xviii. p. 152; Moniez, "Faune des Eaux souterraines du Département du Nord &c.," extrait de la Revue Biologique du Nord de la France, tome i. (1888–89) p. 53.

Specific diagnosis. No trace of eyes. Antennæ subequal, upper slightly shorter than the lower, and with four joints; lower with the third joint only half as long as the fourth. First pair of legs with powerful subchelate hand; propodos triangular, broadest at base palm straight, armed with two rows of setæ. Uropoda slender, inner branch narrow, almost rod-like, not enclosing the end of the pleon. Telson linguiform, extremity tipped with three or four short setæ.

Colour translucent, slightly yellowish, owing to the liver-tubes showing through the transparent integument.

Length of largest specimens about 12 mm.

Habitat. Eyreton, North Canterbury (*Chilton*); Leeston (*R. M. Laing*); Winchester, South Canterbury (*D. L. Inwood*) (in wells).

Detailed Description.

The following detailed description is derived from the comparison and examination of a considerable number of specimens. I can detect no differences between the specimens from the various localities mentioned above.

Body (fig. 1). The body is cylindrical throughout; the head is slightly flattened vertically and is smaller than the first segment of the peræon. The first segment of the peræon is rather shorter than the second and is rather loosely articulated to it, the body being narrowed at this point, thus allowing free movement between the two; the second segment is in the same way loosely articulated to the third, though not quite to the same extent; the third, fourth, fifth, and sixth segments subequal, about as long as the second, oblong in outline as seen in dorsal view, about half as long again as broad, and firmly articulated together, the body not being narrowed at the articulations; the seventh segment is small, only about one-third as long as the sixth, and bears no appendages.

Pleon (fig. 20). The pleon to the end of the telson is rather longer than the sixth and seventh segments of the peræon. The first segment is longer than the succeeding, the second, third, and fourth are subequal, the fifth longer than the first; each of these five segments quite separate and bearing a seta on each side; the sixth segment is longer than the fifth, widest in the centre, where its posterior margin is deeply cleft, and in a dorsal view it does not extend quite to the sides of the pleon. It is apparently clearly divided off from the telson, although this seems to be very exceptional in the Isopoda.

The surface of the whole body is smooth and bears a few short separate setæ scattered over it, especially on the dorsal surface.

The *upper antennæ* (figs. 2, 3) are rather shorter than the lower; peduncle of three joints: first joint the largest, with an "auditory seta" on its outer margin and one or two simple setæ at the extremity; second joint about two-thirds the length of the first and narrower, with two "auditory setæ" and one or two simple setæ at the extremity; third joint longer than the second, nearly as long as the first, extremity bearing simple setæ and one auditory seta. The remaining portion of the antenna appears to represent the flagellum; it consists of one very short, indistinct joint, followed by one as long as the second joint of the peduncle; this joint bears at its extremity a few simple setæ and about four or five "olfactory cylinders"; it is followed by two or three very minute joints, of which the first bears an "olfactory cylinder" and the last ends in a small pencil of three very long simple setæ.

The *lower antennæ* (figs. 2, 4, 5) have the first joint very small, nearly rectangular, broader than long; this joint can be seen only when the antenna is viewed from below, as in fig. 5; it is quite concealed in a view from above by the base of the upper antennæ. The second joint is large and broad, considerably longer than the first joint of the upper antennæ, which rests on the top of it in an oblique groove; it bears a minute seta at the extremity on the inner side. The third joint is short, narrow at the base, more or less geniculate with the first, and bears one or two minute setæ at the extremity on the inner side. The fourth joint is twice as long as the third; it bears several long setæ at the extremity and one or two small ones on the inner margin. The fifth joint is rather longer than the fourth, but slightly narrower; at the extremity it bears several simple setæ, some of them very long, and three "auditory setæ." The remaining part of the antenna may by analogy be considered as the flagellum; it consists of one joint about as long as the second joint of the peduncle, and at its extremity a minute joint ending in a pencil of long setæ.

Mouth-parts. The mouth of *Cruregens fontanus*, like that of other Anthuridæ, is adapted for suction. It is situated near the anterior end of the head, and the various parts project forwards and can usually be seen in a dorsal view between the bases of the antennæ. To form the sucking-apparatus the various parts are much modified, and have coalesced to such an extent that I have found considerable difficulty in determining the homologies of all the parts. My difficulty has been increased by the want of the necessary works of reference. Spence Bate and Westwood give very little information on the subject in their 'British Sessile-eyed Crustacea' [4]. Norman and Stebbing [106], in their account of the "Isopoda of the 'Lightning,' 'Porcupine,' and 'Valorous' Expeditions," supply figures of the mouth-parts of some of the Anthuridæ, but, unfortunately, they give no description beyond the brief accounts comprised in the generic diagnoses. I regret that I have not been able to consult

Schiödte's paper on the mouth-parts of *Cyathura carinata* referred to by Norman and Stebbing *. I have consulted Dohrn's paper on *Paranthura costana* [36] with much benefit. *Cruregens*, however, differs from all other Anthuridæ that I know in having the mandibles entirely without palps, and the mouth-parts seem more specialized than in other species.

The projecting tube formed by the mouth-parts is closed above by the *upper lip* (fig. 6), which projects downward and forward from below the bases of the lower antennæ. It consists of a triangular plate with doubly-curving sides and an acute extremity, which is chitinous throughout and seems very hard and strong. The sides of the tubes are enclosed by the greatly modified *mandibles* (fig. 7) and by the distal portions of the much simplified *maxillipedes*, which also form the covering for the tube below. The mandibles, which show no sign whatever of a palp, appear more or less completely ankylosed to the wall of the head and almost incapable of independent movement. Fig. 8 is a view of them from below and partly from the side, to show how they are attached to the ends of the maxillipedes and form the covering on the sides between them and the upper lip. The mandibles are subtriangular, running out to a sharp point distally; the distal portion bears on the inside a thin chitinous plate with rounded margin, which is very thin and sharp, and perhaps acts as a lancet or cutting-organ of some kind.

Within the tube of the mouth, enclosed as above described, we should expect to find a lower lip and two pairs of maxillæ. Fig. 12 represents what I suppose to be the *lower lip*; it consists of an oblong plate narrowed at the base, with the distal extremity truncate, the corners being rounded off and the extremity fringed with a few fine setæ directed forward. The margins appear to be curled in or thickened, and the centre is strengthened by a thickening which extends distally from the narrow base and gradually thins out. The *first maxillæ* (figs. 9, 10) are easily recognized and are of the form usual in this section of the Anthuridæ; they are very long, extending back at the base nearly to the posterior end of the head; each consists of a long, slightly curving, and gradually tapering shaft, which bears at the extremity on the outside a fine saw-like edge made up of a number of sharp teeth; on the opposite side is a thin flange curving out from the maxilla and having a very sharp razor-like edge. The maxilla is acutely pointed at the extremity: at the base it is jointed on to a short chitinous piece, which is again jointed on to a curving transverse bar; to the distal end of the first piece is attached the tendon of a strong muscle, by the contraction of which the maxilla is protruded, while it is drawn back again by muscles attached to the base of the maxilla itself; possibly also the maxilla can be somewhat rotated on its base so as to bring the two saw-like edges together. In any case they evidently form most efficient lancet-like organs. It appears probable from Dohrn's figure [36, pl. ix. fig. 8] that at the base of the first maxilla of *Paranthura costana* there is an apparatus similar to that here described, but his figure is not very clear and shows the transverse bar as though continuous with the maxilla itself.

* "Krebsdyrenes Sugemund," Naturhistorisk Tidsskrift 3 R. 10 B. (1875), p. 211, tab. iv.

I have not been able to make out the *second maxillæ* quite satisfactorily, for they seem to be closely connected at the base with the part I have considered the lower lip, and it is difficult to separate the two without injuring them; the first maxillæ are not connected with these, simply working between them and being articulated to the head much posteriorly. Usually the lower lip and second maxilla come away together and then present the appearance shown in fig. 11; this evidently corresponds to Dohrn's "fig. 9," which he calls the "Verwachsenes zweites Maxillenpaar (?)"; but in the species he describes the central portion (lower lip ?) is deeply cleft, while it is not so in *Cruregens*. In this figure 11 the base of the second maxilla can be seen as a strongly curving bar proceeding from a central portion that lies just along the base of the lower lip, and is perhaps joined to it; on each side this bar afterwards curves inward and ends in an expanded distal portion bearing numerous fine setæ. The whole of this end is soft and delicate; it is difficult to make out its exact form, but it appears to widen out vertically, and probably helps to close in the sides of the suctorial tube formed by the mouth (see fig. 13).

The *maxillipedes* (fig. 14) have the basal portion completely ankylosed to the underside of the head; about the middle there is a small and chitinous plate similar to that figured by Dohrn in *Paranthura costana* and by Norman and Stebbing in *Anthelura elongata* [106, pl. xxv. fig. 1, C, L]. In the latter species the corresponding plate is slightly pointed at the extremity, and is situated nearer the posterior end of the head, at the base of the maxillipedes. Hence it appears probable that this plate represents the large chitinous plate found in *Phreatoicus*, the Idoteidæ, Asellidæ, &c., and is therefore the epipodite. In *Cruregens*, however, this plate is situated much further from the posterior margin of the head, and the remainder of the maxillipede has been so modified that all trace of its separate joints has been lost. Anteriorly from this the two maxillipedes are contiguous for a short distance, but then rapidly separate, a seta being placed in the middle of the inner concave margin. The extremity narrows nearly to a point, and has at the end a very small terminal joint bearing a number of rather long setæ, one or two others being situated on the outer edge at a little distance from the extremity.

The *first pair of legs* (figs. 15, 16) forms powerful subchelate claws, which can be extended considerably beyond the head and even beyond the ends of the antennæ. The coxa is indistinguishable and appears completely ankylosed to the body-segment. The basos is narrow at the base and rapidly widens out to its greatest breadth at the middle, where the breadth is rather more than one-third of the length; it narrows again slightly towards the distal end; the posterior margin is regularly arched, the anterior sinuous; near the base there are two rather long "auditory setæ." The ischium is equal in length to the basos and is similar in form; the posterior margin is convex and bears four small spinules; the anterior side is hollowed out into a longitudinal groove to receive the rest of the limb when bent back upon it. The meros is short, transverse; at its junction with the ischium it is narrow, but it rapidly widens out, forming anteriorly an oval lobe, which bears at the end a few small setæ; the posterior margin is straight, lies in the same line as that of the ischium, and bears two setæ at the extremity. The carpus is small, subrectangular, and is surrounded by the propodos, except on the posterior side, where it is produced at the extremity into a small rounded lobe bearing a few long setæ and covered with a thick fur of very short setæ. The propodos is very large, about as long as the three preceding joints together; it is subtriangular, widest towards the base, where it is more than half as broad as long; the anterior margin is very convex and bears no setæ except a small one at the base of the dactylos; the posterior margin is straight and is produced along the end of the carpus into a small rounded lobe; all the rest forms a rather broad palm, fringed throughout its whole length on the outside with a row of serrated setæ of fair length, one or two of these being considerably longer than the others, and two or three long ones being situated at the extremity. The dactylos is as long as the propodos, is considerably curved, and tapers gradually to the acute extremity; the inner margin bears about 15 minute spinules at regular distances; the tip is brown in colour, but is otherwise not clearly marked off into a distinct unguis.

When the limb is seen from the inner side (fig. III. *p*) only a triangular portion of the carpus is seen, the rest being overlapped by the propodos. The inner margin of the palm appears slightly convex and is fringed with a thick row of setæ, which appear simple and are much more numerous than those in the row on the outer margin. At the base this row leaves the margin of the propodos, and curves along the side, thus marking the place where the tip of the dactylos overlaps the propodos.

The *second pair of legs* (figs. 17, 18) is slender and subchelate. The basos is longer than the ischium, narrow at the base, widening distally, greatest breadth rather more than one-fifth the length; two "auditory setæ" near the base as in the first pair of legs, both margins with a few small spinules. The ischium is similar in shape to the basos, widest at the middle, where the breadth is about one-fourth the length, narrowing toward both ends, a few spinules on each margin. The meros is triangular, very narrow at the base; posterior margin straight, with two or three long setæ at the extremity; antero-distal angle produced and tipped with two setæ. The carpus is small, with three setæ at the extremity of the posterior margin; the junction with the propodos oblique. The propodos is narrow ovate, as long as the ischium, length about two and a half times the greatest breadth; anterior margin convex, with a few small setæ, and at the base of the dactylos a small group of two longer ones and an "auditory seta"; the palm occupying about two-thirds the posterior margin, not clearly defined, slightly convex, armed with about eight stout setæ, each bearing a subapical hair and being serrate on the opposite side; besides these there are also a few simple setæ. The dactylos is slightly curved, fitting closely on to the palm; inner margin with a few minute spinules, and towards the end one or two small setæ marking off the terminal unguis.

The *third pair of legs* is similar to the second in size and form.

The *fourth pair of legs* (fig. 19) is about as long as the third, but they are simple and not subchelate. The basos and ischium are similar to those of the second and third pairs, but the basos is a little more widened in the centre and bears three "auditory setæ." The meros is rather more than half as long as the ischium, triangular, narrow at the base; anterior margin straight, with a seta about the middle and two longer ones at the extremity; posterior margin slightly convex, somewhat produced distally, and bearing at the end three or four setæ. The carpus is rather longer than the meros, oblong; the anterior margin with three spiniform setæ and two or three simple setæ at the end; the posterior margin straight, with a few simple setæ, and in the middle a long "auditory seta." The propodos is similar to the carpus, but considerably longer; the anterior margin armed with four or five spiniform setæ and a few simple ones, the posterior margin having at the extremity a group of two or three simple setæ and one "auditory seta." The dactylos is similar to that of the third pair of legs. The spiniform setæ on the anterior margins of the carpus and propodos are similar to those on the palms of the second and third pairs of legs, but are smaller and not quite so well marked.

The *fifth* and *sixth pairs of legs* are similar to the fourth, but may sometimes be a little longer.

The *seventh pair of legs* is entirely absent in all the specimens that I have examined.

The *first pleopoda* (fig. 21) form an operculum completely closing in the branchial plates below. The protopodite appears to consist of two joints, a very short coxa, and a rectangular basos, which is broader than long, and bears on the inner margin three stout setæ, dentate at the extremity; these appear to act like the "coupling-spines" to which Stebbing has drawn special attention in the Amphipoda. The exopodite which forms the operculum is an oval plate bulging downward; it is about twice as long as broad, its inner margin nearly straight, outer margin very convex, bearing on the distal half about six very delicate plumose setæ, with three or four shorter ones at the extremity. The endopodite is narrow styliform, slightly enlarged at the base, somewhat sinuous, sides parallel, extremity rounded and tipped with three or four plumose setæ.

The *second, third, fourth,* and *fifth pleopoda* (fig. 22) are all alike and of the usual form. Each consists of a short transverse protopodite, an oval endopodite well rounded at the end and with the margins free from setæ, and a longer and rather narrower expodite, which is slightly constricted on the outer margin toward the extremity; the margin is rather irregular, and bears a few finely plumose setæ on the inner side and at the end, with sometimes one on the outer side. The number of these setæ appears to vary somewhat in the different pleopoda, but I have not noticed any other differences between them.

I have not hitherto met with any special modification of the pleopoda of the male like that occurring in the Asellidæ, &c., and do not know whether such a peculiarity has been recorded in the Anthuridæ.

The *uropoda* (fig. 23) are articulated to the end of the sixth segment of the pleon. The basal portion or peduncle is large, flat, and nearly rectangular, and reaches nearly to the end of the telson; it is about two and a half times as long as broad; the outer margin is straight and bears a few setæ on the distal half; the inner portion extends as a flat plate to the median line of the body, the right or the left uropods often having their inner margins in contact below the telson; the inner distal angle bears a single small seta. The endopodite is articulated to the posterior margin of the peduncle on its outer half; it is oblong, more than three times as long as broad, extremity rounded, the end and the two margins being fringed with long setæ, which are thickest and longest at the extremity;

these setæ appear to be simple, but among them are two small groups, each containing two "auditory setæ." The expodite is articulated to the dorsal and outer surface of the peduncle near its anterior end: it is slender, and consists of a thin rod or narrow plate, a little deeper than broad, and shows no tendency to enclose the hinder end of the pleon as in *Anthura*, &c.; it reaches slightly beyond the extremity of the peduncle, and has its upper and lower margins and the extremity fringed with setæ, those at the end being the longest.

The *telson* (see fig. 20) is slightly longer than all the preceding part of the pleon; it is squamiform, rather more than half as broad as long, the distal portion ovate, the extremity tipped with five or six small setæ.

The telson is distinctly separated from the sixth segment of the pleon, a very unusual feature in the Isopoda, which generally have the sixth segment of the pleon and the telson confluent; this character is, in fact, so constant that it is given by Blanc [12] as one of the points of difference between the Isopoda and the Amphipoda. Most authors have drawn the telson of *Anthura* and other species as separate from the sixth segment of the pleon, but I am not aware that anyone has drawn special attention to this unusual character.

It will be seen that I have described the uropoda as consisting of a peduncle and two branches, each consisting of a single joint, whilst most authors have described the inner branch as *two*-jointed, considering the part I have taken as the flagellum to be the first joint of the endopodite. If the endopodite were really two-jointed it would be an exception from all other Isopods. It may consist of several joints in the Tanaidæ and the Apseudidæ, which differ in several well-marked features from the Isopods, but in all others, so far as my knowledge goes, the endopodite never consists of more than a single joint. The interpretation of the uropod that I have given is certainly correct for *Cruregens*, for in this genus the exopodite can be plainly seen to be articulated to the dorsal side of the peduncle, and the peduncle is quite continuous past the base of the exopodite to its junction with the sixth segment of the pleon; this can be seen both above and still more easily below. In most other species of the Anthuridæ the exopodite is broad and its articulation extends right across the peduncle, thus concealing its true nature. Gerstaecker [45, pl. xiv. fig. 26] certainly figures the uropod of *Paranthura costana*, Sp. Bate, with a short separate peduncle bearing two branches, one of which is *two*-jointed; but his figure is not very clear, and I think he has probably been misled in the way suggested above. Dohrn [36], dealing with the same species, interprets the uropod in the same way that I have done, and as I had formed my own conclusion before consulting Dohrn's paper, I was particularly pleased to find my opinion confirmed by him. This portion of his paper appears to have been overlooked by systematic writers on the Anthuridæ. The great enlargement and elongation of the peduncle in *Cruregens*, *Anthuria*, &c., are only exaggerations of what we find in most of the Oniscidæ, where the two rami are widely separated; and in *Hyssura*, Norman and Stebbing [106, pp. 128, 129, pl. xxv. fig. v.), we have evidently an intermediate form where the peduncle is quite short and the two rami therefore much more closely approximated at their bases. Even in this genus, however, Stebbing and Norman speak of the endopodite as *two*-

jointed, though according to their figure their "first joint" of the endopodite is quite continuous with the true peduncle and evidently a part of it.

Gerstaecker considers the branch I have described as the *exopodite* to be the *endopodite* or inner branch; and in this he may perhaps be right, though without an appeal to embryology there seems to me little to help us to decide which is the exopodite and which the endopodite, and I have therefore followed the majority of authors. In *Hyssura* as figured by Stebbing the shorter branch certainly appears to be the *endopodite*; but this may be apparent only, and due to the fact that in the figure the animal is "viewed dorso-laterally" [106, pl. xxv. fig. v. *Pl.*].

AMPHIPODA.

Genus Crangonyx, Spence Bate.

(British Sessile-eyed Crustacea, vol. i. p. 326.)

The following is the definition given by Spence Bate when establishing this genus:—"Superior antennæ having a secondary appendage. First pair of gnathopoda rather larger than the second. Posterior pair of pleopoda unibranched, not longer than the preceding pair. Telson single, entire."

In his subsequent explanation he gives the additional information that the eyes are imperfectly developed, that the superior antennæ are not much longer than the inferior, but rather more robust, and that the first two pairs of legs are small, rather unequal in size, and subchelate.

Numerous species belonging to this genus have been described by Packard, O. P. Hay, S. I. Smith, Grube, &c., but, so far as I am aware, no one has revised the characters of the genus, although it is evident that this must be done before it can be made to suit all the species that have been assigned to it. The genus *Stygobromus*, Cope [30], is considered by S. I. Smith [104] to be equivalent to *Crangonyx*; but Cope's description is very imperfect, and does not in any way add to our knowledge of the genus. Wrześniowski points out that no description of the mouth-parts of *Crangonyx* is known to him [124, p. 635]. I am able to give below some account of the mouth-parts of *Crangonyx compactus*; and from this it will be seen that in the mouth-parts the genus approaches very closely to *Niphargus*, which it resembles also in many other points, such as in the antennæ, the gnathopoda, and the uropoda. Although Spence Bate described the terminal pair of uropoda as *uni*branched, the inner ramus is really present in *C. gracilis* and *C. compactus*, and probably in others, though it is rudimentary as in *Niphargus*. It appears, however, that there is a great amount of variation in the development of the terminal uropoda in different species; this has been pointed out by O. P. Hay, who shows the transition in three species as follows:—

C. gracilis has the outer ramus of the third uropoda twice as long as the peduncle, the inner ramus present, but rudimentary.

C. bifurcus has the outer ramus of the third uropoda two-thirds the length of the peduncle, while it is doubtful whether there is anything to represent the inner ramus.

C. lucifugus has both rami absent and the peduncle itself reduced [56, pp. 143–146].

This variability of the third uropoda is only what we might have expected from the affinity of the genus to *Niphargus*, where the third uropoda are also very variable, differing in length in the two sexes, and often being greatly elongated. Although *Crangonyx* evidently comes very close to *Niphargus*, it appears to be a good genus, and to differ constantly from *Niphargus* in the more robust body and in the telson, which is always entire and never cleft as in *Niphargus*. This difference in the telson is very striking, and is somewhat remarkable, as it appears to give us some insight to the direction that the development of the telson has taken in this group; for if we are to look upon *Gammarus* as representing one of the older types among the Amphipoda, as suggested by Stebbing [108, p. xvi], from which *Niphargus* and *Crangonyx* have successively developed, then it is evident that the development must have been from the double telson of *Gammarus* to the deeply-cleft telson of *Niphargus*, and then to the single entire telson of *Crangonyx*. Considerations such as these naturally give rise to the questions:—What is the use of the telson? and why is it double in some species, deeply cleft in others, and entire in others again? But in propounding such questions we only draw attention to our ignorance, and a much more complete knowledge of the habits of these animals must be gained before we can hope to give any solution. In *Crangonyx mucronatus*, Forbes, which Packard leaves in the genus *Crangonyx*, though the species is, he says, perhaps entitled to rank as the type of a new genus, there appears to be a great difference between the male and the female in the development of the telson. Forbes thus describes the two:—

"The telson of the male is a smooth cylindrical appendage, usually about as long as the first three abdominal segments, and as large as the last joint of the pedicel of the lower antenna. It presents a very slight double curve, is obliquely rounded at the end, and tipped by a cluster of short hairs. In some cases this appendage is half as long as the body. . . . . . In the female this (the telson) is very similar to the telson of *C. gracilis*, Smith. It is flattened and slightly emarginate, a little longer than broad, extending to the tips of the second pair of anal legs, and bears two terminal clusters of spines of four or five each." Quoted from Packard [83, pp. 37, 38].

I am not aware of any other species of *Niphargus* or *Crangonyx* in which there is a difference between the sexes in the telson, and a cylindrical telson half as long as the animal is so remarkable that I was at first almost inclined to suspect some mistake; but specimens lately received from Mr. W. P. Hay, of Irvington, Indiana, agree in all respects with Mr. Forbes's description; but, as he points out, there can be little doubt that the species should form the type of a separate genus distinct from *Crangonyx*.

The species that I have to describe, *Crangonyx compactus*, is remarkable in that the three pairs of pleopoda have each only *one* branch instead of *two*, as in almost all Amphipoda, the inner branch being apparently the one that is absent. These examples are sufficient to show how imperfect our knowledge of the Amphipoda still is, and what startling variations may be found when least expected.

It would be interesting to know whether the other species of *Crangonyx* agree with

C. compactus in the possession of *single*-branched pleopoda, or whether they have normal pleopoda with two branches *. Unfortunately, the pleopoda are usually neglected in the brief descriptions given of new species, and are seldom referred to even in more elaborate descriptions; this is, of course, due to the fact that the pleopoda are less subject to variation than most organs of the Amphipoda. To such a degree is this the case that Fritz Müller speaks of them as being "reproduced in wearisome uniformity throughout the entire order" [79, p. 15, footnote]. Stebbing [108, p. 350] has, however, pointed out that this statement is somewhat overdrawn, and has perhaps had the disadvantageous tendency of discouraging the examination of these organs.

Wrześniowski [124, p. 634] remarks that there is much variation in the degree of development of the eyes in the different species of *Crangonyx*, some being described as without eyes, others having more or less perfectly developed eyes. I had originally stated that I could find no eyes in *Crangonyx compactus*; I find, however, that they are represented by two or three small lenses, which, however, do not appear to be furnished with any pigment, and are probably useless so far as sight is concerned.

As I have examined only the one species belonging to the genus, and as the descriptions of other species to which I have access do not give much information on the details of their structure, I have not attempted to revise the characters of the genus, but must leave that for some one with a wider knowledge of the subject. It will be sufficient for the present to repeat that the genus appears to differ from *Niphargus* in the more robust body, in the last pair of uropoda, and in the single uncleft telson.

CRANGONYX COMPACTUS, Chilton. (Pl. XX. figs. 1–30.)

Crangonyx compactus, Chilton, New Zealand Journal of Science, vol. i. (March 1882) p. 44; id. Transactions New Zealand Institute, vol. xiv. p. 177, plate x. figs. 13 to 19; Thomson & Chilton, Transactions New Zealand Institute, vol. xviii. p. 147; Moniez, "Faune des Eaux souterraines du Département du Nord &c.," extrait de la Revue Biologique du Nord de la France, tome i. (1888–1889) p. 50; Wrześniowski, 'O trzech kielzach podziemnych,' De tribus Crustaceis Amphipodis subterraneis, pp. 16, 41, 90; Wrześniowski, "Ueber drei unterirdische Gammariden," Zeitschrift für wissenschaftliche Zoologie, L. 4, pp. 611, 634, 698.

Specific diagnosis. Eyes small, without pigment, consisting of two or three imperfect lenses only. Upper antennæ about one-third the length of the body; first joint of peduncle much larger than the second; flagellum longer than the peduncle; secondary appendage small and slender, consisting of one long and one short joint. Peduncle of lower antennæ longer than peduncle of upper; flagellum shorter than the last joint of peduncle, consisting of four joints. Gnathopoda subequal, propodos of each only slightly broader than the carpus; palm about one-half the length of the inferior edge, defined by a stout spine on each side. Peræopoda subequal, the last three pairs having the basi narrow, not expanded as usual. Inferior edge of the three anterior segments of the pleon furnished with five or six small setæ. The three pairs of pleopoda *one*-branched. The uropoda short and broad, the third pair with the outer branch about

* In both *C. gracilis*, Smith, and *C. mucronatus*, Forbes, specimens of which have recently been sent to me by Mr. W. P. Hay, the pleopoda have the normal *two* branches.

three times as long as the peduncle, the inner branch rudimentary. Telson about half as long as the terminal uropoda, narrowing slightly towards the extremity, which bears two stout setæ.

Colour. White, semi-transparent.

Length. About 8 mm.

Habitat. Eyreton (*Chilton*) and Leeston (*R. M. Laing*); Canterbury (in wells).

Remarks. Moniez says [78, p. 50] that this species differs little from *Crangonyx subterraneus*, Spence Bate. Bate's description of that species is, however, not sufficiently detailed to allow of a comparison of any value between the two.

Detailed Description.

Body (Pl. XX. fig. 1.). The body is rather stout and deep, especially in the pleon. The side-plates (*coxæ*) are about half as deep as their respective segments, and are all nearly equal in size. The head is as long as the first segment of the peræon; segments of peræon subequal, the posterior ones a little longer than those preceding them. First three segments of the pleon subequal, a little longer than the last segment of the peræon, about twice as deep as long; inferior margin of each segment slightly convex and furnished with four or five setæ, arranged chiefly towards the anterior end; last three segments of the pleon very short.

Eyes rudimentary, represented by two or three imperfect lenses without pigment.

Upper antennæ (figs. 2 & 3) considerably longer than the lower, about one-third the length of the body; peduncle slightly shorter than the flagellum; first joint nearly as long as the second and third together, upper margin straight and furnished with a few minute spinules, lower surface grooved, bearing on the inner margin three stout setæ, the third being at the distal end, the outer margin without setæ, winged, produced downwards at the base, where it is slightly convex; the second joint half as long again as the third, a few fine setæ on both upper and lower margins, those at the extremity being longest and most numerous; third joint similar to the second except in size. Secondary appendage small, reaching to about the end of the second joint of the main flagellum, consisting of two joints, the first as long as the first joint of the flagellum but very slender, bearing ordinary setæ; the second small, bearing ordinary setæ and a minute olfactory cylinder at the extremity. Flagellum consisting of about thirteen joints, those at the base nearly as broad as long, the others becoming more and more slender, each joint from the second onwards bearing on the lower side of the distal extremity two olfactory cylinders nearly as long as the succeeding joint, and two small tufts of ordinary setæ, one above, the other below.

Lower antennæ (fig. 4) having the first two joints very short, the gland-cone arising from the second joint being very long and reaching nearly to the end of the lower margin of the third joint; third joint subquadrangular, with two stout setæ in the middle of the upper margin and one long simple seta at the extremity of the lower margin; fourth joint only half as broad as the third, upper margin bearing a stout seta near the base, followed by two or three slender setæ, lower margin with three oblique rows of setæ, each containing four or five, the lateral surface of the joint also bearing two or three small tufts of setæ; the fifth joint is as long as the fourth, but rather more slender, armed with setæ in a similar way to the fourth, but with more numerous tufts; the flagellum shorter than the fifth joint, consisting of five joints, of which the first is the longest; the articulations between the joints are oblique, and each bears at the extremity a row of four or five small setæ, and there is another row of four or five rather longer setæ on the lower margin towards the extremity.

The *upper lip* (fig. 5) is rather delicate, broader than long, the extremity very slightly emarginate and somewhat sparingly supplied with the usual incurving setæ.

The *mandibles* (figs. 6, 7, 8, 9) closely resemble in general shape those of *Niphargus*, as described by Humbert and other authors. The palp is rather large in proportion to the mandible itself; it has the first joint small, the margins without setæ; the second joint rather broad, especially in the middle, where it is strongly curved, the convex margin bearing about six or seven long setæ, which project almost at right angles to the joint; the third joint about as long as the second, outer margin nearly straight and without setæ, inner margin bearing on the distal half a double row of long setæ, which increase in length towards the distal end. The palp is the same in both mandibles.

The outer cutting-edge is practically the same in both mandibles, and consists of five teeth, the two largest of which are somewhat widely separated, the other three teeth are smaller and subequal. In the right mandible (fig. 6) the secondary cutting-edge is very similar to that of *Niphargus puteanus*, figured by Humbert, and resembles in shape an open hand with the fingers close together; the part corresponding to the thumb is denticulated throughout, while that corresponding to the fingers has the distal extremity oblique and finely serrate. At the base of this secondary cutting-edge are two stout spiniform setæ denticulated similarly to the thumb, and following these is a stout plumose seta (see fig. 7).

The secondary cutting-edge of the right mandible usually has the form just described, but it is evidently subject to some variation, for in one specimen, which otherwise appeared quite normal, it had the form represented in fig. 8, which, it will be seen, is very different from the usual form. Whether this was the result of accident or not I cannot say, but it shows how careful one ought to be before laying much stress on the form of these minute mouth-parts unless they are found to be constant by the examination of a large number of specimens.

In the left mandible (fig. 9) the secondary cutting-edge resembles the outer cutting-edge, and consists like it of five separate teeth; at its base are stout denticulated setæ similar to those in the left mandible. It will be seen that this figure is inverted.

The molar tubercle, which appears to be the same in both mandibles, is small and presents no remarkable feature.

The lower lip (fig. 10) is very delicate, broad; extremity of each outer lobe very broadly rounded and covered with fine setæ; inner lobes small and very delicate; the lateral backward processes are short and rather obtuse.

The *first maxilla* (figs. 11, 12, 13) is very similar to that of *Niphargus puteanus.* The palp has the first joint short, its extremity oblique; the second joint slightly narrowing towards the extremity, which bears three stout setæ at the end and one more slender placed a slight distance from the end; the three stout setæ are finely serrate at the ends (fig. 13). The middle lobe of the maxilla is broad, nearly as broad as long, the extremity slightly oblique, bearing seven stout spiniform setæ, of which the innermost one is the largest and is a little separated from the others; it is serrate on the inner margin towards the extremity, on the surface of the lobe at its base are several fine hairs; the seta next to it is only about half as long and bears one strong tooth on the inner margin, the remaining setæ bear one or more denticulations or serrations, as shown in fig. 12. The inner lobe is small and delicate; its extremity is rounded and bears one or two finely plumose setæ.

A few very fine hairs are scattered over the surface of the whole maxilla. The extremity of the palp appears to be the same both in the right and left mandibles, and does not take different forms as in some species of *Gammarus*.

The *second maxilla* (figs. 14 & 15) is very similar to that of *Niphargus*. Its outer lobe is slightly longer and broader than the inner, and bears at the extremity a great number of slightly curved setæ; the inner lobe bears about six large setæ, the innermost one of which is much the largest, and is situated a little distance from the extremity on the inner margin, the basal portion of it is sparingly plumose, and its extremity is plumose or almost dentate on one side. Some of the remaining setæ are similar to this one, but others appear to want the plumes at the end (fig. 15).

A few fine hairs are sparingly scattered over the whole surface of the maxilla.

The *maxillipedes* (figs. 16, 17, 18) do not present any remarkable feature. The lobe attached to the basos ("inner lobe") is rectangular, the extremity truncate and bearing about four stout setæ much curved inwards; there are two fine setæ on the inner margin and a few fine hairs on the surface towards the outer margin (fig. 17); the lobe attached to the ischium reaches nearly as far as the extremity of the outer margin of the next joint, the meros, its inner margin is nearly straight and bears about ten to twelve setæ, of which two near the extremity are pretty stout, the others being rather slender; besides these spiniform setæ there are a few finer setæ or hairs along the inner margin (fig. 18).

When seen from below, the basos bears no setæ on its outer margin, but there are three at the extremity near the inner angle; there are three or four setæ on the inner margin of the ischium and one at the extremity of the inner margin of the meros; the last-mentioned two joints have no setæ on their outer margins. The carpus has the outer margin much curved, with a single seta at the extremity, its inner margin is curved and thickly fringed with long setæ; on the upper surface of this joint there is a distinct row of six setæ running parallel to the inner margin near the extremity. The propodos has the outer margin very convex, and produced on the upper surface into a small lobe at the base of the dactylos; on the upper surface (fig. 17) towards the end of the joint is a dense mass of long setæ, arranged chiefly in three longitudinal rows; the inner margin has the basal portion free from setæ, but the distal half thickly fringed with long setæ; on the under surface of the propodos there are two or three long setæ at the base of the dactylos. The dactylos is as long as the propodos, and is very acutely pointed; on the outer margin near the base it bears a single seta; its extremity is marked off into a distinct unguis, at the base of which is a small seta on the inner margin.

First gnathopod (fig. 20). The coxa (side-plate) is almost rectangular, sloping a little forward, its anterior edge bearing five or six short setæ. The basos is narrow at the base, but rapidly widens until it is quite half as broad as long; its anterior edge is nearly straight and bears a tuft of five long setæ near the base and a single seta at the extremity; the posterior margin is very convex and bears four or five setæ, the longest being at the extremity. The ischium is short, broader than long, and bears five or six setæ at the extremity of the posterior margin. The meros is rounded distally, and has the whole extremity thickly fringed with long, rather stout setæ. The carpus is triangular, extremity nearly straight, with a row of long setæ running parallel to it along the posterior half of the inner surface; the short posterior margin densely covered with setæ, apparently arranged in three or four transverse rows. The propodos is ovate, about as long as the three preceding joints together, scarcely wider than the carpus; anterior margin convex, with four or five setæ separately situated along the inner surface near it and a small tuft at the base of the dactylos; posterior margin with numerous setæ partially arranged in five or six tufts; palm oblique, occupying rather more than half the posterior margin, defined by two stout spines and fringed with numerous short setæ, a few longer setæ being situated on the surface of the propodos near the palm. The dactylos is slightly curved, fitting closely on to the palm; the terminal unguis distinct and marked off by a small tooth on the inner margin at its base; on the outer margin the dactylos bears a plumose seta at a little distance from the base.

The *second gnathopod* (fig. 21) is about as large as the first and closely resembles it in form. The coxa is similar but somewhat larger, the basos slightly longer in proportion to its breadth. The carpus much longer than in the first gnathopod, with more numerous tufts of setæ on its posterior margin and a shorter row along the extremity. The propodos is like that of the first gnathopod, but the palm does not occupy so much of the posterior margin, and there is a larger number of tufts of setæ between the end of the palm and the base of the posterior margin.

In both gnathopoda the outer surface bears fewer setæ than the inner.

The *first peræopod* (fig. 22) has the coxa like that of the second gnathopod. The basos is longer, and widens considerably about the middle, where the breadth is rather more than one-third the length; it is much constricted on both sides near the base, and after widening narrows again slightly at the extremity; the anterior margin bears a few small setæ, and the posterior margin bears six stout setæ, each situated in a slight serration. The ischium is similar to that of the second gnathopod. The meros is slightly longer than the carpus, and is a little produced at the antero-distal angle; the anterior margin slightly convex, and bearing one spiniform seta at the centre and another at the extremity; posterior margin straight, with a few long setæ, the longest two being at the extremity. The carpus is oblong, narrowed at the base; anterior margin with one or two minute spinules; posterior margin straight, with five stout setæ. The propodos is shorter and narrower than the carpus but of similar shape; posterior margin with a row of six or seven short setæ, the last being the longest;

anterior margin with a small tuft at the base of the dactylos and a single seta situated more proximally. The dactylos is short.

The *second peræopod* is exactly similar to the first in size and form.

The *third*, *fourth*, and *fifth peræopoda* are all similar to each other, but each is slightly larger than the preceding; they are all somewhat remarkable in having the basos rather narrow and not expanded posteriorly into a semicircular plate as in most Amphipoda. Fig. 23 represents the fourth peræopod, and it will be convenient to take this one for description, as it represents a mean between the fifth and seventh. The coxa is almost semicircular, upper margin straight, the lower convex margin thickly fringed with short spines, which are most numerous posteriorly. The basos is narrowed a little at the base; it is oblong, the breadth being slightly more than one-third the length; anterior margin with two setæ, one at the extremity and one above it; posterior margin straight, with two or three stout setæ about the middle and one or two longer ones at the extremity. The ischium is very similar to that of the preceding peræopoda; the meros oblong, about three times as long as broad, both margins bearing stout setæ, especially at the extremity; the carpus slightly longer than the meros, but a little narrower, the setæ on it more numerous and larger than in the meros; the propodos as long as the carpus, but narrower, apparently twisted so that the dactylos projects backwards, both margins having stout setæ or spines, those on the posterior margin being most numerous; the dactylos is short, not much longer than the setæ at the end of the propodos.

The *pleopoda* (figs. 24, 25, 26) are small and are very remarkable, in that each bears only one branch, which appears to be the outer one, there being no trace whatever of the second branch. I do not know of any other species of the Amphipoda where this is the case: in the *Cerapinæ* the inner branches may be rudimentary and even entirely absent in the case of the third pleopod; but it is easy to see that this is due to the habit of the animal living in a tube, which has to some extent modified all its pleopoda and the tail-part. In the present species the portions of the pleopoda that are present appear quite perfect, and I know of nothing in the habits of the animal to explain why these pleopoda should have only one branch while those of *Gammarus fragilis* and *Calliopius subterraneus* have the normal two branches.

The *first pleopod* (fig. 24) is the longest; the basal portion is oblong, slender, without setæ, except the two "coupling spines" at the extremity of the inner margin; these seem not unlike those of *Niphargus*, each bearing two or three tubercles on the one side and being slightly hooked at the end. The single branch is nearly twice as long as the peduncle and consists of eleven joints, each bearing the two long plumose setæ in the usual way. I cannot find any trace of the "cleft spines" mentioned by Stebbing [108, p. xiv &c.], Sars [91, p. 53], Humbert [62, p. 351], &c., on the inner margin of the first joint of this branch, and it is therefore probable that it represents the outer branch, the inner one being absent.

Stebbing [108, p. xiv] has drawn special attention to these "cleft-spines" and also to the "coupling-spines," and, with regard to the latter, points out that they have been described and figured by Sars in his account of *Gammarus neglectus* [91, p. 53], and indicated by S. I. Smith in his figure of *Cerapus tubularis*, but not, he thinks, alluded to by any other writers. It is but just to Humbert to mention that he had drawn and described the "coupling-spines" ("deux petits crochets") of *Niphargus puteanus*, var. *Forelii*, in 1876 [62, p. 350].

The *second pleopod* (fig. 25) has the peduncle considerably longer and broader than in the first, the basal part of it being pretty distinctly marked off as a separate joint, probably representing the coxa. The outer margin bears four small spines on the distal half, the inner margin having only the coupling-spines at the extremity. The branch is only as long as the peduncle and contains only six joints, of which the first is much the largest.

The *third pleopod* (fig. 26) is similar to the second, but smaller and more reduced; the peduncle is similar, but narrowed at the base; the branch is not so long as the peduncle, and consists of three joints only, the first being much larger than the other two together.

The *uropoda* are all short and rather stout. The *first uropod* (fig. 27) has the peduncle much longer than the rami, stout, broad above, the upper surface being somewhat concave, its outer margin bearing seven small spines; the outer ramus is slightly smaller than the inner, both falciform, curving upwards, the lower surface of each regularly curved and with setæ, the upper surface with three or four small spines near the base and one near the apex.

The *second uropod* (fig. 28) is similar to the first, but shorter and bearing fewer setæ.

The *third uropod* (fig. 29) has the peduncle short, with two spines on the lower margin at the extremity; the inner ramus very small, rudimentary, with a small spine at the end; outer ramus about three times as long as the peduncle, gradually tapering, the upper margin with eight setæ arranged in four pairs in a longitudinal row, the extremity separated from the other portion and forming a small second joint.

The *telson* (fig. 30) reaches about halfway to the end of the last uropod. It is more or less oblong, narrowing slightly towards the end, which bears a stout spine in a slight emargination at each corner; the sides are slightly convex and the extremity between the two spines is either straight or slightly concave. There is no sign whatever of any cleft or division.

Genus GAMMARUS, Fabricius, 1775.

(See Stebbing's Report on the 'Challenger' Amphipoda, p. 1005.)

Full information on this very old genus will be found in Stebbing's Report as quoted above. In it he quotes the following generic diagnosis as having been given by Boeck in 1876:—

"*Mandibles* with the third joint of the palpi elongate, narrow.

"*First maxillæ* with the inner plate broad, long, furnished on the inner margin with very many plumose setæ.

"The body not carinate. The three hinder segments of the pleon furnished in the middle with fascicles of spines. The anterior side-plates of moderate size.

"*Upper antennæ* longer than the *lower*; the peduncle moderately elongate.

"*Lower antennæ* with a short flagellum.

"*First* and *second gnathopods* with the hand small; the *second* larger than the *first*.

"The *third uropods* with long rami, furnished on the margin with spines and plumose setæ, extending beyond the rami of the two preceding pairs; the inner ramus more or less shorter than the outer.

"*Telson* long, cleft to the base."

This definition answers very well to include *Gammarus fragilis*, which is the only species of the genus that I have had an opportunity of closely examining.

GAMMARUS FRAGILIS, Chilton. (Pl. XXI. figs. 1–25.)

Gammarus fragilis, Chilton, New Zealand Journal of Science, vol. i. (January 1882) p. 14; id. Transactions New Zealand Institute, vol. xiv. p. 179, plate ix. figs. 11 to 18; id. New Zealand Journal of Science, vol. ii. (March 1884) p. 89; Thomson & Chilton, Transactions New Zealand Institute, vol. xviii. p. 146; Moniez, "Faune des Eaux souterraines du Département du Nord &c.," extrait de la Revue Biologique du Nord de la France, tome i. (1888–89) p. 50; Wrześniowski, "O trzech kiełzach podziemnych," De tribus Crustaceis Amphipodis subterraneis, pp. 16, 90; id. "Ueber drei unterirdische Gammariden," Zeitschrift für wissenschaftliche Zoologie, L. 4, pp. 611, 698.

Specific diagnosis. Eyes wanting. Body rather slender. Superior antennæ somewhat longer than the body; flagellum much longer than peduncle, secondary containing from five to nine joints. Peduncle of lower antennæ longer than peduncle of upper; flagellum longer than peduncle. Gnathopoda subequal, moderately large, each with the propodos ovate; palm very oblique. First and second peræopoda rather short, slender; last three pairs of peræopoda very long, the last (fifth) about as long as the body. Terminal uropoda with the rami subequal, about twice as long as the peduncle, cylindrical, not flattened or expanded.

Colour. White, semi-transparent.

Length of largest specimen 15 mm.

Habitat. Eyreton, North Canterbury (*Chilton*), Leeston (*R. M. Laing*), Winchester, South Canterbury (*D. L. Inwood*): in wells.

Remarks. It will be seen from the following detailed description that this species is a true *Gammarus*, and that in all generic characters it agrees very closely with *Gammarus neglectus* as described by Sars. I have not attempted to compare *G. fragilis* with the numerous other species of the genus already described. It appears to be well characterized by the very long peræopoda, the want of eyes, and the long cylindrical rami of the terminal uropoda.

Detailed Description.

The *body* (Pl. XXI. fig. 1) is smooth, rather slender; the appendages are also very long and somewhat slender. The coxæ (side-plates) of the first four segments of the peræon are rather deep, though not so deep as their respective segments. The segments of the peræon are all of about the same length and as long as the head; the first three segments of the pleon are rather longer, their inferior margins bear two or three stout setæ towards the anterior end; the fourth segment of the pleon has a strong spine on the inferior margin at the base of the uropod, and each of the last three segments bears four or five long spine-like setæ on the dorsal surface.

The *upper antennæ* (fig. 2) appear to vary somewhat in length as compared with the body, but they are always very long, usually about as long as the body. The first joint of the peduncle is stout, rather more than twice as long as broad; the upper margin is straight, with a tuft of fine setæ at the extremity; lower margin slightly curved and bearing two short transverse rows of spiniform setæ, the second row being situated at the extremity. Second joint about as long as the first, but only about half the width; upper margin with three or four fine setæ; lower margin with three or four tufts each containing a spiniform seta and one or more fine hairs, at the extremity there are tufts above and below and in the centre. Third joint about one-third as long as the second, a few setæ above and below at the extremity. Secondary appendage slender, usually containing six or seven joints, though there may be as many as nine, each joint with minute setæ at the extremity; flagellum more than twice as long as the peduncle, consisting of a great number of joints, the setæ on which are very short and fine, each joint bears a single small olfactory cylinder.

The *lower antennæ* (fig. 3) are more than half as long as the upper. The first joint of the peduncle is very short and bears a single seta at the extremity of the lower margin; second joint very short, the gland-cone (the so-called "olfactory denticle") not reaching quite to the end of the succeeding joint; the third joint more than twice as long as the second, upper margin curved, lower margin with a tuft of strong spiniform setæ at the extremity; fourth joint very long, upper surface bearing five tufts of two stout setæ each, the lower surface with numerous small tufts of stout setæ and fine hairs irregularly arranged; the fifth joint slightly longer than the fourth and narrower, upper surface with about five small tufts, lower surface with five larger tufts of longer setæ; flagellum usually about as long as the peduncle, though the relative lengths vary somewhat; it usually contains about twenty joints, each bearing a few fine setæ at the extremity.

The *upper lip* (fig. 4) is strongly chitinous and of the usual shape, being more or less semicircular, very broad; the apex bears a thick fur of minute setæ, mostly converging inwards.

The *mandibles* (figs. 5, 6, 7, 8) appear to present a pretty close resemblance to those of *Gammarus neglectus* as described and figured by Sars. The palp, which is the same in both mandibles, is large and strong. The first joint is the shortest; it widens slightly distally and bears four or five setæ at the extremity. The second joint is about twice as long as the first; it is rather broad, and bears on the inner margin about a dozen long setæ, those towards the end being the longest. The third joint is somewhat shorter than the second, and bears on the surface of the side four small tufts each containing two setæ; the outer margin is slightly curved and is free from setæ; the inner margin has along its whole length, except a little at the base, a thick fringe of stiff setæ about half as long as the joint is wide; at the extremity are three long setæ nearly as long as the joint itself.

The armature of the right mandible differs from that of the left, as is the case in this and many other genera of the Amphipoda. In the left mandible (fig. 6) the outer cutting-edge consists of five strong teeth and the inner or secondary cutting-edge is similar in general form but contains only four teeth, one of which is considerably longer than the other three; both outer and inner cutting-edges are curved so as to be concave on the inner side. In the right mandible (figs. 7, 8) the outer edge is not unlike that of the left, but contains only four teeth, and the inner cutting-edge is very different. When seen in profile, as in figure 8, it appears slender, dividing into two branches or forks, the upper one apparently tubercled, and the lower one bearing two or three denticulations at its base; in this view it seems not very unlike that of *Gammarus neglectus* as figured by Sars [91, pl. iv. fig. 4]. When this inner cutting-edge is seen *en face* (fig. 7), however, it is found to be much more like that of *Crangonyx compactus* than would at first have been suspected; the upper portion proves to be broad and triangular in shape, with the edge dentate, and it is these denticulations which make the piece appear tubercled when seen in profile; the lower piece is narrow and bears one or two teeth on the surface at its base as already described.

Next to the secondary cutting-edge in each mandible follow four or five strong denticulate or stiffly plumose setæ. The molar tubercle does not appear to present any remarkable feature.

The *lower lip* (fig. 9) is of the usual form, deeply cleft, each lobe bearing on its rounded extremity a number of very fine irregular setæ, and on its inner margin a thick fringe of rather stouter setæ.

The *first maxilla* (figs. 10, 11, 12) has the inner lobe very delicate and fringed with nine or ten * delicate plumose setæ, each of which shows a transverse division at some distance from the base; the surface of this plate is also covered with fine delicate scattered setæ. The middle lobe ends in about ten strong setæ, curving inwards; most of them have two sharp teeth on the inner edge, but the two innermost bear more numerous teeth. The palp has the first joint short, rectangular, and the second large, flat, and curved inwards. On the left side (fig. 11) the palp ends in about seven stout setæ or spines, closely approximated together; a single small simple seta is situated on the surface at a slight distance from the extremity. In the maxilla on the left side (fig. 12) the palp has the same general shape, but the setæ at the end are much more slender and not so crowded, and there appear to be only six of them. The difference between the extremities of the two palps is really rather greater than would appear to be the case from figs. 11, 12, for the right maxilla is here considerably compressed in order to show the spines more distinctly.

The *second maxilla* (fig. 13) has the form usual in *Gammarus*. The inner lobe

* The number of setæ on the inner lobes of the first and second maxilla varies very greatly in different specimens. The numbers given in the text probably represent the average. I have another drawing showing 13 on the inner lobe of the first maxilla and 21 on that of the second maxilla.

bears a very oblique row of about twelve * finely plumose setæ similar to those on the inner lobe of the first maxilla; the inner margin of this lobe is fringed with many simple setæ and the surface of the lobe bears a few very fine simple setæ scattered over it. The outer lobe bears many long curved setæ at the extremity as usual; many, if not all, of these are finely serrate on the inner side.

The *maxillipedes* (figs. 14, 15) are somewhat slender. When viewed from below (fig. 14) the first joint (*coxa*) is seen to bear three setæ on the outer margin. The next joint, the basos, is obliquely articulated with the coxa and bears near its base a short transverse row of short setæ, and at its extremity towards the inner margin a dense row of stout setæ. The meros is rather longer than broad and bears a single seta on its inner margin at the extremity. The carpus is about as long as the three preceding joints together, and more than twice as long as broad; its outer margin is regularly curved and bears no setæ; the inner margin is nearly straight and is thickly fringed with setæ, which are chiefly arranged in irregular, short, transverse rows containing about two or three setæ each. The propodos is rather more than half as long as the carpus; on its outer margin at the extremity it bears two or three very long setæ and its inner margin is thickly fringed with long setæ irregularly arranged in tufts. The dactylos is very nearly as long as the propodos; it is strongly curved and very acute; the outer margin bears a fairly long seta near the base, and the inner margin bears three small setæ, the third situated at the base of the terminal unguis, which is distinctly marked off from the rest of the dactylos.

When seen from above (fig. 15) the carpus bears at the extremity an oblique row of four or five long setæ and another similar row on the surface at some distance from the extremity; the propodos has a longitudinal row of about twelve long setæ along the centre of the upper surface (just like that which Humbert draws in *Niphargus puteanus*, var. *Forelii* [62, pl. vi. fig. 9]), and a small tuft of two setæ near the outer margin. The inner lobe of the maxillipede—that is, the one attached to the basos—is rectangular, and bears at the end three stout spines and five or six longer stiffly-plumose setæ; the inner margin also bears three or four similar plumose setæ. The outer lobe attached to the ischium bears on the inner margin about twelve stout spines, which, at the extremity, gradually merge into long denticulate setæ; a few simple setæ are found along the inner margin, more particularly on the basal portion.

The *gnathopoda* are about equal in size and almost identical in structure and in the arrangement of the setæ on them, but the setæ on the inner surface of each are more numerous than, and very different from, those on the outer surface and require separate description.

The *first gnathopod* (fig. 16) has the coxa (side-plate) nearly square, the lower surface bearing a few fine setæ. The basos is long, the front margin with a few irregular setæ, the posterior margin with a tuft at the extremity. Ischium very short, with a tuft of setæ on the posterior margin at the extremity, and this is extended into a short row along the inner surface of the joint. Meros narrow when seen from the outside, being partially overlapped by the carpus; on the inner side it appears nearly rectangular, the

* See note on previous page.

end truncate and fringed with a dense double row of long setæ, which also form a dense tuft on the posterior side. The carpus is triangular, widening distally, the short posterior margin being densely covered with long setæ arranged in five or six transverse rows; there are no setæ on the outer surface, but on the inner surface there is a transverse row of long setæ along the end and another shorter row at a slight distance from the end; there are also two small tufts at the antero-distal angle and another situated more proximally. The propodos is large, fully as long as the basos, ovate, about twice as long as broad, and not much broader than the carpus; the outer surface bears few setæ, then a few very small ones along the anterior margin, a small tuft at the base of the dactylos, and a few along the palm; on the inner surface near the anterior margin are five transverse rows each containing from five to seven long setæ: the palm is slightly convex and occupies almost all the lower margin, it is defined by two large spines, a third large spine is situated on the inner surface a little nearer the base of the propodos, and near it are two or three small transverse rows of setæ; between the end of the palm and the base of the propodos are two other transverse rows on the posterior margin; the palm is armed with a double row of short stout spines, and near the edge of the palm on the inner surface are about six small tufts of setæ. The dactylos is long and curved, fitting closely on to the palm; the inner surface bears about six small tufts of setæ; the inner margin is minutely serrate, the serrations lying close to one another, and it bears about fifteen minute spinules placed at regular distances from one another along the inner edge; the extremity is acute.

The *second gnathopod* (fig. 17) differs from the first in having the extremities of the ischium and meros less densely fringed with setæ; on the inner surface of the carpus the transverse row situated a little from the end is very short, containing only about six setæ, and there is another small tuft near it; in the propodos on the posterior margin are six transverse rows, instead of two, between the base and the end of the palm, and the tufts of setæ near the palm are much smaller, containing only two or three setæ each.

The description of the gnathopoda, as given above, applies to the adult female. I am unable at present to say whether the male differs in any particulars or not.

The *first peræopod* (fig. 18) is slender, of the same length as the second, and very much shorter than the third. The coxa (side-plate) is rounded below and bears a few small setæ irregularly placed along the margin. The basos is long, oblong in shape; the anterior margin with three or four rather long setæ near the base, and three short spines towards the extremity; the posterior margin is similarly supplied with setæ, but the long setæ are further from the base. The ischium is short, rectangular, with a single seta on the posterior margin at the extremity. The meros is slightly more than half as long as the basos, and is somewhat produced at the antero-distal angle; the anterior margin is slightly convex, and bears three short spines, the last being at the extremity; the posterior margin is straight, and bears three tufts, each containing two slender setæ. The carpus is shorter than the meros, and bears on the posterior margin two spines and a few slender setæ. The propodos is a little longer than the carpus, and bears on the posterior margin short spines arranged in four groups; the anterior margin bears a few fine hairs and a small tuft of setæ at the base of the dactylos. The dactylos is rather short, and bears a single seta on the inner margin, imperfectly marking off the terminal unguis.

The *second peræopod* is similar in all respects to the first.

The *third*, *fourth*, and *fifth peræopoda* (see fig. 19) are all very long, and each is longer than the preceding; the fifth is about as long as the whole body. The lengths of the peræopoda, as compared with the body, appear to vary, as is the case also with the antennæ, and to increase with the age and size of the animal. The coxæ of these peræopoda are not easy to make out very distinctly; that of the fifth is small, almost semicircular, regularly curved below, and bearing four setæ on the posterior portion; those of the third and fourth peræopoda appear similar, but flatter inferiorly, and with fewer setæ; that of the third fits in front into an emargination on the posterior side of the coxa of the second peræopod.

It will be sufficient to describe the *fourth peræopod* (figs. 19, 20) as a mean between the third and fifth. The basos is not much expanded, and narrows distally; both margins bear small spines arranged in slight serrations; the ischium bears one or two spines at the extremity of the anterior margin; the meros, carpus, and propodos are all similar, but each is longer and narrower, and bears more numerous setæ than the preceding. In all both margins bear numerous tufts of long spines arranged in slight serrations; the dactylos is fairly long, of the same width throughout until near the end, where it narrows suddenly; at this point on the inner margin are usually three setæ, though in large specimens there may be as many as six. In the tuft of setæ at the base of the dactylos are stout spines, fine setæ, and one or two plumose setæ similar to the "auditory setæ" found on the antennæ and elsewhere, but much curved or bent at the middle. Similar setæ are found in most of the tufts on the posterior margin of the propodos.

The *pleopoda* are of the usual shape, and the three pairs are almost identical. Fig. 21 represents the *third* pair; in it the peduncle appears to consist of a short coxa and a long basos about three times as long as broad. The outer margin is somewhat convex, inner margin straight and bearing four fairly long setæ, the longest being at the extremity near the two "coupling-spines." The latter seem to closely resemble those of *Gammarus neglectus*, as described and figured by Sars [91, p. 53], except that there are two only instead of three, as in that species; each bears three or four teeth on each side.

The outer ramus, which is somewhat shorter than the inner, is hollowed out on its inner side for the reception of the base of the inner ramus, and its margin, which is thinned out, bears four or five of the ordinary plumose hairs. The first joint of the inner ramus bears on its inner margin three "cleft-spines," like those described by Stebbing.

The *first* and *second pleopoda* appear slightly larger than the third, and have the spines on the inner margin of the peduncle smaller and fewer, otherwise they precisely resemble the third pleopoda.

The *first uropoda* (fig. 22) extend as far backwards as the extremity of the second uropoda; there is a strong spine on the body-segment just at their base. The peduncle is considerably longer than the rami; its lower margin straight or slightly curved, upper surface broad, concave; both inner and outer margins supplied with about six small spines, a large spine nearly half as long as the inner ramus being situated at the extremity of the inner margin. The outer ramus is slightly longer than the inner; upper margin with three small spines, a large one and two small ones at the extremity; inner ramus similar, but with two large spines at the extremity.

The *second uropoda* (fig. 23) are small, not reaching to the end of the peduncle of the third uropoda. Peduncle stout, about as long as the rami, concave above, both inner and outer upper margins with two or three spines; outer ramus slightly shorter than the inner, upper margin with three small spines, a large one and two small ones at the extremity; inner ramus with its upper margin supplied with about twelve small spines arranged closely in a row, two large ones and two or three short ones at the extremity.

The *third uropoda* (fig. 24) are very long, nearly as long as the whole pleon. The peduncle is rectangular, about three times as long as broad, two setæ on the side near the lower margin; upper surface slightly concave; both inner and outer margins with spines, two or three at the extremity of the outer margin and one large one at the extremity of the inner margin. The two rami of equal length, nearly twice as long as the peduncle, each cylindrical, scarcely tapering towards the end; outer surface of each with five groups, each containing three spines; inner surface with five similar groups of stout spines, and in addition a number of long plumose hairs; extremity of each with about six or seven spines of various lengths.

In fig. 24 the last uropoda are represented as usually seen, the outer row of setæ being shown on the outer ramus and the inner row with the plumose hairs being seen on the inner ramus, which is somewhat twisted round. The spines or setæ on these uropoda are shorter in proportion to the appendage in large specimens, and this is the case also with the spines on the legs and in other parts of the body.

The telson (fig. 25) is short, reaching only slightly beyond the base of the peduncle of the last uropod. It is cleft right to the base, each half being more or less rectangular; the outer margin curved, extremity straight or slightly rounded, bearing on the inner half four long spines about half as long as the telson, and towards the outer side two or three similar spines situated a slight distance from the extremity.

The above description applies to fully developed females. I am not able to say whether the males differ from the females in the last pair of uropoda, as in *Niphargus*, but the numerous specimens that I have seen and closely examined all agree with the description given above.

Genus Calliopius, Leach.

(Bate & Westwood, Brit. Sessile-eyed Crust. i. p. 259.)

Of this genus Bate and Westwood give only the following as the generic character:—
"Like *Pherusa*, except that at least the second pair of gnathopoda have the propodos

largely developed" [4, p. 259]; and of *Pherusa* they merely say, "Like *Atylus*, but telson not divided. Gnathopoda small" [4, p. 252].

According to Stebbing the genus *Amphithopsis*, Boeck, is most probably a synonym of *Pherusa*, and of this genus he gives the following account in his notice of Boeck's work. The genus is, he states, instituted for those species which have "an elongate, compressed body with moderate epimera and long antennæ; the inner plate of the first maxillæ furnished with four or five long, thick, plumose setæ; the inner plate of the second maxillæ with many simple setæ at the extremity, but several on the inner side very strong and plumose; the maxillipeds large, with palps of moderate length; the two first pairs of feet with hands of nearly the same size, small; the third and fourth pairs of legs with the fifth joint very long, longer than the third joint; the telson simple; the last uropods with the branches long, often unequal; the marsupial plates much larger than the branchiæ, closely margined with hairs" [108, p. 324].

It appears to me that all the genera mentioned, together with several other allied genera, require careful revision and systematic redescription; and in the meantime I prefer to leave my species *Calliopius subterraneus* under *Calliopius*, where I first placed it, although, if we consider only the female, it should no doubt be put in the same genus as *Pherusa cærulea*, G. M. Thomson. It is evident, too, that due attention must be paid to the sexual differences, for in *Calliopius subterraneus* the female is a *Pherusa*, while the male, which differs chiefly in the possession of larger gnathopoda, would be better placed under *Calliopius*.

CALLIOPIUS SUBTERRANEUS, Chilton. (♂, Pl. XXII. figs. 1–15, Pl. XXIII. figs. 1–9; ♀, Pl. XXIII. figs. 10–18.)

Calliope subterranea, Chilton, New Zealand Journal of Science, vol. i. (January 1882) p. 14; id. Transactions New Zealand Institute, vol. xiv. p. 177, plate ix. figs. 1–10; id. New Zealand Journal of Science, vol. ii. (March 1884) p. 89.

Calliopius subterraneus, Thomson & Chilton, Transactions New Zealand Institute, vol. xviii. p. 148; Thomson, Transactions New Zealand Institute, vol. xxi. p. 262.

Calliope subterranea, Moniez, "Faune des Eaux souterraines du Département du Nord &c.," extrait de la Revue Biologique du Nord de la France, tome i. (1888–89) p. 50; Wrześniowski, "O trzech kielzach podziemnych," De tribus Crustaceis Amphipodis subterraneis, pp. 16, 90; id. "Ueber drei unterirdische Gammariden," Zeitschrift für wissenschaftliche Zoologie, L. 4, pp. 611, 698.

Specific description.—Male. Cephalon not produced into an appreciable rostrum. Eyes wanting. Upper antennæ about two-thirds the length of the body; first joint of peduncle stout, second and third each much shorter than the preceding; secondary flagellum represented by a minute joint shorter than first joint of main flagellum. Lower antennæ stout, much shorter than the upper; flagellum about as long as the peduncle. Calceoli are present on the second and third joints of the peduncle, and on the flagellum of the upper antenna, and on the flagellum of the lower antenna. First gnathopod very large and strong; carpus very short; propodos much longer than basos; palm occupying nearly the whole of the posterior margin. Second gnathopod also large, but more slender than the first; carpus triangular, more than half as long as propodos; palm of propodos convex, occupying about half the posterior margin. Last three pairs of peræopoda long and slender, each much longer than the preceding. Second uropods with the outer branch only about half as long as the inner. Telson rather short, sub-rectangular; posterior angles rounded and each furnished with a single fine seta; hinder margin slightly concave.

Female. Differs from the male in the following points: the size is smaller, only about two-thirds as large; the antennæ are more slender and less strongly supplied with setæ, and apparently do not bear calceoli; the gnathopoda are much smaller and more slender, the first having the carpus triangular, as long as the propodos, which is elliptical, and has the palm only slightly oblique; the second gnathopod is very long and slender, carpus and propodos similar, narrow oblong, carpus much longer than propodos, palm of latter quite transverse.

Length. Largest male 12 mm.; largest female about 6 mm.

Colour. White, semitransparent.

Habitat. Eyreton (*Chilton*), Lincoln (*E. Wilkinson*), Ashburton (*W. W. Smith and J. B. Mayne*), Winchester (*D. L. Inwood*): in wells.

Remarks. The female of this species bears a very close general resemblance to *Pherusa cærulea*, G. M. Thomson [107, p. 206]. I had judged this to be the case from the comparison of Stebbing's figures of the latter with my specimens, and an examination of specimens of *Pherusa cærulea*, kindly supplied by Mr. Thomson, shows that the resemblance is even closer than I had imagined. *Pherusa cærulea* is stouter in body, has the side-plates deeper, and of course differs also in the possession of eyes and in its very distinct dark blue colour, but in the form of the antennæ, the mouth-parts, and the gnathopods there is little difference of any importance. The upper antenna has a rudimentary secondary flagellum (not mentioned in Stebbing's description), as in *Calliopius subterraneus*, but it is somewhat longer, being longer than the first joint of the main flagellum; in the specimen I have dissected there are small calceoli on both antennæ, just as in the specimens of *Calliopius subterraneus* that I have described below as "immature males." The gnathopods have the same general shape, but are not so long and slender, and, especially in the second, do not bear so many tufts of setæ as in the female of *Calliopius subterraneus*; the peræopoda are shorter, the uropoda are similar and in like manner armed with spines, but the second has the branches less unequal in length, and the telson is rounder. The specimen of *Pherusa cærulea* that I have examined is probably a young male, but none of the few specimens in my hands have the gnathopoda so largely developed as in *Calliopius subterraneus*. On the whole it appears that the two species are very closely related, and either *Calliopius subterraneus* has been derived from *Pherusa cærulea*, or, what is more likely, both have been derived from a closely allied species once widely spread in New Zealand.

Calliopius fluviatilis, G. M. Thomson, is very common in freshwater streams in New Zealand, but is not so closely allied to the subterranean species as is *Pherusa cærulea*. It differs considerably in the gnathopoda, and in the last pair of peræopoda, which have the last joint simple, ending in a small pencil of long hairs, as in species of the Œdiceroidæ, and it seems scarcely necessary to compare it in detail with *Calliopius subterraneus*.

Detailed Description.

In this species the male differs in a very marked manner from the female, being of considerably larger size, differing also in the antennæ and particularly in the gnathopoda. The males are very much rarer than the females; I have seen only about half a dozen males altogether, while I must have seen hundreds of specimens of the female. It will be convenient to describe the male first, and afterwards to point out more in detail the characters in which the female differs from the male.

The *body* (Pl. XXII. fig. 1) is smooth, fairly stout. The head is longer than the first segment of the peræon; the segments of the peræon subequal; first three segments of the pleon considerably longer than the last segment of the peræon. The side-plates of the first four segments of the peræon are nearly as deep as their respective segments. The inferior margins of the first three segments of the pleon are regularly rounded and have no setæ.

Eyes. There is no external sign of the eyes.

The *upper antennæ* (fig. 2) are more than two-thirds as long as the body. The peduncle has the first joint stout, about half as broad as long, with a few minute setæ scattered over it, the lower surface with a row of about seven or eight short setæ, and at the extremity three or four long auditory setæ. The second joint is about two-thirds as long as the first, but not much more than half the width; the lower surface bears a few minute spinules and some longer setæ at the extremity; on the inner surface, towards the upper side, is a row of three or four "calceoli," at the base of each of which are two or three simple setæ. Third joint about half as long as the second, similarly furnished with calceoli and setæ. There is a minute secondary appendage on the inner surface, consisting of a single small joint tipped with two setæ. The flagellum is more than twice as long as the peduncle, and consists of a great number of joints, of which about the first third bear calceoli arranged in two rows, the first being situated on the inner surface towards the upper margin, the other also on the inner surface but lower down, and being on joints of the flagellum alternating with those that bear the first-mentioned row of calceoli, the part of each joint that bears a calceolus is somewhat produced into a small rounded prominence, which bears three or four simple setæ as well as the calceolus. Towards the extremity of the flagellum the joints become much more elongated and cease to bear calceoli. Olfactory cylinders are found on the joints which do not bear calceoli, as well as on some, if not all, of those which do bear calceoli.

The *lower antennæ* (fig. 4) are about half as long as the upper, both the peduncle and the flagellum being rather stout. The "gland-cone" attached to the second joint is rather large and prominent, and bears two separate setæ at some little distance from the apex. The short third joint is grooved below, and bears at the extremity of its lower margin two simple setæ; its articulation with the fourth joint is very oblique. The fourth joint is rather broad, nearly half as broad as long; its upper margin bears three setæ in slight serrations; there is a tuft of four setæ in the middle of the lower margin and another larger tuft at the extremity. The fifth joint is slightly longer than the fourth; on the upper surface it bears four or five small tufts of setæ, and on the lower margin four larger tufts; along the extremity is a row of about seven auditory setæ. The flagellum is rather longer than the peduncle, and is stout, especially toward the base, where each joint is much broader than long. It bears two rows of calceoli, arranged in the same way as in the upper antenna; the calceoli decrease in size towards the end of the flagellum, and cease entirely at about the seventh joint from the end. In addition to the calceoli each joint bears a few simple setæ at the extremity.

The general appearance of the calceoli is shown in fig. 3. These organs have been fully investigated by Blanc, as I learn from the abstract given by Stebbing. The general arrangement of the calceoli in the present species appears to resemble closely that in *Eusiroides cæsaris* as described and figured by Stebbing [108, p. 970]. When seen in profile, the outline of the calceolus is very different from that shown in fig. 3, and is more like that shown by Stebbing in his figure of the calceoli of *Tryphosa antennipotens* [108, pl. vi. fig. *a. s.* with enlargement]. In that species, too, the calceoli on both antennæ are arranged in the same way as in the present species—"in both pairs so placed that, while the calceoli of alternate joints are seen full face, those of the other alternate joints will be seen in profile" [108, p. 618].

The *upper lip* (fig. 5) is rather large, oval in outline, widening distally; the end is regularly rounded at the corners and nearly straight in the centre, and bears many short converging setæ.

Mandibles (figs. 6, 7, 8). The *left mandible* is shown in fig. 6, and differs considerably from the right in the details of the cutting-edges. The palp, which is the same in both mandibles, is large and rather broad. Its first joint is very short, not much longer than broad; it bears no setæ. The second joint is the largest, being rather more than three times as long as the first; it expands slightly towards the distal end, and bears at the extremity on the inner margin, which is there convex, a row of six or seven fairly long setæ. The third joint is about three-fourths as long as the second; it is broadest near the base, narrows considerably toward the end, and is much curved, so that the extremity is almost at right angles to the plane in which the base of the joint lies (the double curving is not well shown in the figure). Along its concave margin it is thickly fringed with a dense row of short setæ; three longer ones are situated at the extremity. The surface on the concave side appears striated, the appearance being probably due to rows of very minute setæ.

The molar tubercle is strong; it has the extremity oblique, and covered, as usual, with rows of short spines. The sides of the tubercle bear numerous fine setæ, and in connection with it is a long filament or seta, as described by Humbert in *Niphargus puteanus*, by Sars in *Gammarus neglectus*, and by other authors.

The outer cutting-edge of the left mandible (fig. 7) consists of about six sharp teeth of varying shape, as shown in the figure; the inner or secondary edge is somewhat similar, but contains only four main teeth. Both edges are very concave on the inside, and were a good deal compressed in the slide from which fig. 7 was drawn; between the inner edge and the molar tubercle are five or six stout bristles.

The right mandible differs principally from the left in the two cutting-edges. The outer edge is similar to that of the left, but appears to consist of five main teeth only, and usually presents the appearance shown in fig. 8. The inner edge is very different from that of the left; it has a stout rounded base, and bifurcates towards the end; each division tapers to a point, bears one or two teeth, and is more or less tubercled, as shown in the figure.

Lower lip. Fig. 9 represents a portion of the lower lip of the large male from which this description is taken, the appendage having been torn in dissecting it out; the whole of the lip is better shown in Pl. XXIII. fig. 10, which is taken from a female specimen. The two outer lobes are comparatively long and narrow towards the extremity; their outer margins are fringed with very delicate setæ, and the inner margins bear numerous short setæ curving inward. The division between the two lobes does not appear to reach quite to the base of the lip. The inner lobes were not observed in the female; a part which probably belongs to them is shown in the drawing taken from the male (Pl. XXII. fig. 9). The lateral backward processes are moderately long and narrow.

The *first maxilla* (Pl. XXII. fig. 10, 11, 12, 13) in the male specimen dissected had the inner plate very small and delicate, oval, and with five plumose setæ on the inner margin. The middle lobe is broad, rectangular, squarely truncate at the end, and bears about twelve strongly denticulated spines, as shown in fig. 11; the form and position of these spines will be more easily understood from the figure than from a verbal description. The palp has the first joint short, not much longer than broad, the end somewhat oblique; the second joint is long and curved, rather broad, and terminates in the right (?) maxilla (fig. 12) in about seven stout, short setæ or spines. The two outermost are the longest and narrowest and are bristled; the others, which are short and stout, form very sharp teeth; near the base of the second tooth from the outside arises a single simple seta. In the other maxilla (fig. 13) the end of the palp is very different; it bears five setæ, very much longer and narrower than those on the right (?); the single simple seta arises from the base of the second outermost one as on the right (?).

The *second maxilla* is shown in fig. 14, and does not appear to present any remarkable feature. On the surface of the inner lobe is an oblique row containing seven plumose setæ. The surface of this lobe towards the base is covered with very fine delicate setæ, and similar setæ are found on the outer margins of both lobes towards their extremities. The end of the outer lobe bears about seven or eight long setæ, curved slightly inward; the end of the inner lobe bears similar setæ, which are, however, much shorter, and some of them plumose. The setæ extend some distance along the inner margin, but gradually become smaller as they recede from the extremity.

The *maxillipedes*, as seen from below, are shown in fig. 15. The *basos* bears at its extremity, towards the inner side, a group of nine or ten long setæ; the plate attached to it—the inner plate—extends only as far as the end of the inner margin of the meros; it bears at the end two stout sharp teeth and a third more slender, and numerous stiffly plumose bristles; its inner margin bears five or six plumose hairs. The *ischium* bears at the extremity a group of setæ as in the basos; the plate attached to it—the outer plate—reaches as far as the extremity of the outer edge of the meros; its inner edge is straight and bears about ten moderately stout spines, which gradually merge at the end into long, stiffly plumose, curved setæ; in addition to these spines the inner margin bears numerous slender setæ; the convex outer margin of the plate is also supplied with many very fine setæ like those found on some parts of the maxillæ. The *meros* bears about six setæ on the outer margin towards the extremity and numerous setæ on its inner margin. The *carpus* is similarly supplied with setæ. The *propodos* is about two-thirds as long as the carpus; it bears three or four setæ on the outer margin, and numerous long ones on the inner margin and on the surface near to it; on the upper surface of the propodos (fig. 16) is a longitudinal row of about twelve setæ, extending right along the centre, with a few others more or less irregularly placed; the outer extremity of the propodos at the base of the dactylos is produced into a small rounded lobe. The *dactylos* is long and slender, being about two-thirds the length of the propodos; both margins bear five or six setæ; it narrows somewhat abruptly at the extremity, and bears a stout spine or nail. The normal form of the dactylos is shown in fig. 16; that shown in fig. 15 is evidently deformed, and was found on the right side of the same maxillipede.

The foregoing descriptions of the mouth-parts have been taken from a large-sized male specimen. The mouth-parts of the female differ in several respects and are described below, where some remarks on the probable changes that take place in the mouth-parts during the development of the male will also be found.

The *first gnathopod* (Pl. XXIII. fig. 1) is very large and strong, much larger than the second. The coxa (side-plate) is nearly as deep as its segments and is rhomboidal in outline, projecting strongly forward; it bears a very minute seta at the anterior end of the lower margin, and one or two at the hinder end. The basos is long, somewhat curved at the base; the anterior surface is grooved to receive the propodos when the limb is bent back at rest. The ischium is short and of the usual form. The meros is short, not much longer than the ischium; the anterior surface is rounded and bears a number of setæ more or less regularly arranged in three transverse rows. The carpus is very short, subtriangular, produced below on the outer side into a small rounded lobe, densely tipped with setæ; when seen from the inside (fig. 2) the carpus appears quite rectangular. The propodos is very large, much longer than the basos; the upper margin is regularly curved and without setæ, except one or two very small ones at the base of the dactylos; the basal part of the lower margin forms a rounded lobe densely covered with numerous setæ arranged in five transverse rows; the palm occupies the whole length of the lower margin with the exception of this lobe; it appears rather broad, the outer edge bearing ten small tufts of rather long setæ, each tuft containing from two to four setæ. When seen from the inside (fig. 2) the end of the palm, against which the dactylos impinges, appears to be slightly concave; the end is defined by three long spines; round the edge of the hollow on the inside is a row of about seven shorter spines, and near them are some simple setæ more or less regularly arranged in tufts. The inner edge of the palm is rather convex, and, except towards the proximal end of the palm, it extends beyond the inner edge; it is minutely serrate and fringed with a few small setæ, and near it is a longitudinal series of about twelve short oblique rows of long setæ, each containing from five to ten setæ. The dactylos is large and strong, slightly curved, and with a few very minute setæ on the concave margin, but these do not project beyond the margin of the dactylos; the extremity is not distinctly marked off into a terminal unguis.

The *second gnathopod* (Pl. XXIII. figs. 3, 4) is slightly longer than the first, but is much more slender. The coxa is rectangular, deeper than broad, the lower angles rounded, and with six minute setæ on the lower margin; arising from the coxa there appear to be *two* * gill-plates, one rather larger than the other. The basos is long, nearly straight, the posterior margin bearing seven or eight long setæ on the proximal half, and a shorter one at the extremity. The ischium is rather long, one-third as long as the basos; its posterior margin bears three or four small setæ. The meros is about as long as the ischium; its distal extremity bears a fringe of about eight or nine long setæ. The carpus is nearly as long as the ischium and meros together; it is subtriangular, very narrow at the base, and rather loosely articulated to the meros, so that the distal part of the limb can readily turn upon this as a pivot, and hence often appears reversed, as shown in the figure of the whole animal (Pl. XXII. fig. 1). The anterior margin of the carpus is nearly straight, with a single minute seta at the extremity; the posterior margin is strongly curved, and thickly fringed with long setæ arranged in about twelve transverse rows, a small tuft of two or three being situated on the outer surface near the extremity. On the inner surface (Pl. XXIII. fig. 4) the carpus bears towards the extremity a transverse row of four or five setæ and three or four separate setæ placed more proximally along the middle of the joint. The propodos is longer than the carpus and meros combined; the anterior margin is straight, giving the limb a somewhat awkward appearance; towards the end it bears three or four minute setæ and two or three at the base of the dactylos; the posterior margin is strongly convex, the palm occupying more than one-half the whole length; it is defined by a stout spine and fringed on the outer surface with minute spinules, arranged singly, and a row of six separate long setæ running parallel to the palm; the basal part of the margin below the palm is thickly fringed with long setæ, arranged in about eleven transverse rows as in the carpus. When the propodos is viewed from the inside, the dactylos is seen to extend a little beyond the defining-spine and to fit into a slight depression bordered by four spines, one of which is much longer than the others; running parallel to the palm is a longitudinal series of from twelve to fifteen oblique rows of long setæ, each containing from two to four. The dactylos is similar to that of the first gnathopod, but is not so large and powerful.

The *first peræopod* (fig. 5) has the coxa (side-plate) and basos entirely similar to those of the second gnathopod, and, like it, appears to bear a double gill-plate. The ischium is short and of the usual form. The meros is oblong, rather more than half the length of the basos; its posterior margin straight, with five or six separate setæ, the anterior margin slightly convex and with the distal angle a little produced; it bears a seta near the middle and another at the extremity. The carpus is more than half the length of

* Though there are certainly two plates attached to the coxa, both in the second gnathopod and in the first and second peræopoda, in the male specimen dissected, I have not found them in female specimens, and am not sure that the second plate is a gill-plate. It differs in appearance from the true gill-plate, and might be considered a brood-plate, but it bears no setæ on the margin, and I am practically certain that the specimen is a male.

the meros and is similarly furnished with setæ, but those on the posterior margin are rather stouter than in the meros. The propodos is longer than the carpus and rather more slender; its anterior margin bears six fine setæ and the posterior margin six groups, each containing one stout seta and usually one or two small ones. The dactylos is of average length, very acute, with the terminal unguis imperfectly defined; on the outer margin, near the base, it bears a single seta, sparingly plumose at the end.

The *second peræopod* is similar in all respects to the first.

The *third*, *fourth*, and *fifth peræopoda* are all similar to each other, but each is larger than the preceding; each appears to have only one gill-plate. Fig. 6 represents the *third peræopod* and may be taken as a sample. The coxa is normally deep, distinctly bilobed, the posterior lobe being rather the larger. The basos is considerably expanded, oval in shape, about two-thirds as broad as long; its anterior margin bears nine or ten stout setæ; the posterior margin minutely serrate and having a small seta in each serration. The ischium as usual. The meros is rather broad, the postero-distal angle somewhat produced, both margins with groups of long stout setæ. The carpus is longer than the meros, but much narrower; the propodos somewhat longer than the carpus; both bear groups of long stout setæ on both margins, those on the anterior margin being larger than those on the posterior margin. The dactylos is like that of the first peræopod, but bears three small setæ on the outer margin in addition to the plumose one near the base.

The *first pleopod* is of the usual form; the peduncle is rather short and has both margins free from setæ; there are two coupling-spines, each bearing three or four teeth; the first joint of the inner ramus bears two cleft spines; the inner ramus is slightly longer than the outer.

The *second* and *third pleopoda* are similar to the first.

The *first uropod* (fig. 7) has the peduncle long and slender, much longer than the rami; its upper surface is flat or slightly concave; both the upper margins supplied with spines. In the large male there were only three or four spines on each margin, but in females the spines are usually much more numerous (compare Pl. XXIII. figs. 7, 16). The two rami are similar, with spines on both margins and longer spines at the ends; the outer ramus is a little shorter than the inner.

The *second uropod* (fig. 8) is shorter than the first and has the outer ramus not much more than half as long as the inner. It is supplied with setæ in a similar manner to the first uropod.

The *third uropod* (fig. 9) reaches further back than the others, the peduncle reaching as far as the ends of the first and second uropods; it bears spine-like setæ on both the upper margins. The rami are longer than the peduncle, somewhat broad, narrowing gradually to the ends, which are acute and bear no setæ; both margins of each bear three or four tufts of small spines. In the male specimen drawn the outer ramus is somewhat shorter than the inner, but in females the two rami are of about the same length and the whole uropod is rather longer and more slender (compare figs. 9, 11, Pl. XXIII.).

The *telson* (see fig. 17) is short, not reaching to the end of the peduncle of the third uropod; it is nearly rectangular, rather broader than long; the angles at the extremity rounded, and each bearing a fine hair; the hinder margin slightly concave. Fig. 17 is taken from a female; in one male specimen examined the hinder margin was slightly more concave.

Sexual differences. The female differs from the male as above described in many characteristic features, and especially in the gnathopoda, so that if they had not been taken together it is rather unlikely that the two forms would both have been assigned to the same species. With the facts before me, however, I have no doubt that we have to deal with the two sexes of the one species. The one form I consider the male from its largely developed gnathopoda, from the absence of brood-plates &c., although I have not actually found fully-developed spermatozoa in it. The other form is undoubtedly a female, for I have frequently taken it bearing eggs; it is found associated with the male both at Eyreton and Ashburton; it is much smaller, the largest specimens being not more than two-thirds the size of the largest male, and it is very much more numerous. Although I have not yet obtained a complete series of transitional forms, still from the facts given below I feel convinced that in this species, as in many other Amphipoda, the young male at first resembles the female in the form of the gnathopoda &c., and that the peculiar characteristics of the male are not acquired until the animal has attained to sexual maturity.

In the female the *antennæ* are more slender than in the male; in accordance with the smaller size of the animal, the setæ on them are less prominent, especially in the lower antennæ, and the calceoli are wanting. I have found calceoli in some specimens which in other characters closely resembled females, but, as I have already said, these are more probably immature males. As the calceoli in these specimens are of very small size, extremely delicate and transparent, and hence easily overlooked, I thought at first that they were perhaps present also in the females, though I had failed to see them; however, I have since looked for them very carefully in several mature females and can find no trace of them.

In the *upper lip*, the *mandibles*, and the *lower lip* the female does not appear to differ from the male.

In the *first maxilla* the inner lobe is larger and bears fully twice as many plumose setæ as in the male specimen drawn in fig. 10, Pl. XXII. It is quite possible that the number of plumose setæ on the inner plate of this maxilla bears some relation to the size of the animal irrespective of its sex; but all the female specimens examined have about twice the number found in the male, and I have not had sufficient male specimens of different sizes to be able to decide how many of these setæ are usually present, or whether the one figured is exceptional or not.

In full-grown females the setæ on the middle lobe and at the end of the palp closely resemble those of the male as drawn, the two palps being different as in the male.

In the *second maxilla* in the female the oblique row of plumose setæ contains about twice as many setæ as in the male figured in fig. VI. *n*, and the remarks made in connection with the first maxilla apply to the second maxilla also.

In the *maxillipedes* (fig. 11, Pl. XXIII.) we find a very considerable difference between the two sexes (compare fig. 15, Pl. XXII., and fig. 11, Pl. XXIII.). In the female the two lobes are considerably larger than in the male, the inner lobe reaching nearly to the end of the *outer* margin of the meros, and the outer lobe nearly to the end of the carpus; the lobes are also broader, but the armature of each is practically the same in both sexes. The meros, carpus, and propodos bear fewer setæ in the female, especially on the outer margins, and I cannot find the central row of setæ along the upper surface of the propodos which was certainly present in the male specimen figured. Notwithstanding these differences, there is a very close agreement in other respects, the resemblance being greater than would be imagined from a comparison of fig. 15, Pl. XXII., and fig. 11, Pl. XXIII.; and I wish to repeat that I am not yet certain how far the differences observed are due to sex and how far to size alone.

It is, however, in the gnathopoda that we find the greatest difference between the sexes; and it is, perhaps, worthy of note that each gnathopod is quite different in the two sexes, while in most cases in the Amphipoda one pair, at least, is the same, or nearly the same, in both male and female.

The *first gnathopod* of the female (figs. 12, 13, Pl. XXIII.) has the basos rather stout, widening distally, its posterior margin bearing a few setæ. The *ischium* and *meros* short, subequal, each with a few setæ at the extremity on the posterior margin. The *carpus* triangular, a few setæ on the anterior margin; the posterior margin irregularly serrate and with small tufts or transverse rows of setæ, an oblique row of four or five setæ being situated on the surface of the joint near the postero-distal corner. The *propodos* is about as long as the carpus and not broader than the latter at its distal end, subelliptical in outline; the anterior margin with three or four setæ and a small tuft at the base of the dactylos; the posterior margin with four short transverse rows, an oblique row of seven or eight widely separated setæ extending along the surface of the joint near the posterior margin; the palm is a little oblique, defined by two stout setæ, its edge somewhat crenate and fringed with a few small setæ. The *dactylos* moderately stout, curved, with a few setæ on its inner margin.

The *second gnathopod* (figs. 14, 15) is similar in general structure to the first, but is much longer and more slender. The *basos*, *ischium*, and *meros* are all similar to those of the first gnathopod, but more slender; the *carpus* is very long, much longer than the propodos, narrow oblong, its posterior margin with about eight or nine tufts of setæ in slight serrations; the *propodos* is also oblong in outline, of the same width as the carpus, both margins with tufts of setæ, those on the posterior margin the longer, a very distinct transverse row being situated at the base of the dactylos; the palm is transverse, defined by a small projection and a stout seta; the *dactylos* very short.

In the *peræopoda*, *pleopoda*, and *uropoda* the female does not differ from the male except in the few small points already mentioned, and it is quite probable that these are as much due to size as to difference of sex. I have, however, usually found the telson a little more deeply emarginate on the hinder margin in the male than in the female, but the difference is very slight.

I have several times found small specimens otherwise like the ordinary female form but bearing calceoli on both antennæ, the calceoli being much smaller and much less numerous than in the adult male, as above described, but similarly arranged. The gnathopods of these forms, which I consider immature males, are usually quite like those of the ordinary female form; but I have rough drawings of one (made in 1883) in which the propodos of the first gnathopod is more ovate, the palm oblique, occupying fully half the posterior margin, and the tufts of setæ much reduced in number and containing shorter setæ or spines; the second gnathopod has the carpus as usual, but the propodos is shorter and differs in shape, being somewhat expanded distally, the posterior margin bears only three tufts of setæ instead of about eight as usual, and the palm is rather oblique. It will be seen that in so far as this specimen differs from the female it approaches towards the male; I have, however, not succeeded in finding any other forms intermediate between this and the fully-developed male. This particular specimen presented a peculiarity in the third pair of uropoda, having the two rami very unequal, one being as long as the peduncle and the other twice as long; I have never seen any other specimen with this peculiarity in such a marked degree, though specimens are occasionally seen in which the two rami are a little unequal.

In the first maxilla these "immature males" differ very considerably from the adult form; the ends of the palps of the right and left maxillæ are quite symmetrical, and the armature of the end of the outer lobe consists chiefly of broad comb-like setæ like those shown in fig. 18, Pl. XXIII., being thus about as different as can be from the adult form as shown in fig. 11, Pl. XXII. In the former figure, only some of the setæ are shown, those on one side; the other curved denticulated setæ which are found on the other side and particularly towards the inner margin have been omitted in order to show clearly those that are represented. I have found the first maxilla to be similar to this in other small forms in which I could find no calceoli whatever, which were probably either still younger males or young females, and I suppose that this form of the first maxilla is to be found only in immature individuals. Adult females have the first maxilla practically the same as that of the large male represented in figs. 18, 19, 20, 21, Pl. XXIII., so far as the two palps and the armature of the middle lobe are concerned. I have not as yet found intermediate forms between the adult and the small specimens.

Summary of the more important points in Part IV.

It will be convenient here to summarize briefly the more important points that have been brought out in the examination of the six species now described, as some of them might otherwise be overlooked in the mass of technical description.

(1) The genus *Phreatoicus* is shown to be a very peculiar one, requiring for its reception the creation of a new family, the Phreatoicidæ, which approaches in some respects to Asellidæ, differing, however, very much in the laterally-compressed body and the long six-jointed pleon.

(2) The pleopoda of *Phreatoicus* are well-developed and in some respects different from those of most other Isopoda. In the first pair there is a one-jointed endopodite and a one-jointed exopodite; in all the other pairs the exopodite is two-jointed, while in the third, fourth, and fifth pairs there is also a separate appendage arising from the protopodite and probably representing the epipodite. In the male the second pair of

pleopoda are specially modified, the penial filament being formed from a portion of the endopodite, a fact that will perhaps be useful to throw light on the more modified second pleopoda in the males of various Asellidæ, &c.

(3) A consideration of the coxæ of *Phreatoicus* leads to a short discussion in support of Spence Bate's contention that the "epimera" or "side-plates" are in reality the coxæ of the appendages of the peræon.

(4) In discussing the systematic position of *Phreatoicus* reference is made to the external characters by which the Amphipoda are separated from the Isopoda, and an additional difference is shown to exist in the *ischia* of the appendages of the peræon, as these are of moderate length in all Isopoda except the Apseudidæ and Tanaidæ, while they are almost always very short in the Amphipoda.

(5) The genus *Cruregens*, belonging to the Anthuridæ, is described and compared with some allied genera. It has only six pairs of legs, and thus appears to permanently retain this larval character of the Isopoda, owing probably to an arrest of development.

(6) The mouth-parts of *Cruregens*, which are very difficult to determine, are fully described, and it is shown that the mandibles are small and without any trace of a palp—a character very exceptional in the Anthuridæ.

(7) The terminal uropoda of *Cruregens* are shown to consist of an oblong peduncle, a long narrow exopodite arising from near the anterior end of the peduncle, and a one-jointed endopodite arising from its posterior end. Other authors, with the exception of Dohrn, have apparently wrongly described the uropoda of the Anthuridæ as having a two-jointed endopodite, the distal portion of the peduncle having been mistaken for a part of the endopodite.

(8) The telson of *Cruregens* and of some other Anthurids is distinctly separated from the last segment of the pleon, though this is exceptional among the Isopoda.

(9) The genus *Crangonyx* is discussed at some length, and the mouth-parts of *Crangonyx compactus* are described. The mouth-parts of *Crangonyx* do not appear to have been previously described.

(10) The pleopoda of *Crangonyx compactus* have each only *one* ramus instead of *two*, as is almost universally the case in other Amphipoda. It appears to be the inner branch that is wanting. Nothing appears to be known of the pleopoda of most of the other species of *Crangonyx*.

(11) The species *Gammarus fragilis* appears to correspond well with the characters usually assigned to the genus, but it is interesting to note that the present species has very long antennæ, peræopoda, and terminal uropoda, thus showing some approach to the characters of *Niphargus*.

(12) In *Calliopius subterraneus* there is very great dissimilarity between the two sexes, chiefly in the gnathopoda, *both* of these in the male differing considerably from those of the female, while in other species one pair is usually almost or quite alike in the two sexes. There are also differences in some of the mouth-parts, viz. in characters which are often made use of for generic differentiation.

Some remarks are made on the calceoli found in the males of this species; they are also found in some specimens which otherwise resemble the females, but these are looked upon as immature males which have not yet acquired the peculiar gnathopoda of the fully-developed male.

V. The General Fauna of the Subterranean Waters of Canterbury.

In addition to the Crustacea described in the present paper there are doubtless many other forms to be found in the underground waters of the Canterbury Plains. In his paper on the fauna of the subterranean waters of the North of France, Dr. R. Moniez [78] gives a very long list, including Protozoa, Cœlenterata, Turbellaria, Nematoda, Annelida, Rotifera, Gasteropoda, and various Crustacea, in addition to the Amphipoda and Isopoda, viz. Copepoda, Ostracoda, and Cladocera. In the various caves of North America, as described by Packard [83], and likewise in those of Europe, described by Joseph [67] and other writers, the fauna is a very extended one, and naturally includes many air-breathing forms that would be unable to exist in subterranean waters.

I have made no extended search for other forms from the wells of Canterbury, but in collecting the Crustacea I have occasionally met with others, and it will perhaps be well to mention briefly here what is known on the subject, in the hope that greater attention will be directed to the matter in the future.

Attached to the Amphipoda (*Crangonyx compactus*, *Gammarus fragilis*, *Calliopius subterraneus*) I have, on several occasions, noticed a small stalked Infusorian, probably a *Vorticella*, or something allied thereto. Various worms have been brought up by the pump—one, an Oligochæte, is, Professor Haswell tells me, *Phreoryctes Smithii*, Beddard; another is a very remarkable Turbellarian, which is at present being investigated by Professor W. A. Haswell, of Sydney.

Mr. W. W. Smith, who has examined the water brought up by pumps in the Ashburton district with great care and perseverance, has succeeded in detecting several forms that have not yet been observed from the Eyreton wells. Among these are some small Gasteropoda, a small Centipede, and a peculiar worm, *Phreodrilus subterraneus*, Beddard [8]. The shells have been observed from several wells, but only very few specimens have as yet been obtained; these were submitted to Mr. Suter of Christchurch, who states that they appear to be *Potamopyrgus antipodum*, Gray, var. *spelæa*, Frauenfeld. *P. antipodum* is a freshwater species which is very widely distributed in New Zealand, and has probably received various names for its different varieties: the type of *P. spelæa* was found in the Collingwood Caves near Nelson. There seems no doubt that the shells found at Ashburton really belong to the true subterranean fauna, as Mr. Suter states that they were without pigment and of a dirty white colour, and the animals were still alive when got from the pump by Mr. Smith, who watched their movements for some hours before sending them off to Mr. Suter.

The aquatic worm obtained by Mr. Smith was forwarded to Mr. F. E. Beddard, who has described it as "*Phreodrilus subterraneus*, nov. gen. et n. sp.," making it the type of a new family of the Aquatic Oligochæta, viz. the Phreodrilidæ [8]. The genus is, he considers, a very remarkable one, and, in addition to various peculiarities in the internal anatomy, the character of the setæ is alone sufficient for the creation of a new family. He regards the Phreodrilidæ as a very low form of Oligochæta, greatly specialized in certain directions. He adds :—" I should explain that in using the term 'low' I do not mean that this genus is in any way near the ancestral form of the Oligochæta. The simplicity of structure in this and other aquatic genera is rather to be looked upon as evidence of degeneration." He places the Phreodrilidæ nearer the Naidomorpha than to any other group of the Oligochæta, though admitting that the position of the genital organs suggests an affinity with the Enchytræidæ. There are also a few points in which *Phreodrilus* recalls the higher among the Oligochæta, and Mr. Beddard comes to the conclusion that " it should be placed some way off the line leading from the more highly-developed Lumbriculidæ to the lower Naidomorpha, but that its precise relationships require further study, and cannot be determined with any probability of success at the present time" [8, p. 292].

I have given the above account of *Phreodrilus* pretty fully because it appears in many respects to be parallel to the case of *Phreotoicus*, for which I have had to establish a new family. The two cases confirm each other, and show how exceedingly interesting the subterranean fauna really is. No doubt other discoveries quite as interesting as these will yet repay careful and systematic search, for as yet the ground has been prospected merely, not thoroughly worked.

Besides animals which, like the above-mentioned, undoubtedly belong to the true subterranean fauna, it appears that surface animals from the neighbourhood of the wells may sometimes be obtained through the pump, apparently from the well. Thus I have several times taken *Cyclops novæ-zealandiæ*, G. M. Thomson, from wells at Eyreton. The specimens were exactly like those found in surface pools in the neighbourhood and had the eye perfect, and had no doubt got into the well by accident—an accident that with this small creature might very easily happen. On one occasion Mr. Smith, after pumping for three quarters of an hour from a well at the Elgin Schoolhouse near Ashburton, 50 feet deep, and fitted with a cylinder-pump, obtained a spider and a small Gasteropod shell, and the seeds of some plants. The spider, which has perfect eyes, is, Mr. Goyen informs me, a species of *Theridion* frequently found in dark situations, such as crevices of rocks, &c. The seeds were submitted to Mr. D. Petrie, who writes that one belongs to *Chenopodium*, which is abundant everywhere in the district. The shell, determined by Mr. Suter, is *Amphipeplea ampulla*, Hutton, a species found everywhere in creeks, rivers, pools, &c.; the animal had evidently been dead for some time, as the body was decayed; the shell was of the normal horny colour, and, like the spider and the seeds, it must apparently have got into the pump by some accident, and forms no part of the true subterranean fauna. Mr. Suter points out that the shell of this specimen showed no approach to the dead-white colour of the *Potamopyrgus*, which is no doubt truly subterranean.

At the same time and from the same pump Mr. Smith obtained one or two specimens of *Calliopius subterraneus*.

VI. The Canterbury Plains and their Underground Waters.

All the localities from which subterranean Crustacea have been as yet collected in New Zealand are situated on the Canterbury Plains, and in order to clear the way for the discussion of the probable origin of these forms it will be convenient to state first a few facts about the formation of the plains and as to their underground waters. Much of what follows is taken from the late Sir Julius von Haast's 'Geology of the Provinces of Canterbury and Westland, New Zealand' [53]. In speaking of the plains formed on the eastern side of the Southern Alps he says :—

"The most prominent amongst these are the Canterbury Plains, which, by their position, nature, and general characteristics, form a prominent feature of this island, and are already the centre of a rich, industrious, and large population. They begin at the dolerite plateau of Timaru, and stretch without interruption to Double Corner, in a general direction from south-west to north-east, with a length of about 112 miles. Their breadth from a few miles at both extremities, north and south, augments as we advance towards their centre, having their greatest lateral extension near Banks Peninsula, where, in a direction from east to west, they stretch a distance of nearly 50 miles to the base of the mountains. The Pacific Ocean is their boundary on the eastern side, where a long shore stretches in a line nearly from south-west to north-east—from Timaru to Double Corner—being only interrupted by the volcanic system of Banks Peninsula, which rises so conspicuously in the middle of that low shore, and to the existence of which so great a portion of the loose strata composing these plains owes its preservation from the destructive agencies of the waves and currents. The western boundary is formed by the outrunning spurs of the Southern Alps, having, as I have pointed out previously, by their disintegration, offered the material for the present configuration and other physical features of the plains. In their great bulk they consist of the accumulation of post-pliocene torrents. Having had their glacier-sources much nearer to Banks Peninsula than in present times, the latter were able to throw the boulders, shingle, sand, and ooze, carried along with them, not only in greater masses, but also on steeper slopes than the present rivers crossing them can do, for reasons given in the geological portion. These post-pliocene deposits of large rivers have covered with an almost uniform gradient the palæozoic, volcanic, or tertiary rocks composing here the sea-bottom" [53, p. 231].

The Canterbury Plains slope towards the sea at the rate of about 40 feet to the mile for the first fifteen or twenty miles from the mountains, and at an average of 24 feet to the mile for the remainder of the distance to the sea. This may be illustrated by the following figures taken from Sir Julius von Haast's 'Geology' [53, p. 403], showing the fall of two of the rivers in the basins of which subterranean Crustacea have been found :—

Name of River.		Difference between two Stations.	Length of Plains.	Fall of Plains per mile.
		feet.	miles.	feet.
Ashburton	From Two Brothers to sea .... mean	1500	35½	42¼
	From Two Brothers, 1500 feet, to Railway crossing, 305 feet	1195	25	48
	From Railway crossing, 305 feet, to sea (50 feet above sea-level)	255	10½	29
Waimakariri ..	From upper gorge to sea .... mean	1580	44	36
	From junction of Kowhai, 1410 feet, to lagoon at gorge hill, 1182 feet	228	5	41½
	From lagoon, 1182 feet, to the so-called 18th-mile peg, 355 feet.....................	827	18¾	44
	From 18th-mile peg, 355 feet, to last raised beach near North Road, 33 feet	322	13¼	24¼
	From last raised beach, 33 feet, to sea........	33	4	8

Some of the other rivers show rather more gradual falls than those quoted in the table above; thus the River Selwyn from its entrance into the plains to its mouth at Lake Ellesmere has a total fall of 790 feet in a distance of 29 miles, or an average of 27¼ feet per mile.

With regard to the origin of the plains Sir Julius von Haast says:—"All the levels, surveys, engineering works, together with well-sinking, have amply confirmed my views that the Canterbury Plains are of fluviatile origin, that, with the exception of some morainic accumulation in the upper portion and the drift sands round Banks Peninsula, and the partial lacustrine deposits filling the former extension of Lake Ellesmere, the whole of the plains were formed by huge rivers issuing from the frontal end of gigantic glaciers" [53, p. 396]. Consequently the Canterbury Plains consist of river shingle and sand, cemented more or less by a ferruginous matrix; this has been proved by the sinking of wells in many directions on the Plains, some of them to considerable depths. In a well between the Ashburton and Rakaia, "where a supply of water was reached at a depth of 220 feet, the shingle at the bottom became much cleaner and incoherent, resembling the small shingle in the Rakaia river-bed" [53, p. 473].

All over the plains water is found at a greater or less depth below the surface, the depth varying according to the locality, the dryness of the season, the condition of neighbouring rivers, &c. In a great many places this water is found within about 30 feet of the surface, and can hence be brought up by suction-pumps; in some cases, however, as in the one quoted above, water is not found until a depth of 200 feet or more is reached. These underground waters can percolate through the river-shingle of which the plains are composed with considerable freedom; thus whenever a hole is dug to the water-bearing stratum, it is quickly filled by the water running in from the shingle all around: the various wells at Eyreton, again, are quickly affected by the state of the river Eyre, which is from one to three or more miles distant from them; thus if the water in these wells has sunk owing to drought when the river continues dry, it quickly rises again when the river is in flood. Evidently a considerable quantity of the water of the Eyre and of other rivers flowing across the Canterbury Plains must leak away through the loose sand and shingle in their beds, and go to supply the subterranean waters. The Canterbury rivers are so rapid and so frequently in flood that they are continually washing away parts of their beds, and thus opening up a way for the water to escape through the loose shingle thus exposed, and there is no opportunity given for such openings to be permanently closed by the finer sediment brought down by the rivers. It frequently happens that in the bed of the river Eyre, some five or ten miles above East Eyreton, towards the source of the river, there is a considerable quantity of water, while the whole of this, except of course that lost by evaporation, sinks into the ground before Eyreton is reached, so that there the river-bed is quite dry.

The subterranean waters, instead of being evenly spread over a whole district, often no doubt form more or less distinct streams, and probably different streams arising from different sources may be found one below another; thus Mr. Smith says that in the sections of the Canterbury Plains exposed at the mouths of the Rangitata and Ashburton rivers, subterranean streams may be seen to flow out at various heights in considerable volume and force. These different streams are no doubt separated by harder and more impervious strata, and they will have different sources; some of them will, perhaps, obtain their supply of water from the leakage that takes place at the foot of the hills owing to the break of the continuity of the strata of the plain.

In his Presidential Address to Section E at the Christchurch Meeting of the Australasian Association, Mr. G. S. Griffiths [52] has given a number of facts about the subterranean waters of a part of Australia which it will be interesting to compare with what we know of those of Canterbury. Speaking of the artesian wells which are being sunk on the back blocks from the centre of Queensland down towards the mouth of the Murray, he says:—"The chief sources of these water-supplies must be looked for in the great eastern cordillera, which sheds the surface streams that also cross Riverina. Along its crests the rainfall is of course greatest, being from 20 in. to 40 in. per annum in the Queensland portion; and it is near to the long ribbon-shaped region of heaviest rainfall —that is, along the sides of the watershed—that the superficial deposits, being largely composed of gravel and rock *débris*, are most pervious. Further, the continuity of the strata of the plains is broken at the hill-foot, where they die out against the outcropping rocks of the main range, and this line of break affords to the water flowing down the hills a ready passage beneath the sediments of the plains.

"Under these circumstances a large proportion of the rain caught on the ranges leaks under the subsoil directly it falls, and it flows to the sea slowly indeed, but with its volume undiminished either by the evaporation which lowers the surface waters of the Riverina 6 ft. per annum, or by the demands of vegetation, which are much greater upon river-water than the public has any idea of.

"As these subterranean waters travel away from their sources they must thin out.... But it appears to me that in every district of any size there must be deeper channels in that ancient land-surface which is now the bed-rock or reef of the miner.....

"These underground watercourses, or, as the miner would describe them, these wet leads, will run out into the plains for greater distances than a hundred miles. Indeed, when we remember that the streams are undiminished by evaporation or the demands of vegetation, and that they have been the recipients of all the leakage of the hills throughout all the ages that have passed since the sea retired, it appears to me that the deeper leads must be saturated with water right through from the mountain-foot to the Australian Bight. For, however slow the circulation of the system may be, as the water has never ceased to run in at the upper ends of the region, and as it does not rise to the surface as springs, it must run out at the lower end into the sea, escaping in the form of submarine springs. As a matter of fact, along the south coast of Australia, between Warrnambool and the Murray mouth, the sea literally bubbles up with fresh water which has leaked up through the sea-sands" [52, pp. 235, 236].

Doubtless a large portion of the deeper underground waters of the Canterbury Plains escapes into the sea in the same way by submarine springs, for in many cases they are known to be much below the sea-level. Thus the water-bearing stratum that supplies the ordinary artesians of Christchurch is, at the coast at New Brighton, 136 feet below the surface, and there is another stratum below at about twice that depth [63, p. 33]. Other portions of these underground waters in Canterbury rise to the surface, before reaching the sea, as springs, like those which form the source of the river Avon near Christchurch.

Facts like those quoted above from Mr. Griffith's address, and the widespread distribution of the subterranean genus *Niphargus* in Europe, and of the closely-allied genus *Crangonyx* in North America and elsewhere, remind us of what might otherwise be overlooked, viz. the universality and great extent of underground waters. An instructive example is given by Wallace in his 'Malay Archipelago':—

"The little island of Kilwaru is a mere sandbank, just large enough to contain a small village, and situated between the islands of Ceram-laut and Kissa—straits about a third of a mile wide separating it from each of them. It is surrounded by coral-reefs, and offers good anchorage in both monsoons. Though not more than fifty yards across, and not elevated more than three or four feet above the highest tides, it has wells of excellent drinking-water—a singular phenomenon, which would seem to imply deep-seated subterranean channels connecting it with other islands" [114, pp. 375–6].

Many similar facts have been brought to light in connection with the boring of artesian wells, and some of these will be found collected in Lyell's 'Principles of Geology' [76, vol. i. p. 385 &c.], where it is shown not only that the underground waters extend to great depths, often far below the level of the ocean, but that various distinct sheets of water may be met with, one below another, five distinct sheets having been intersected in a well at St. Ouen, in France [76, vol. i. p. 389]. Lyell also gives some examples showing that there are often open passages by which the subterranean waters circulate. Thus, in a well at Tours, from a depth of 364 feet, there were brought up a freshwater shell, some land species, some seeds of plants and other vegetable matter, all of which, it was supposed, had flowed from some valleys of Auvergne or Vivarais, distant about 150 miles, since the preceding autumn. After giving other examples of a similar kind, Lyell says, "we see evidence of the water not having been simply filtered through porous rock, but having flowed through continuous underground channels. Such examples suggest the idea that the leaky beds of rivers are often the feeders of springs" [76, vol. i. p. 391].

Professor Forel, in considering the origin of the blind *Niphargus Forelii* and *Asellus Forelii*, comes to the conclusion that they have originated, not in the lakes themselves, but in the underground waters, and he gives various interesting facts showing the communication that must exist between these waters and the deep waters of the lakes [40, pp. 182–183 &c.]. The same thing is found in North America, for some of the blind cave-species, *Cæcidotæa stygia* for example, are obtained from wells in various districts, showing that they exist widely spread in the underground waters, and not merely in the caves themselves. It is possible that some of the species, perhaps *Cæcidotæa stygia*, may have originated in the underground waters, and not actually in the caves, thus forming an exact parallel to the case of *Asellus Forelii* in the Swiss lakes.

It will not be necessary to bring forward any additional facts to show that there must be abundant opportunities by which specimens of the freshwater fauna of any country might be carried into the underground waters which almost everywhere exist, and thus have a chance of giving rise to subterranean species.

In the case of the Canterbury Plains, the subterranean waters have almost everywhere sunk several feet further from the surface of the land during recent years, owing to a succession of exceptionally dry seasons. Thus at Eyreton the level of the water has sunk on an average about 10 or 12 feet; Miss Young tells me that it has sunk also at Winchester, and that the well there, from which subterranean Crustacea have been obtained, has had to be deepened, and it will be seen from the following interesting account, prepared by Mr. W. W. Smith, that the lowering of the water has been very marked at Ashburton:—

"Previous to the years 1890 and 1891 no lowering or discoloration of the subterranean water was observed on the plains, at least there are no records of such existing. The water in the pipe-wells and in the outflowing streams at the base of the terraces of the Ashburton river, and also in the surface springs on the plains, remained constant at all seasons and perfectly pure. As the drought increased, the water in the pipe-wells lowered, and left them all, with one exception, dry. Near one house a large surface spring rose in a small gully, and discharged a heavy flow of cool pure water. It began to diminish in volume in October 1890, and by the December following it had ceased to flow. The terrace springs, situated 25 feet lower, held out several months longer, and they in turn gradually became dry. Half a mile below Ashburton a large strong-flowing spring exists right in the river-bed; it is distant about a quarter of a mile from the nearest terrace, and situated 12 feet below it. It flows out of a partially conglomerated bed of small stones and clay, and unquestionably belongs to a lower stratum or stream of water than those supplying the pipe-wells in the town. The water in this spring is never affected in volume or colour by the flooding of the river, but retains its purity at all seasons. The nearest terrace is 12 feet above it, and is composed chiefly of clay. It is only a few feet above the stratum of water which supplies the wells in the town. Before the drought several springs arose at the base of the terrace, none of which, nor any of the surface-springs, have at present recommenced to flow.

"I may mention that Mr. W. F. Dolman, a practical well-sinker in business here, informed me that there is no question about the water flowing between the various strata or irregular beds of shingle and sand composing the plains, at least in the Ashburton district. Some of the beds are intensely hard and extremely difficult to pierce with the steel-pointed pipes. After the lowering of the water, Mr. Dolman ascertained when driving the pipes to unusual depths that the pipe frequently entered 'dry-beds,' and he had either to draw up or lower the pipe to tap the water. The deepest well he has driven is 65 feet, and it has continued to give a good flow ever since it was driven. Mr. Dolman states that there is no limit, so far as he knows, to the depth the water is found in the plains, although it flows in thinner or shallower streams the lower he sinks. Referring to the discoloration of some streams, he informed me that he has found small round particles of clay in the water, and he attributes its discoloration to these floating particles. When sinking open wells, Mr. Dolman has occasionally observed the direction and rate at which the subterranean water flows. He estimates its motion at from one-quarter to one-half a mile an hour. One important fact he has several times ascertained, when driving the pipes through the lower and harder beds, is the rising of the water in the pipe to various heights from the newly-tapped stream. He has known it to rise from 2 feet to 14 feet, and afterwards to remain permanent. There is considerable difference in the work of sinking the various wells—some are put down in a few hours, the pipes driving freely, and others require as many days, and this sometimes with a heavier 'monkey' at work. These facts can be better studied by an examination of the high sections of the plains at the mouths of the Rangitata and the Ashburton Rivers.

"The exceptional well I have mentioned, which did not become dry, is driven 27 feet, and is in a low-lying part of the town. Nearly all the pipe-wells originally driven were sunk to various depths, ranging from 15 feet to 22 feet. These, without any exception, became dry."

VII. Origin of the Subterranean Crustacea.

In considering the source from which the subterranean Crustacea have been derived, it will be well to state first what little is known of the freshwater forms of the Amphipoda and Isopoda found in New Zealand and Australia.

In New Zealand only one freshwater Isopod is known, *Idotea lacustris*, G. M. Thomson [21, p. 263], and this one has no connection whatever with the subterranean fauna. In Australia, however, a species of *Phreatoicus* is known, *P. australis* [26], as yet found only on the top of Mt. Kosciusko, about 6000 feet above the sea. In the Amphipoda we have two freshwater species recorded from New Zealand. One, *Calliopius fluviatilis*, is very common in almost all running streams of the South Island; but is also found in various places in Otago Harbour, in water that is quite salt. This species is very abundant in the surface-streams of the Canterbury Plains, in the localities where the subterranean forms also abound; but, as I have already pointed out, although it approaches *Calliopius subterraneus*, it is dissimilar in several respects, and it does not seem at all likely that *C. subterraneus* is directly descended from it. The other species is *Pherusa cærulea*, G. M. Thomson [107, p. 206], found by Mr. Thomson on the top of the Old Man Range, 3000 feet, in Otago, and as yet known from this locality only. I have compared this species in some detail with *Calliopius subterraneus* (see above, p. 235), and have shown that in many points the resemblance is very great, and that most probably *Pherusa cærulea* and *Calliopius subterraneus* are both descended from a species formerly widely spread in New Zealand.

This is all that is as yet known of the freshwater Amphipoda and Isopoda; but it must be remembered that our knowledge of the subject is very imperfect, and that careful search of other streams, especially in the mountainous parts, will probably reveal other forms. As an example, I may mention that until lately *Idotea lacustris* was known only from the Tomahawk Lagoon near Dunedin, a lagoon situated very close to the sea; I have, however, since collected a variety of the same species in great abundance in the streams, up to a height of about 1000 feet, around Mt. Mihiwaka, between Port Chalmers and Blueskin, as well as in streams some five or six miles distant, and on the other side of the Waitati valley [21, p. 263]. In the same situations I have also taken another Amphipod, at present undescribed; this, however, appears to belong to the genus *Hyalella*, and throws no light on the origin of any of the subterranean forms.

No freshwater Amphipoda have been described from Australia, but in January 1892 Mr. Thomson collected two species on Mt. Wellington, near Hobart, Tasmania, and examples of both species have since been kindly supplied to me by Mr. Alex. Morton, of the Tasmanian Museum. They are being examined by Mr. Thomson and have not yet been fully worked out. One is a rather large species, and seems to belong to *Niphargus* in its general structure and in the uropoda, though the terminal uropoda are not very long. The other species, which is smaller, and comes from the top of Mt. Wellington, about 4000 feet high, also seems to approach very closely to *Niphargus*, though very different from the preceding species in general appearance; it closely resembles that species in the antennæ, the mouth-parts, and the gnathopoda, which are subequal, and have the propodos subquadrate, as in most species of *Niphargus*; the telson also is deeply cleft, not double, and bears stout spines on the hinder margin of each lobe, as in *Niphargus*; the body, however, is not slender, but rather compact, and the third uropods, though consisting of a very small inner branch and a longer two-jointed outer branch, are not elongated, and the second joint of the outer branch is very small, so that in these respects the animal resembles *Crangonyx* rather than *Niphargus*. It is, however, very different from *Crangonyx compactus* in the gnathopoda, the side-plates, the base of the peræopoda and the pleopoda, and of course also in the telson. However, the species presents a nearer approach to both *Niphargus* and *Crangonyx* than any form at present found in the surface-streams of Europe, and it is interesting, because it shows the wide distribution of forms similar to those from which *Niphargus* and *Crangonyx* must have been derived *.

The question of the origin of the subterranean Crustacea has from the first given rise to much discussion and to the most diverse opinions. Unfortunately, too, the question has been obscured by some of the conclusions being based on insufficient facts, and by some of the facts themselves being at first incorrectly stated, as, for example, the affinities of *Cæcidotæa*.

The explanation that most readily offers itself is that the subterranean Crustacea are

* This species Mr. Thomson has named *Niphargus montanus*, sp. nov.; the one previously mentioned he calls *Niphargus Mortoni*, sp. nov., though he tells me he does not feel satisfied about placing it in the genus *Niphargus*.

direct descendants from those now living in fresh waters on the surface of the earth. This view has been strongly upheld by some—by Fries, among others—and appeared to receive some support from the fact that specimens of *Gammarus fossarum*, kept in darkness during the winter, lost to some extent the pigment of the eyes, thus showing some approach to the blind *Niphargi*. I shall refer to this again later on.

Others, again, confining their attention more particularly to the special affinities of one or two genera of the subterranean Crustacea, have pointed out that, in place of being allied to freshwater forms, they more closely resemble marine forms, some of which are inhabitants of deep water. Thus Spence Bate states that *Niphargus* resembles the marine *Eriopis* much more than the freshwater *Gammarus* [4, p. 314], and that *Crangonyx* appears to have its nearest ally in the marine *Gammarella* [4, p. 326]. This resemblance of the subterranean forms to members of the marine fauna appeared at first to receive some confirmation from the unfortunate name *Cæcidotæa* [81] given to the blind Isopods from the North-American caves, and from the mistaken ideas as to its affinities; and, misled by this and by the very imperfect knowledge of the freshwater Crustacea of New Zealand, I have also stated that the subterranean Crustacea of New Zealand appeared to have been derived from a marine source [23, p. 88]. No doubt the subterranean Crustacea, as well as the freshwater forms, have originally sprung from forms inhabiting the sea, but from the fuller array of facts now before us there can be no doubt that they have not been derived directly from these, but from a freshwater fauna. *Niphargus* and *Crangonyx* may, perhaps, show affinities to marine forms, and there certainly does not appear to be any closely-allied form now inhabiting the surface fresh waters of Europe; but in North America various species of *Crangonyx* are found in surface-streams, &c., and the fact that a closely-allied form is found in the fresh waters of Tasmania seems to show that the genus has probably been at one time widely spread in the freshwaters of the globe. *Cæcidotæa* is really a very close ally of the freshwater *Asellus*, species of which are found in the streams of both Europe and North America, with representative subterranean forms in both places. Professor S. I. Smith, in view of the fact that the Crustaceans have several times been referred to as indicating the partially marine origin of the cave-fauna of the Western States of North America, has considered their affinities in detail, and points out that, looking at the Crustaceans alone, there is "no reason for supposing that the fauna of the caves of Kentucky and Indiana has been derived from any other source than the recent fauna of the surface of the neighbouring region" [104]. The fuller knowledge that we now possess forces us to a somewhat similar conclusion with regard to the subterranean fauna of New Zealand, though here our knowledge is not so complete. The New-Zealand forms at present known are six in number—*Gammarus fragilis*, *Crangonyx compactus*, *Calliopius subterraneus*, *Cruregens fontanus*, *Phreatoicus typicus*, and *Phreatoicus assimilis*; and if we consider in turn the freshwater allies of these, we find the following facts:—No freshwater species of *Gammarus* is known from New Zealand or Australia as yet, but the genus is one very widely distributed and has freshwater species in other parts of the world; *Crangonyx*, as has been already pointed out, appears to be exclusively confined to fresh water, species are known either from surface-streams or from caves and wells in England (*C. subterraneus*), Italy (*C. pungens*), North America (*C. gracilis*, *C. vitreus*, &c.), Kamtschatka (*C. Ermanni*), New Zealand (*C. compactus*), and a form more or less closely allied still inhabits the fresh waters of Tasmania; *Calliopius subterraneus* appears to have its nearest ally in *Pherusa cærulea*, found in a stream on the top of mountains 3000 feet high in Otago, New Zealand, while another species (*Calliopius fluviatilis*), which perhaps belongs to the same genus, is very abundant in the freshwater streams of the South Island of New Zealand; no freshwater form at all approaching *Cruregens* is as yet known; besides the two subterranean species, the only other known species of *Phreatoicus* is found on the top of the Mt. Kosciusko Plateau in Australia, living in pools and streams.

It will thus be seen that there is no difficulty in supposing that the subterranean fauna of New Zealand has been derived directly from a freshwater fauna, and when we consider the affinities of the general fauna of the North-American caves as given by Packard [83], or of the various European caves, there can no longer be any doubt that the cave- and well-fauna has been derived from the surface-fauna of the neighbourhood.

While this conclusion thus appears to be well founded, it by no means follows that the subterranean fauna is necessarily derived from the freshwater fauna *at present* inhabiting the surface-streams and lakes; indeed there are several facts which seem to show that some species at any rate are derived from a more ancient surface-fauna. Thus, while the subterranean species *Asellus cavaticus* may perhaps be the direct descendant of the surface-species *A. aquaticus*, there is no doubt that *Niphargus* is not a mere modified form of any of the surface-inhabiting *Gammari* at present found in Europe. Wrześniowski has clearly pointed out that experiments like those made by Fries and observations on pale forms of *Gammarus* found in mines, &c., like the one described by Schneider, do not bear on the question, for the specimens approach *Niphargus* only in the pale body and in the partial loss of the eyes while still retaining the general build and characteristic mouth-parts, &c., of *Gammarus*. As to the actual origin of *Gammarus* and *Niphargus* we are, he says, quite in the dark; but he is of opinion that neither is derived from the other, but both from a common ancestor. Humbert had previously come to much the same conclusion and is of opinion that *Niphargus* is an ancient genus derived from a form now extinct.

The Crayfish inhabiting the caves of North America also appear to be more ancient than those at present found in the surface-water of the neighbourhood. Speaking of *Cambarus pellucidus*, Professor Faxon says it "is a very aberrant species, with no very closely related form outside the cave. The simple form of the male appendages, and the combination of characters belonging to different groups, seen in *C. pellucidus*, indicate, to my mind, that it is a very ancient form, which has been preserved in the seclusion of the cave, whilst its nearest kin succumbed in the sharper struggle incident to life outside, or were replaced by modified descendants evolved to meet the changeable conditions which obtain without the caverns" [37, p. 42].

This view is, he says, confirmed by the fact that the same form, *C. pellucidus*, is found in caves on both sides of that ancient river, the Ohio, and by the discovery by Gustav Joseph of a species of *Cambarus* in the caves of Carniola in Southern Austria. As the present Crayfish of Europe belong to a different genus, *Astacus*, Professor Faxon looks upon the existence of a *Cambarus* in the Carniolan caves (if the species really belongs to that genus) as evidence of the former existence of the genus *Cambarus* in the rivers of Europe [37, p. 42]. In connection with the latter point it is as well to mention that Packard has stated that Joseph's species, *Cambarus stygius*, is based only on a single dry specimen from one cave and remains of the forceps of another specimen from another cave, and that "it seems premature to draw conclusions from such limited facts" [83, p. 119, footnote].

Passing on to the New-Zealand forms we find that although six species are known from the underground waters of the Canterbury Plains, only one, *Calliopius fluviatilis*, G. M. Thomson, is found in the surface-waters of the neighbourhood, and that this species, though allied to some extent to *Calliopius subterraneus*, is dissimilar in several points, and certainly not so close to it as is *Pherusa cærulea* *. It would therefore seem that the subterranean forms are more ancient than the present surface-fauna of the Canterbury Plains; and this is confirmed by the fact that their nearest allies are found in remote situations. Thus *Pherusa cærulea*, the nearest ally of *Calliopius subterraneus*, is known only from one situation on the top of a mountain between 200 and 300 miles distant; no allies of *Gammarus fragilis* nor of *Cruregens fontanus* are known from the fresh waters of the southern hemisphere; *Crangonyx compactus* has its nearest allies in Europe and North America; while *Phreatoicus*, which is proved to be an ancient form by the possession of characters common to several families, appears to have been preserved only in the subterranean waters of New Zealand and on the top of Mt. Kosciusko in Australia.

Although it is thus probably true that some species of the subterranean fauna are ancient forms that have long since taken up their abode in the underground waters, we should naturally expect to find others, especially in the fauna of caves, that have much more lately adopted a cave life and are the direct descendants of surface-species still inhabiting the neighbourhood. Such specimens we undoubtedly do find, and they appear also to show several stages or transitions from surface-forms accidentally carried into the caves up to true cave-inhabiting forms. Thus in the caves of America among others the surface-forms *Cambarus Bartonii* [83, p. 40] and *Asellus communis* [83, p. 33] have been found, the specimens of these being more or less bleached and much paler in colour than the ordinary surface-forms; again, the cave Myriopod *Pseudotremia cavernarum* is, Packard says, only a modified form of the widely diffused *Lysiopetalum lactarium*, Say, and various other examples of the same kind are also to be found in Packard's work.

In the same way Schneider has described a subterranean variety of *Gammarus pulex*, found in mines at Clausthal, which differs from the normal forms of that genus in its pale colour, the partial degeneration of the eye, and the lengthening of the anterior antennæ [96]. Moniez also has found in the reservoir at Emmerin in the north of France a single specimen of a *Gammarus* which has been modified in much the same way as the

* I have already pointed out, p. 234, that *Calliopius subterraneus* should perhaps be transferred to *Pherusa*, but that for the present I have left it in the genus in which it was originally placed, as the limits of these two and other allied genera appear to me to need fresh and careful definition.

variety described by Schneider, forming to some extent a link between this variety and the surface-type, though approaching again towards *Gammarus fluviatilis*, while Schneider's variety seems to come from *Gammarus pulex* [78, p. 40]. These examples are sufficient to make it clear that the subterranean fauna of any country is not always to be looked upon as a whole, but that the different species have in many cases adopted the subterranean life at different times, and that under favourable circumstances the subterranean forms may even at the present time be reinforced by immigrants from the surface. It is, however, obvious that transitional forms of the kind spoken of above will be much more common in caves than in underground waters, for the means of entrance will usually be greater, and immigrants from the surface will have to struggle with the forms that have already become adapted to a subterranean life, and will hence find it difficult to establish themselves unless they should happen to be carried into regions not already peopled. This is probably the reason why the subterranean Amphipod fauna of Europe is so fixed in character and uniform as it is, and why the subterranean species sometimes belong to such ancient forms.

In the case of the New-Zealand forms it is rather rash to speculate, but, considering the similarity of conditions all over the Canterbury Plains and the fact that all the known species, with the exception of *Phreatoicus assimilis*, are found together in the same stratum of water at Eyreton, it seems probable that all the forms adopted the subterranean life at about the same time, and that they are not now being reinforced by fresh immigrants from the surface. This is not for want of opportunities (for I have shown above, on p. 249 *et seq.*, that there are doubtless many ways by which the surface-forms can gain access to the underground waters), but because the surface-fauna from which the subterranean forms were derived no longer exists in its entirety. If it still exists at all it will doubtless be found preserved in mountainous situations in the same way as *Pherusa cærulea* and *Phreatoicus australis*.

The deep-water fauna of the sea and especially of freshwater lakes presents many resemblances to the subterranean fauna. The deep-water fauna of the Swiss Lakes, as described by Professor Forel [40], is particularly interesting in this connection, as it contains two species at least which also belong to the subterranean fauna, viz. *Niphargus Forelii* (= *N. puteanus*, Koch, var. *Forelii*, Humbert) and *Asellus Forelii*, Blanc. In considering the origin of this deep-water fauna Professor Forel comes to the conclusion that the greater part of it is derived from the littoral fauna of the lakes themselves, the animals having descended to greater or less depths, and having become more or less modified accordingly, and he also points out that every year new immigrants come to renew the deep-water fauna, just as we saw probably happens with the cave-fauna. With regard to the two species mentioned above, however, the case is different, and after a very long and full discussion of the whole problem [40, pp. 170–183] he decides that these come, not from the littoral fauna, but from the subterranean fauna that is so widespread throughout Europe. This confirms the conclusion of Humbert, Wrześniowski, and others, that *Niphargus* is not the direct descendant of *Gammarus pulex* of the surface. The latter species is found in the littoral fauna of the lakes and sometimes extends to deep water; but though it may be somewhat modified as regards colour, eyes, &c.,

it still preserves the distinguishing marks of *Gammarus* and shows no approach in structure to *Niphargus*. Professor Forel points out that there must be means of communication—not necessarily permanent—between the subterranean waters and the deep waters of the lakes and also between the subterranean waters of different localities, thus fully confirming what I had already written above on p. 258 before I had read Professor Forel's remarks on the subject.

VIII. The Special Characteristics of the Subterranean Fauna.

The special conditions of cave- and well-life and the peculiarities of the subterranean fauna have been discussed more or less elaborately by many authors, and a complete dissertation on the subject would require a volume to itself. All that can be done here is to mention a few points upon which information is supplied by the six subterranean Crustacea described in this paper. The subject has been fully discussed by Schiödte, Joseph, and Packard; and Forel has considered the conditions of life in the deep waters of the Swiss Lakes, the fauna of which presents many analogies to that of the underground waters.

Colour.

The effect of the absence of light on the colour of all animals living in caves and in underground waters seems to be very uniform, all such permanent residents being bleached and colourless. Speaking of the inhabitants of caves, Packard says:—"As regards change of colour, we do not recall an exception to the general law, that all cave-animals are either colourless or nearly white, or, as in the case of Arachnida and insects, much paler than their out-of-door relatives" [83, p. 117].

The same statement might be made concerning the inhabitants of underground waters, different authors speaking of them as "colourless," "snow-white," "translucent," &c. The Crustacea are usually more or less translucent, vitreous, and pellucid, though by no means so much so as pelagic members of the same group. The six species dealt with in this paper may be described as white or colourless, more or less translucent. I have sometimes noticed a slight pink or rosy tint on the body of *Calliopius subterraneus*, which is most apparent in female specimens bearing eggs, and then appears to arise chiefly from the yolk of the eggs themselves; the "liver"-tubes of *Cruregens fontanus*, which can easily be seen through the transparent integument, are of a very pale yellow colour, and the tip of the dactylos of the first pair of appendages of the peræon (gnathopoda) is of a very distinct but light brown.

The subterranean worm *Phreodrilus subterraneus*, Beddard, is stated by Mr. Smith (quoted by Beddard [8, p. 273]) to be "fleshy red" during life. This is chiefly due to the red colour of the fluid in the various vessels of the vascular system, the integument and the greater part of the body being colourless; this was plainly seen in a very fine specimen that Mr. Smith kindly sent alive to me in September 1892.

Professor S. I. Smith has pointed out that the deep-sea Crustacea present a marked contrast to cave Crustacea in colour. In a general account of the Crustacea of the

'Albatross' dredgings in 1883 [105] he points out that the colour of these deep-sea forms is very striking. A few are nearly colourless, but the majority are some shade of red or orange. A few species (100 to 300 fathoms) are conspicuously marked with scarlet or vermilion, but such markings were not noticed in any species from below 1000 fathoms. Below this, orange-red of varying intensity is apparently the most common colour. He also shows that some of the species ranging down to 2000 fathoms possess eyes, some of them as well developed as in corresponding shallow-water forms. Summing up these facts he says:—

"However strong may be the arguments of the physicists against the possibility of light penetrating the depths from which these animals come, the colour and the structure of their eyes, as compared with blind cave-dwelling species, show conclusively that the darkness beneath 2000 fathoms of water is very different from that of ordinary caverns. While it may be possible that this modification of the darkness of the ocean abysses is due to phosphorescence of the animals themselves, it does not seem probable that it is wholly due to this cause" [105, p. 56].

I wished to test this conclusion by studying the colour of animals found in the deep waters of lakes, such as those of Switzerland, but, unfortunately, the facts that I find ready to hand are not very conclusive either way. In considering the modifications undergone by the deep-water species, Forel says under the head "Pigmentation":— "La couleur est généralement plus claire dans les espèces littorales" [40, p. 167]. He also states that Du Plessis has noticed a rosy colour in some Turbellarians from the deep waters, which is not found in those of the littoral region. There does not, however, appear to be a prevailing red or orange tint at all comparable to that which has been noticed by Smith in deep-water marine Crustacea, or special attention would have been drawn to it by Forel; but, again, the species of Crustacea found in the deep waters of the Swiss Lakes are very few in number compared with those in the deep waters of the sea, and there are none of the larger forms like those examined by Smith, so that there is scarcely a sufficient basis for a comparison of any value. Forel describes *Niphargus Forelii* as "blanchâtre avec des teintes rosées," and *Asellus Forelii* as "d'un blanc grisâtre, sale" [40, pp. 112, 113].

On the whole, however, the colour of the animals in the deep waters of the Swiss Lakes appears to resemble that of the animals in caves and underground waters rather than that of the inhabitants of the deep waters of the ocean; and this would incline us to imagine that the difference in colour between the two last-mentioned is due to some differences of chemical composition rather than to the presence or absence of light.

Loss of Eyes.

In all animals inhabiting caves and underground waters the eyes appear to undergo more or less degeneration. Schneider has described the commencement of such degeneration in *Gammarus pulex*, var. *subterraneus* [96], and in *Asellus aquaticus*, var. *freibergensis* [97], and Moniez in *Gammarus fluviatilis*, var. *d'Emmerin* [78, p. 39]. Packard, who has considered the subject very fully in connection with the inhabitants of the North-American caves, in which all stages of degeneration are met with, thus sums up the effects of the loss of sight on the eyes and optic lobes:—

"1. Total atrophy of optic lobes and optic nerves, with or without the persistence in part of the pigment or retina and the crystalline lens (*Cæcidotæa, Crangonyx, Chthonius, Adelops, Pseudotremia*).

"2. Persistence of the optic lobes and optic nerves, but total atrophy of the rods and cones, retina (pigment), and facets (*Oronectes*).

"3. Total atrophy of the optic lobes, optic nerves, and all the optic elements, including rods and cones, retina (pigment), and facets (*Anophthalmus, Scoterpes*, and ? *Anthrobia*)" [83, p. 118].

He also points out that we never find any rudiments of the optic lobes and optic nerves; if they are wanting at all they are totally abolished; while, "on the other hand, we have series, as in *Cæcidotæa* or *Chthonius*, where there is but a single, or two or three, or several crystalline lenses, partially enveloped in pigment" [83, p. 118]. He lays stress on these facts as opposed to what he calls the "invariably slow action involved in pure Darwinism."

Many conflicting statements have been made by different authors as to the presence or absence of the eyes of the European species *Niphargus puteanus*, and in consequence it was fully investigated by Leydig, who found "that the optic ganglion is present, but not the eye, though pigment-spots mimicking the eye have led some observers to believe that an eye existed in fact" [quoted from Stebbing, 108, p. 481].

While this may no doubt be quite true of the specimens observed by Leydig, it appears from Packard's results that the external eye may be represented in varying degrees of completeness in different specimens of the same species; and that being so, there is no ground for refusing to believe that it may be altogether absent in some, though present (more or less imperfectly) in others. Forel, too, has pointed out that the blindness of *Asellus Forelii*, Blanc, is not without exception; two specimens taken near Morges and Ouchy, at depths of 200 m. and 300 m., presented rudiments of eyes, whilst all other specimens taken up to that time—even young taken from the brood-pouch of the female—were absolutely devoid of eyes [40, p. 114]. We can hardly suppose that Forel was deceived by mimicking pigment-spots in these two specimens only.

In the New Zealand subterranean Crustacea I have not been able to find any external trace of eyes except in the one species *Crangonyx compactus*, in which the eye is represented by two or three imperfect lenses apparently quite without pigment. In all the other species all trace of external eyes appears to be wanting. I regret that as yet I have had no opportunity of making sections to study the condition of the optic lobes and nerves.

Compensation for Loss of Eyesight.

Several authors have pointed out that in many species inhabiting the dark regions of caves or underground waters the loss of eyesight has been more or less compensated for by increased powers in the other senses—especially those of touch and smell. Many of the species are more slender and possess longer antennæ, legs, and other appendages than their surface-dwelling allies. In some cases the increased length of the antennæ, &c., would no doubt give greater tactile power; but it also appears probable that, in the case of species living in underground waters, the greater slenderness of the body has been acquired in order to adapt the animal for its life in the restricted spaces between the stones and shingle in which it has to live. This explanation is strongly suggested by a comparison of the two subterranean species of *Phreatoicus* with the surface-species *P. australis*.

The whole subject of the compensation for the loss of eyesight has been fully discussed by Packard [83, pp. 123–130], who has supplemented the anatomical descriptions with an account of what is known of the habits of some of the species. To this account I must refer the reader, and I shall only add here the few facts bearing on the same question that I have observed in the New-Zealand species.

In the two species of *Phreatoicus*, *P. typicus* and *P. assimilis*, the body is more slender and the antennæ and legs longer, especially in *P. typicus*, than in the surface-species *P. australis*, but I have not observed any marked increase in the number or size of the olfactory rods, nor have I observed any other sensory setæ like those found in some of the other species.

In *Cruregens fontanus* the antennæ are well supplied with olfactory rods, which appear to be more numerous and of greater length than in allied eyed species; besides these, other sensory setæ, like the "soies auditives" described by Sars, are found in considerable abundance on the antennæ, the various joints of the legs, and the uropoda. Similar setæ are found in the same places in eyed species of *Anthura*, *Paranthura*, &c., and Sars has figured them also in *Asellus aquaticus*, but they are rather more numerous and are longer in *Cruregens* than in the other species.

In *Crangonyx compactus* I have not noticed any increase in the number of sensory setæ beyond what we usually find in similar Amphipods; in this species, too, the body is compact and not elongated as in some other species, and the legs are only of the usual length.

In *Gammarus fragilis* the body is slender, and the antennæ, peræopoda, and terminal uropoda are much elongated. On the peræopoda, the last three pairs of which are of great length, setæ somewhat like the "soies auditives" occur in most of the tufts of setæ found on the various joints, but with this exception there does not appear to be any increase of sensory setæ beyond what we usually find in species of *Gammarus*.

In *Calliopius subterraneus* the body is rather more slender and the various limbs rather more elongated than in the closely allied species *Pherusa cærulea*. Numerous "soies auditives" are found at various places on the antennæ, which, in the male, are also abundantly supplied with "calceoli," which are no doubt also sensory in function. These, however, are also found in *Pherusa cærulea* and in *Calliopius fluviatilis*, and in some species described by Stebbing, such as *Eusiroides Cæsaris*, &c., the calceoli are quite as numerous as in *Calliopius subterraneus*.

On the whole the New-Zealand subterranean Crustacea give only a modified support to the conclusion that subterranean species are more abundantly supplied with sense-organs (other than eyes) than allied surface-animals. Probably the former have been more carefully examined than the majority of surface or marine species, and a fuller examination of the latter will perhaps show that many of them are as well supplied with sensory setæ as the subterranean species.

The Food of Subterranean Animals.

The source of the food-supply for the animals living in caves and underground waters is a question of much interest and of considerable difficulty. Almost all writers on the subject speak of the food-supply being very scanty, and yet the animals, though of course few in numbers compared with those living on the surface of the earth, are yet numerous, and when captured do not look particularly ill-fed. According to Packard [83, p. 24] the blind fish of the caves of North America probably live on the blind crayfish and the *Crangonyx*, and perhaps the *Cæcidotæa*, and the crayfish also lives on *Cæcidotæa*; so that, confining our attention to the Crustacea, the question is narrowed down to the food of *Crangonyx* and *Cæcidotæa*, viz. animals similar to those found in underground waters of the Canterbury Plains. As Packard points out:—"It goes without saying that there are no truly vegetable-eating animals living permanently in the caves; no plant-life exists (except in rare cases a very few fungi, and most of these probably carried in by man) in the caves on account of the total darkness" [83, p. 25].

Crangonyx and *Cæcidotæa* are hence probably mainly carnivorous, but what they find to eat is a great puzzle. Packard suggests that they may devour their own young; but what the young find to live on he considers still more difficult to conjecture, as rotifers, infusoria, and copepods are so very scarce. Cope, writing of the fauna of the Wyandotte Cave [30, p. 13], states:—"As to the small Crustaceans, little food is necessary to support their small economy, but even that little might be thought to be wanting, as we observe the clearness and limpidity of the water in which they dwell. Nevertheless, the fact that some cave-waters communicate with outside streams is a sufficient indication of the presence of vegetable life and vegetable débris in variable quantities at different times. Minute freshwater algæ no doubt occur there, the spores being brought in by external communication, while remains of larger forms, as confervæ &c., would occur plentifully after floods."

Still the supply imported in this way must be very scanty, and as an illustration of the general poverty of the food-supply in the caves Packard mentions that in the Wyandotte Cave the common Myriopod was found gathered around the hardened drops of tallow which strew the pathways of the cave *.

Concerning the food of the *Niphargus* found in the well at Ringwood, Hogan, quoted by Stebbing [108, p. 316], remarks:—"Some water drawn from the pump at Ringwood has been proved by microscopical examination to contain numerous animalcules; and this will probably turn out to be the case with all the waters in which *Niphargi* are found."

The facts bearing on this subject that I have observed in connection with the New-

* "The Cave-Beetles of Kentucky," American Naturalist, x. (1876) p. 285.

Zealand subterranean forms do not, I am afraid, help much toward a solution. The water in which they are found is very clear and pure, with very little sediment, and in almost all cases is used for drinking without being filtered. Some years ago Mr. George Gray, of the School of Agriculture, Lincoln, was kind enough to analyse some of the water from the Eyreton pump for me, and he found that the amount of organic matter in it was considerably below that allowed for a healthy drinking-water. Mr. Mayne, speaking of the Ashburton water, informs me that "it stands the permanganate of potash test." There appear to be very few Infusoria or Rotifera in it; certainly it could not be said to contain "numerous animalcules," as stated by Hogan of the water at Ringwood.

The intestinal canal of the various species is frequently full of a dark blackish or brownish material, but though I have frequently examined this I have not found anything in it that I could recognize except grains of sand and earth.

I have frequently kept specimens of some of the species in small freshwater aquaria, and in this have seen them apparently eating small filamentous algæ. In April, 1890, I put three specimens of *Cruregens fontanus* into a small bottle containing water taken from the Brighton Creek, near the sea; the water in this creek is often brackish, and has *Ruppia maritima* &c. growing in it, but at the time when I filled my bottle the water was quite fresh to the taste. In the bottle I had a small piece of *Ruppia maritima* growing, also various filamentous algæ, and no doubt plenty of Infusoria &c. In this the three specimens of *Cruregens* lived till the beginning of June, when one was lost sight of, a second one died at the beginning of August, and the third about the end of that month, having thus lived for about five months. During this time I frequently saw them seize pieces of the algæ with their gnathopoda, but I could never make quite certain whether they ate them or not.

The mouth of *Cruregens*, like that of the other Anthuridæ, appears to be suctorial, but I can form no idea as to what the underground *Cruregens* sucks, unless it merely sucks up a great quantity of water, retaining any organic materials that it may contain; the maxillæ form lancet-organs, but I have never seen the animals using them for piercing the stems of the *Ruppia maritima* or for any similar purpose. So far as I am aware, we are equally ignorant of the use that the marine Anthuridæ make of their suctorial apparatus: from the structure of their mouths we should almost expect them to suck nutritive fluids from the bodies of other animals; but I have never heard of them doing this, and if they did we might reasonably expect some species at least to have permanently adopted a parasitic manner of life; the only parasitic species, however, known to me is *Eisothistos vermiformis*, Haswell [54, p. 1], which lives in the tubes of Serpulæ (*Vermilia*). Haswell says nothing about the structure of its mouth, and it is uncertain whether it actually derives its nourishment from the *Vermilia* or not. The other species are usually taken creeping freely on the surface of various sea-weeds, but whether they live upon these sea-weeds or not does not appear to be known.

Summing up, we are forced to admit that very little is as yet known as to the source of the food-supply of the subterranean Crustacea, and further observations on this point are very desirable. It must also be remembered that these animals may live for a long time with very little food; thus Dr. John Stoan states that a blind fish (*Amblyopsis spelæus*) lived for twenty months "without having taken any visible food" (see Packard [83, p. 127]).

Arrested Development.

The fauna of caves and underground regions presents us with several examples of what appears to be an arrest of development.

Packard has drawn attention to one example. Writing of the cave-dwelling Myriopod *Pseudotremia cavernarum*, and comparing it with the widely diffused *Lysiopetalum lactarium*, Say, he remarks:—"It differs in having only about half as many segments as in its out-of-door parent form (this diminution in the number of segments being due to arrest of development) . . ." [83, p. 120].

In our New-Zealand forms we have a good example of the same thing in *Cruregens fontanus*, which has the seventh segment of the peræon small and without appendages, as is the case in the young forms of many Isopods. It seems tolerably clear that we have here simply a case of arrested growth, and not a reversion to a true ancestral form, for while in the process of development of the embryo of the Isopoda the seventh pair of the appendages of the peræon are the last to be developed, I am not aware of any reason for supposing that the ancestors of the Isopoda ever possessed only six pairs of appendages to the peræon.

In remarking on this example, Aloïs Humbert quotes other cases observed by Heller. He states (Archives des Sciences naturelles, viii. [Sept. 1882] p. 267):—

"Nous rappellerons à ce sujet que le Dr. Camil Heller a décrit un genre cavernicole de Gloméride (*Trachysphæra*), se distinguant des *Glomeris* en ce qu'il ne possède que 11 segments au lieu de 12, et 15 paires de pattes au lieu de 17; le même auteur a fait connaître un autre Myriapode (*Brachydesmus*) provenant, comme le précédent, des grottes de la Carniole et ne différant des *Polydesmus* que parce qu'il n'a que 19 segments au lieu de 20, nombre normal chez les Polydesmides adultes. Si les *Trachysphæra Schmidtii* et *Brachydesmus subterraneus* ont été établis d'après des individus réellement adultes, ce que nous avons certaines raisons de croire, il y aurait chez ces deux Myriapodes un arrêt de développement tout-à-fait semblable à celui que M. Chilton vient d'observer aux antipodes chez son Crustacé souterrain."

M. Humbert attributes this arrest of development in cave-animals to the influence of darkness, the lack of sufficient food, and the other necessary conditions of their environment.

I have given above merely the examples of arrested development that are known to me; probably a full examination of the literature of the subject would show that many others have been recorded.

Habits.

In their habits in confinement the subterranean Crustacea seem to differ but little from their surface allies. Observations on their habits have been made by Hogan [59 and 60], Stebbing [108], Packard [83, pp. 123–130, &c.], and others. According to Hogan, quoted by Spence Bate [4, i. p. 321], *Niphargus fontanus* "soon dies if exposed to the light." This is certainly not my experience with the New-Zealand forms: I have kept all the species, except *Phreatoicus*, for longer or shorter periods in glass bottles, in which they could get no shelter, exposed to the full light of day; and if the water was properly aerated, they appeared to live without inconvenience. As stated above, species of *Cruregens fontanus* have thus lived for five months. In the same bottle I afterwards kept a specimen of *Gammarus fragilis*, which appeared quite at home, but then unfortunately died during an unsuccessful attempt to moult its exoskeleton. It had no shelter from the ordinary light of day, and made no attempt to hide itself; if placed so that the strong light of a lamp was focussed on to it by the convex surface of the bottle it, however, moved away. I did not notice anything peculiar in its habits; it usually crawled around at the bottom of the jar or along the stems of the plants in the bottle, but at times swam freely like ordinary Amphipods.

There is very little more to record concerning the habits of the *Cruregens*. The animals usually crawled about on the bottom or along the stems and leaves of the *Ruppia maritima*; they could not, however, crawl up the vertical sides of the bottle, the glass being too smooth for them; they ran backward and forward with equal rapidity, and did not seem particular which way they went; they did not swim, but if they dropped off the plant wriggled helplessly till they reached the bottom. I did not notice anything that would indicate any power of vision, but, on the other hand, often saw them running against objects in a way which seemed to indicate that they were totally blind; occasionally I have seen two approach very near each other, apparently without being aware of it, and then suddenly jump apart when one touched the other.

IX. The Bearings of the Phenomena of Subterranean Life on the Theory of Descent.

It has been early recognized that the phenomena of cave and subterranean life have an important bearing on the Theory of Descent. Here the conditions of life are so peculiar, so abnormal, the fauna so scanty, and its environment so simple and so restricted that we may naturally expect to find the problems that are to be solved presented to us in their simplest forms. Thus we have no vegetable life of any kind except a few fungi, only a comparatively small number of animals of various groups, and these surrounded by continual night and exposed to a temperature probably pretty uniform from year to year; in many cases we can tell, with at any rate a fair approach to accuracy, from what surface-species the underground species has descended; and knowing also, within certain limits, the age of the latter, we can estimate the changes undergone and consequently the rate at which these have been made in this particular instance.

The importance of *Isolation* in securing permanence of type in the case of cave-dwelling animals has been dwelt upon by Packard [83, pp. 140–141]. Similar remarks would apply with perhaps even greater force to the subterranean fauna, such as that of the underground waters of the Canterbury Plains, for it is probably even more completely isolated from the surface-fauna than is that of caves.

It is, however, with regard to the effects of the disuse of organs that the cave and subterranean fauna has been studied with the greatest interest, and here we closely approach the controversy between the Neo-Darwinians and the Neo-Lamarckians. While it would be utter presumption on the part of the writer to enter upon a discussion of this question, it will be interesting to review a few of the opinions expressed by various writers on the subject in so far as it is exemplified by the phenomena of subterranean life.

Darwin, in his 'Origin of Species' [35, pp. 110–112], after pointing out that in the case of the mole and similar burrowing animals natural selection will probably aid the effects of disuse in producing blindness, refers to the blind inhabitants of caves, and remarks:—"As it is difficult to imagine that eyes, though useless, could be in any way injurious to animals living in darkness, their total loss may be attributed to disuse" [35, p. 110].

Further on, after quoting Schiödte's observations as to animals, some of which are adapted to the twilight and others to the perfect darkness of caves, he observes:—"By the time that an animal had reached, after numberless generations, the deepest recesses, disuse will on this view have more or less perfectly obliterated its eyes, and natural selection will often have effected other changes, such as in increase in the length of the antennæ or palpi, as a compensation for blindness" [35, p. 111].

That animals living in darkness do as a general rule gradually lose their eyes is now a very familiar fact, and it no doubt appears at first sight simplest to explain this as an example of the effects of disuse; but there are numerous instances known of animals living in darkness that yet possess more or less perfect eyes, and unless these can be accounted for in some way they would appear to prove that the effect of darkness, *per se*, does not necessarily produce degeneration of the eyes. Semper, in his 'Animal Life' [99, pp. 76–87], after giving a number of examples of the loss of eyesight apparently through disuse, adds that "it would nevertheless be wholly false to assume that lack of light must necessarily lead to total or partial blindness" [99, p. 84]; he then proceeds to give examples of animals living in darkness with more or less perfect eyes, and on the contrary, of animals blind or half-blind, which yet "live in well-illuminated situations, where the moderate intensity of the light would allow them the full use of eyes." The examples given by Semper have been considered in detail by Packard [83, pp. 130–132], who points out that some, at any rate, of the first group are "twilight animals," living near the entrance of the caves as well as in the total darkness of the innermost recesses, and that those animals which live in total darkness may perhaps cross with those living near the entrance, and the eyes thus remain unimpaired. Other cases, in which our knowledge is not so complete, may, he considers, perhaps be explained in the same way; and with regard to the second group, *i. e.* blind or half-blind animals living in well-lighted situations, many may spend the greater part of their lives burrowing in the mud or in dark places where eyes would be of little or no service to them; in this way he explains the blind *Cymothoa* mentioned by Semper [99, p. 83] which he found in the full light of day.

Whilst some cases may perhaps be accounted for in this way, it does not seem to me that all, even of those mentioned by Semper, can be thus explained. Thus Packard appears to make no reference to the *Pinnotheres* mentioned by Semper [99, p. 80], the zoœa of which has well-developed eyes of the typical character, while the full-grown animals which live in the "water-lungs" of Holothurians "gradually become blind or half-blind; the brow grows forward over the eyes, and finally covers them so completely that, in the oldest individuals, not the slightest trace of them, or of the pigment, is to be seen through the thick skin; while at the same time the eyes seem to undergo a more or less extensive retrogressive metamorphosis" [99, p. 81].

Cases like this certainly seem to indicate, as Semper observes, "that the influence of darkness is proved to be direct in each individual, and not hereditary." Here we see that the eyes are preserved in the free swimming zoœa, where they are of service to the animal, but are gradually lost in the adult, where they are no longer required; and while this shows the powerful effects of disuse in the individual, it does not show that these effects are inherited without the intervention of Natural Selection, as appears to be assumed by Packard and others, who account for the blindness of cave animals by the *direct* effect of the darkness and the consequent disuse of the organs. If the characters thus acquired through disuse were necessarily inherited, we should expect to find the eyes of the zoœa of the *Pinnotheres* more or less imperfect.

Packard, who discusses the bearing of cave life on the Theory of Descent at considerable length, is thoroughly Neo-Lamarckian in his views, and sees little or no room for the operation of Natural Selection. Thus, on p. 121, he remarks :—

"Given great changes in the physical surroundings, inducing loss of eyes through disuse, the abolition in some cases of the optic ganglia and optic nerves, the elongation of the appendages, isolation from out-of-door allies, and the transmission by heredity owing to close in-and-in breeding within the narrow fixed limits of the cave, are not these collectively *veræ causæ*? Do they not fully account for the original variations and their fixation? In short, can we not clearly understand the mode of origin of cave species and genera? What room is there in a case like this, or in that of parasitic animals, for the operation of natural selection? The latter principle only plays, it has seemed to us, a very subordinate and final part in the set of causes inducing the origin of these forms" [83, p. 121].

If these modifications, however, were the direct inherited effect of the environment, *i. e.* darkness &c., should we not expect to find them similar in all animals subjected to the same conditions? The modifications might be greater in some instances than in others, in accordance with the varying lengths of time that the animals had lived under these conditions, but we should certainly expect that the development in all cases would be proceeding uniformly and in the same direction. Now it seems to me that we do not find this process demonstrated even in the facts adduced by Packard himself, but that there is a certain apparent capriciousness which is inconsistent with the constant and uniformly acting causes that he sets forth. Thus, in the case of the eyes, instead of the degeneration proceeding on similar lines in all individuals, we may have—:

(1) Total atrophy of optic lobes and optic nerves, with or without the persistence in part of the pigment or retina and the crystalline lens;

(2) Persistence of the optic lobes and optic nerves, but total atrophy of the rods and cones, retina (pigment), and facets; or

(3) Total atrophy of the optic lobes, optic nerves, and all the optic elements. [See 83, p. 118.]

If we consider the other modifications of the body, legs, antennæ, &c., which Packard also accounts for as "evidently the result of loss of sight" [83, p. 120], we still find the same capriciousness, and even in a more marked degree. Thus, taking our New Zealand forms, we find that *Cruregens fontanus* and *Calliopius subterraneus* have developed additional sensory setæ beyond what are usually to be found in their surface relatives, while apparently *Gammarus fragilis* and *Crangonyx compactus*, and certainly the two species of *Phreatoicus*, have not. Again, in the species of *Phreatoicus*, in *Gammarus fragilis*, and to a less degree in *Calliopius subterraneus* and *Cruregens fontanus*, the body, antennæ, and appendages are slender and elongated, while there is no sign of a similar modification in *Crangonyx compactus*, which has the body normally stout, the antennæ and legs of only moderate length, and the uropoda even somewhat short and stumpy.

Many similar examples could doubtless be adduced from a review of the underground fauna of other countries. Thus *Boruta tenebrarum* [124, pp. 677–687] does not appear to have the body particularly slender or the appendages elongated, while the species of *Niphargus* usually do possess these peculiarities; in *Niphargus* the outer branch of the third uropoda is greatly elongated, in *Gammarus fragilis* the peduncle and both branches of the third uropoda are similarly elongated, while again in *Crangonyx mucronatus*, Forbes, the elongation takes place, not in the third uropoda at all, but in the telson!

These examples, showing a development apparently capricious and varying in its direction in animals all subjected to the same or similar environment, appear to point rather to the action of Natural Selection seizing here upon one variation useful to the animal and there upon another, and fixing and maintaining these variations just as we find it doing in the more complicated phenomena of surface life. Packard refers to the cave Crustaceans as living "in a sphere where there is little, if any, occasion for struggling for existence between these organisms" [83, p. 110].

But surely here, as elsewhere, the animals tend to increase in a geometrical ratio, and, since all cannot live, must necessarily struggle among themselves for food, which is, as Packard points out, very scanty. The *Cæcidotea* and *Crangonyx* of the North-American caves are, Packard states, eaten by the blind crayfish, and must therefore "struggle," in the sense in which the word is used by Darwin, with their destroyer, and in this struggle they appear to have developed those additional olfactory setæ, &c., mentioned by Packard, which enable them more readily to escape their enemy. If they had no occasion for struggling for existence, why should these additional sense-organs be developed at all?

Packard does not appear to have considered the action of Natural Selection on the individuals of the same species, an action which results in the perfecting and maintaining in a state of perfection any organ that is of importance to the animal. It is, however, this action of Natural Selection which is of the most importance when we consider the case of the blind inhabitants of caves, &c., as has been clearly pointed out by Wallace [115, p. 413, &c.], Weismann [119, p. 90, &c.], &c. My former teacher, Professor Hutton, put it very clearly and impressively in his lectures when he said that Natural Selection consists not so much in the "*Survival of the Fittest*" as in the "*Non-survival of the Unfittest*"; and, as he proceeded to demonstrate, the difference between the two points of view is a real one, and not a mere question of words. Thus, in the case of any animal living in the full light, a certain degree of perfection of eyesight will be required by the animal in order to enable it to escape its enemies, obtain food, &c., and all individuals falling below this standard will perish; so that by the action of Natural Selection the eyesight of the animal will be kept in perfect adaptation to its environment. Now in the case of animals that have taken to living in dark caverns, &c., the eyesight, being no longer of use to the animal, will no longer be maintained in its state of perfection by Natural Selection (although of course Natural Selection will still act on other organs that are of use in the darkness); consequently all degrees of eyesight will stand an equal chance of preservation, and by the intercrossing of individuals of varying degrees of perfection there will result a degeneration of the eyesight—a "regression towards mediocrity," as Galton has called it. The explanation of the gradual loss of the eyes in cave animals is the one adopted by Wallace, in his 'Darwinism' [115, p. 416], who also adds that besides becoming useless, the eyes might also become injurious on account of their delicacy of organization and liability to accidents and disease; so that in addition to the "regression towards mediocrity," owing to the withdrawal of the action of Natural Selection in maintaining perfection, Natural Selection would also actively reduce and finally abort them. It is important to observe that this "regression towards mediocrity" is a general law of heredity, and produces its effect quite irrespective of any use or disuse of the organ in question [Wallace, 115, p. 414]. A similar explanation has been given by Weismann [119, pp. 90 and 292], who has introduced the term "*Panmixia*" for the suspension of the preserving influence of Natural Selection, and the consequent intercrossing of animals of all standards of perfection.

Of course, if we accept his dogma of the non-heredity of acquired characters, that at once excludes the effects of disuse as an explanation of the blindness of cave animals; but even without going to this length the principle of *panmixia*, combined with the other active effect of Natural Selection adduced by Wallace, will be sufficient to account for much of the degeneration of eyesight, and to these must be added another equally important consideration advanced by Lankester [70, p. 818–819]. After pointing out that the eyesight of different individuals varies, owing to congenital fortuitous variations, he remarks:—

"Suppose that a number of some species of Arthropod or Fish be swept into a cavern or be carried from less to greater depths in the sea, those individuals with perfect eyes would follow the glimmer of light, and eventually escape to the outer air or the shallower depths, leaving behind those with imperfect eyes to breed in the dark place. A natural selection would thus be effected."

This explanation is no doubt a true statement of fact, for caverns and underground waters have in all probability been gradually peopled by animals from the surrounding neighbourhood, and as they advanced further and further into the darkness a selection of this kind would go on in each generation, and, as Poulton has observed, "such a sifting process would certainly greatly quicken the rate of degeneration due to *panmixia* alone" [119, p. 292, footnote]. The same explanation is quoted with approval by W. P. Ball, who considers, however, that *panmixia* "would probably be the most important factor in causing blindness" [3, pp. 17, 72].

To the various causes mentioned above we must add the effects of disuse *in the individual*, which are undoubtedly very considerable in amount, and in cave animals breeding in the darkness would commence in all cases from birth.

I may add here one or two notes on the age of the blind fauna of caves and wells, and on the rate at which development has consequently taken place in these animals. Although, as I have pointed out elsewhere (pp. 253–258), there is reason to believe that some, at any rate, of the blind species are older than the surface fauna at present inhabiting the same neighbourhood, there seems little reason to doubt that the whole underground fauna is of comparatively recent origin. Packard [82, p. 25], after considering the facts on the question adduced by Cope, came to the conclusion that "the subterranean fauna of this country does not date back of the Quaternary Period." In his later paper he repeats this opinion, and, after considering the different classes of caves more fully, adds:—

"It seems, then, fair to assume that the final completion of the caverns, when they became ready for occupancy by their present fauna, may not date back more than, to put it into concrete figures, from 7000 to 10,000 years, the time generally held by geologists to be sufficient for the cutting of the present river gorge of the Niagara and the Falls of St. Anthony. We may, then, put the age of our cave fauna as not much over from 5000 to 10,000 years before the dawn of history, which itself extends back some 5000 to 6000 years" [83, p. 23].

He concludes, therefore, that the greatest part of the cave fauna of North America was directly derived from the present fauna, and that consequently the changes undergone have been brought about in at most a few thousands of years.

The fauna of the European caves described by Schiödte, &c., also seems to date from the "close of the Tertiary, or more probably the beginning of the Quaternary Period" (Packard [82, p. 25]).

In New Zealand, too, the subterranean fauna must be very recent, geologically speaking. All the places where subterranean forms are found are marked on Professor Haast's geological map of Canterbury and Westland [53] as either "post-pliocene alluvium" or "recent alluvium," most of them being in the latter. *Phreatoicus*, by its generalized character and by its occurrence in Australia as well as in New Zealand, is shown to be an ancient form, probably once widely spread in fresh waters, but of course it does not follow that its subterranean species are more ancient than the other subterranean forms. If thorough search were made it is quite possible that some species of the genus would still be found inhabiting freshwater streams among the Southern Alps.

In speaking of the variety *freibergensis*, Schneider, of *Asellus aquaticus*, Moniez says:—

"Différents auteurs (Schneider, Chilton, etc.) attachent beaucoup d'importance à la date à laquelle ont été forés les puits dont ils ont étudié les eaux, admettant volontiers, mais bien gratuitement, à notre avis, que c'est à cette époque que les animaux y sont arrivés et ont commencé à se modifier. Nous avons déjà fait entendre, à propos du *Cyclops pulchellus* (p. 34), que cette façon naïve de procéder à l'étude de la variation des espèces ne peut se soutenir, car elle ne tient pas compte d'un facteur important dans la question, celle des *eaux souterraines*, dans lesquelles les animaux observés pouvaient vivre avant le forage, et par lesquelles, grâce aux infiltrations, de nouveaux individus à l'état d'œufs, ou même à l'état parfait, peuvent arriver à tout instant, comme nous l'avons fait remarquer plus haut (pp. 37, 38)" [78, p. 52, footnote].

It is true that in my first paper on the Subterranean Crustacea of New Zealand I did mention the age of the well from which they were obtained, because I wished to give all the facts that might have a bearing on the question, and though the age of the well has, of course, nothing to do with the development of the Subterranean Crustacea, it may have had some effect on numbers occurring at that particular place; but there is nothing in my paper that can be interpreted to mean that I imagined that the Crustacea—all true subterranean forms—had begun to modify only after the well was bored; and in my second paper [23, p. 87, &c.] I made it quite clear that the Crustacea are inhabitants of the underground waters and not merely of the wells.

The cases brought forward by Schneider, i. e. *Gammarus pulex*, var. *subterraneus*, and *Asellus aquaticus*, var. *freibergensis*, seem to me to be quite different. Here, as in the case of *Gammarus fluviatilis*, var. *d'Emmerin*, mentioned by Moniez himself, we have subterranean varieties which differ from the parent species still found on the surface only in a few small points, such as colour, slight degeneration of the eyes, &c., and though I do not know what age is to be assigned to the mines in which Schneider found his examples, I see no reason for doubting that these slight differences have been acquired in a very few generations. Other similar examples are given by Packard; one is that of some examples of an isopod found in subterranean regions, which, although of the normal form and size of *Asellus communis* (the surface species), were bleached as white as *Cæcidotea stygia*, and of this variety, which he calls *pallida*, Packard remarks:—"It is interesting to note the occurrence of this bleached variety, which may have become thus modified after but a few generations, perhaps but one or two" [83, p. 32].

Other examples given appear to confirm this view, and all go to show that slight modifications, such as in the cases mentioned above, may be produced within very short periods.

X. Conclusion.

In the foregoing pages I have endeavoured to give as full and accurate an account of the Subterranean Crustacea of New Zealand as the material and the time at my disposal would allow. But although the work has gradually grown under my hands until the present memoir has far exceeded the limits I originally anticipated, its increase in size has, I fear, only multiplied its imperfections, and given rise to more questions than have been solved. It has, indeed, shown that no single animal can be profitably studied by itself, but that in attempting to explain one we must study all, and that the one can be thoroughly known only when all are known.

In concluding his work on the fauna of the Swiss Lakes, Forel has pointed out that the phenomena connected therewith, which at first appeared strange, anomalous, and altogether unaccountable, were gradually interpreted with increasing knowledge until they harmonized with what we learn of the workings of nature in other places less far removed from man's curious gaze. The same statement applies to the consideration of subterranean life, and we can exclaim with Forel—"La nature est grande et belle, parce qu'elle est harmonieuse en tout et partout."

But one fact that has been impressed upon me more than any other by the very existence of subterranean life is the keenness of the struggle for existence that goes on in the world of animals and plants. I am not aware that he ever did so, but from the tendency of animals to increase in a geometrical ratio, and the consequent struggle for life, Darwin might have deduced the conclusion that every spot on earth capable of supporting life at all would be occupied by its appropriate denizen; and certainly such a conclusion would have been amply verified by the facts now known. Even if we take a single group like the Crustacea, and of these only the small and apparently helpless Amphipoda and Isopoda, we find that they have spread until scarcely any place can be named from which they are absent. They are found on land and in the sea; in running streams and in stagnant ponds; in hot springs and in frozen pools; high on mountain-tops and deep in mines; on the seashore and far out in the ocean; burrowing in mud and boring into wood and stone; on the surface of the sea and in its lowest depths; in the waters on the earth and in the dark recesses of caverns and of the waters under the earth, where no storm ruffles the everlasting stillness, no light illumines the thick darkness, and no sound breaks the eternal silence.

XI. Bibliography.

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[The originals of many of the works quoted below have been inaccessible to the writer, the contents being, however, known to him through abstracts and notices in other works. The chief source from which such information has been gained is given in each case, but in many cases the contents of a paper have been known through abstracts in several other works.

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EXPLANATION OF THE PLATES.

Plate XVI.

Phreatoicus assimilis.

Fig. 1. Side view of the whole animal, a female. × 12.
2. Upper antenna.
3. Lower antenna.
4. Upper lip. × 58.
5. Outer convex surface of mandible with palp attached.
6. Left mandible.
7. Lower lip. × 58.
8. First maxilla. × 58.
9. Second maxilla. × 58.
10 & 11. Maxillipedes.

Plate XVII.

Phreatoicus assimilis.

Fig. 1–3. First appendage of the peræon.
4. Second ditto.
5. Propodos produced along the base of dactylos.
6. Fourth appendage of the peræon.
7. The same, distal extremity enlarged.
8–9. Fifth and sixth appendages of the peræon.
10. First pleopod. × 19.
11. Second pleopod, of male. × 19.
12. Third pleopod. × 19.
13. Side view of end of pleon, showing the telson ana uropoda. × 19.

Plate XVIII.

Phreatoicus typicus.

Fig. 1. Side view of the whole animal, a female. × 6.
2. The antennæ, side view, showing the upper antenna and the peduncle of the lower antenna. × 35.
3. Extremity of the left mandible, much compressed. × 180.
4. Lower lip. × 58.
5. First maxilla. × 58.
6. Second maxilla. × 58.
7. Leg of the first pair, of female. × 19.
8. Extremity of the same. × 45.
9. Leg of the second pair. × 19.
10. Leg of the sixth pair. × 19.
11. Lower margins of the first five segments of pleon. × 19.
12. Side view of end of the pleon, showing the telson and uropoda. × 19.

PLATE XIX.

Cruregens fontanus.

Fig. 1. Side view of the whole animal. × 12.
2. Antennæ, from above. × 45.
3. End of upper antenna. × 180.
4. Portion of lower antenna. × 180.
5. Basal portion of lower antenna, from below. × 45.
6. Upper lip. × 120.
7. Mandibles. × 120.
8. Mandibles and end of maxillipedes, seen from below and partly from the side. × 120.
9. First maxilla. × 56.
10. Portion of same. × 120.
11. Second maxilla and lower lip. × 120.
12. Lower lip. × 120.
13. Second maxilla. × 120.
14. Maxillipedes, distal portion, from below. × 120.
15. Leg of first pair, outside view. × 30.
16. Portion of the same, inside view. × 30.
17. Leg of second pair. × 30.
18. Palm of same. × 83.
19. Leg of fourth pair. × 30.
20. Pleon, with telson and uropoda, from above. × 30.
21. First pleopod, from below. × 30.
22. One of the posterior pleopoda. × 45.
23. Uropoda, from above. × 30.

PLATE XX.

Crangonyx compactus.

Fig. 1. Side view of the whole animal. × 12.
2. Upper antenna. × 45.
3. Portion of flagellum of same. × 120.
4. Lower antenna. × 45.
5. Upper lip. × 120.
6. Right mandible. × 70.
7. Extremity of same. × 240.
8. Extremity of right mandible of another specimen. × 240.
9. Extremity of left mandible (figure inverted). × 240.
10. Lower lip. × 120.
11. First maxilla. × 120.
12. Extremity of middle lobe of same. × 350.
13. Extremity of palp of same. × 240.
14. Second maxilla. × 120.
15. Extremity of inner lobe of same. × 350
16. Maxillipedes, from below. × 70.
17. Extremity of same, from above. × 120.
18. Inner lobe of same. × 120.

Fig. 19. Outer lobe of same. × 120.
20. First gnathopod. × 30.
21. Second gnathopod. × 30.
22. First peræopod. × 30.
23. Fourth peræopod. × 30.
24. First pleopod. × 30, with "coupling-spines" more enlarged.
25. Second pleopod. × 30.
26. Third pleopod. × 30.
27. First uropod. × 30.
28. Second uropod. × 30.
29. Third uropod. × 30.
30. Telson. × 30.

Plate XXI.

Gammarus fragilis.

Fig. 1. Side view of whole animal. × 12.
2. Upper antenna. × 30.
3. Lower antenna. × 30.
4. Upper lip. × 70.
5. Left mandible, showing palp and cutting-edges only. × 70.
6. Extremity of same. × 120.
7. Extremity of right mandible, from above, compressed. × 70.
8. The same seen in profile from below. × 70.
9. Lower lip. × 70.
10. First maxilla of right side. × 70.
11. Extremity of palp of same. × 120.
12. Extremity of palp of first maxilla of left side. × 120.
13. Second maxilla. × 70.
14. Maxillipedes, from below. × 45.
15. The same, from above. × 45.
16. First gnathopod, inner side, from a large specimen. × 30.
17. Second gnathopod, outer side, from smaller specimen. × 30.
18. First peræopod. × 30.
19. Fourth peræopod, basal joints and extremity. × 30.
20. Extremity of same. × 70, with "auditory seta" more magnified.
21. Third pleopod. × 30, with "coupling-spines" more magnified.
22. First uropod. × 30.
23. Second uropod. × 30.
24. Third uropod. × 30.
25. Telson. × 30.

Plate XXII.

Calliopius subterraneus, ♂.

Fig. 1. Side view of male. × 12.
2. Peduncle of upper antenna. × 30.
3. Calceolus from the same, highly magnified.
4. Lower antenna. × 30.

Fig. 5. Upper lip. × 58.
6. Left mandible. × 58.
7. Extremity of same. × 120.
8. Extremity of right mandible. × 120.
9. Portion of lower lip. × 58.
10. First maxilla. × 45.
11. Extremity of middle lobe of same. × 180.
12. Extremity of palp of same, right (?) side. × 180.
13. Extremity of palp of first maxilla of other (? left) side. × 180.
(These two drawings, 12 and 13, were accidentally made one from above and one from below, hence they both face in the same direction.)
14. Second maxilla. × 120.
15. Maxillipede, from below. × 45.
16. Extremity of the same, from above. × 45.

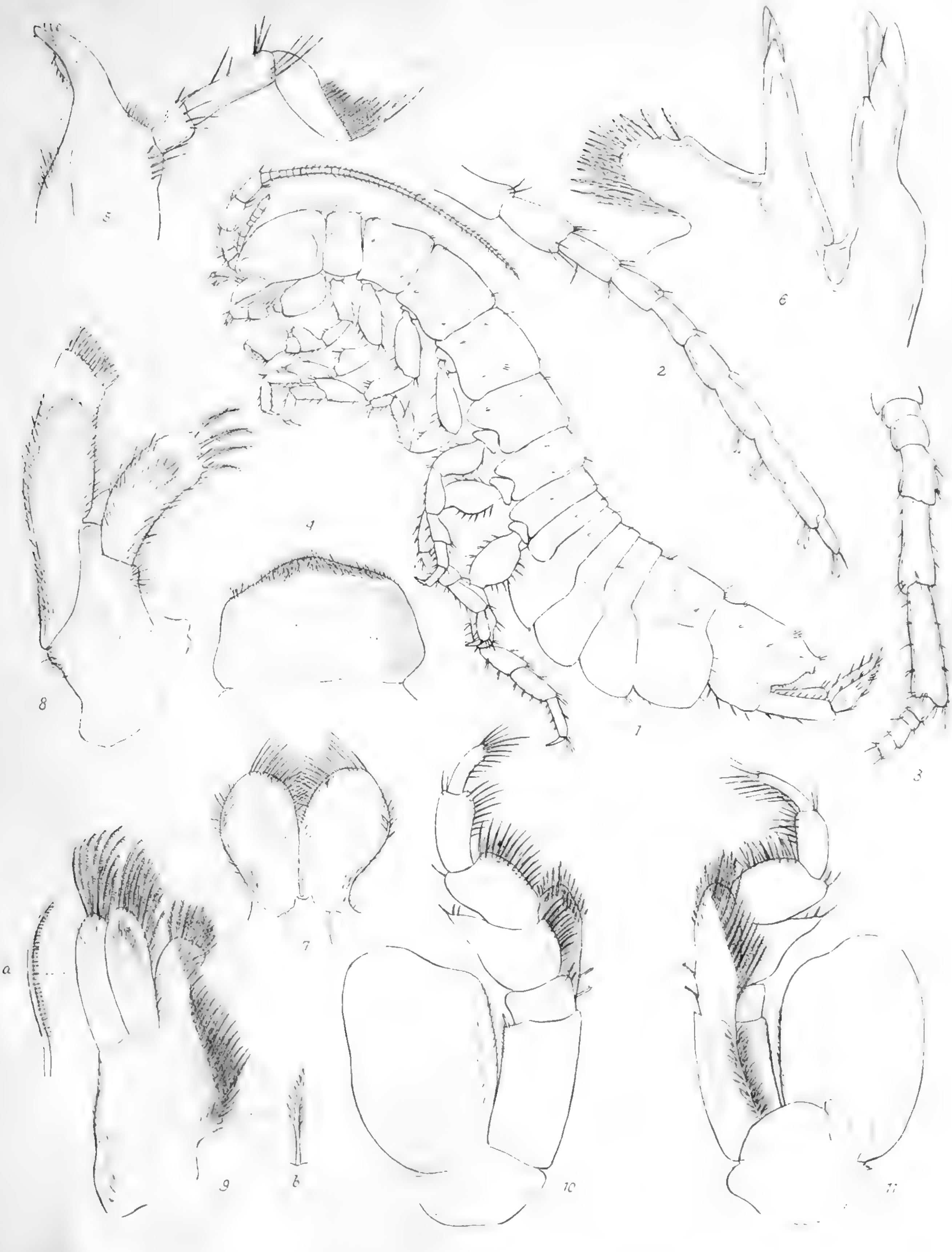
Plate XXIII.

Calliopius subterraneus, ♂.

Fig. 1. First gnathopod, outer side. × 19.
2. Extremity of the same, inner side. × 19.
3. Second gnathopod, outer side. × 19.
4. Extremity of the same, inner side. × 19.
5. First peræopod. × 19.
6. Third peræopod. × 19.
7. First uropod. × 19.
8. Second uropod. × 19.
9. Third uropod. × 19.

Calliopius subterraneus, ♀.

10. Lower lip. × 120.
11. Maxillipede, from above. × 120.
12. First gnathopod. × 45.
13. Extremity of the same. × 120.
14. Second gnathopod. × 19.
15. Extremity of same. × 120.
16. Side view of posterior end of pleon, showing the uropoda and telson. × 45.
17. Third uropod and telson, from above. × 45.
18. Extremity of middle lobe of first maxilla of a small specimen (an immature male?), showing some of the setæ only. × 445.



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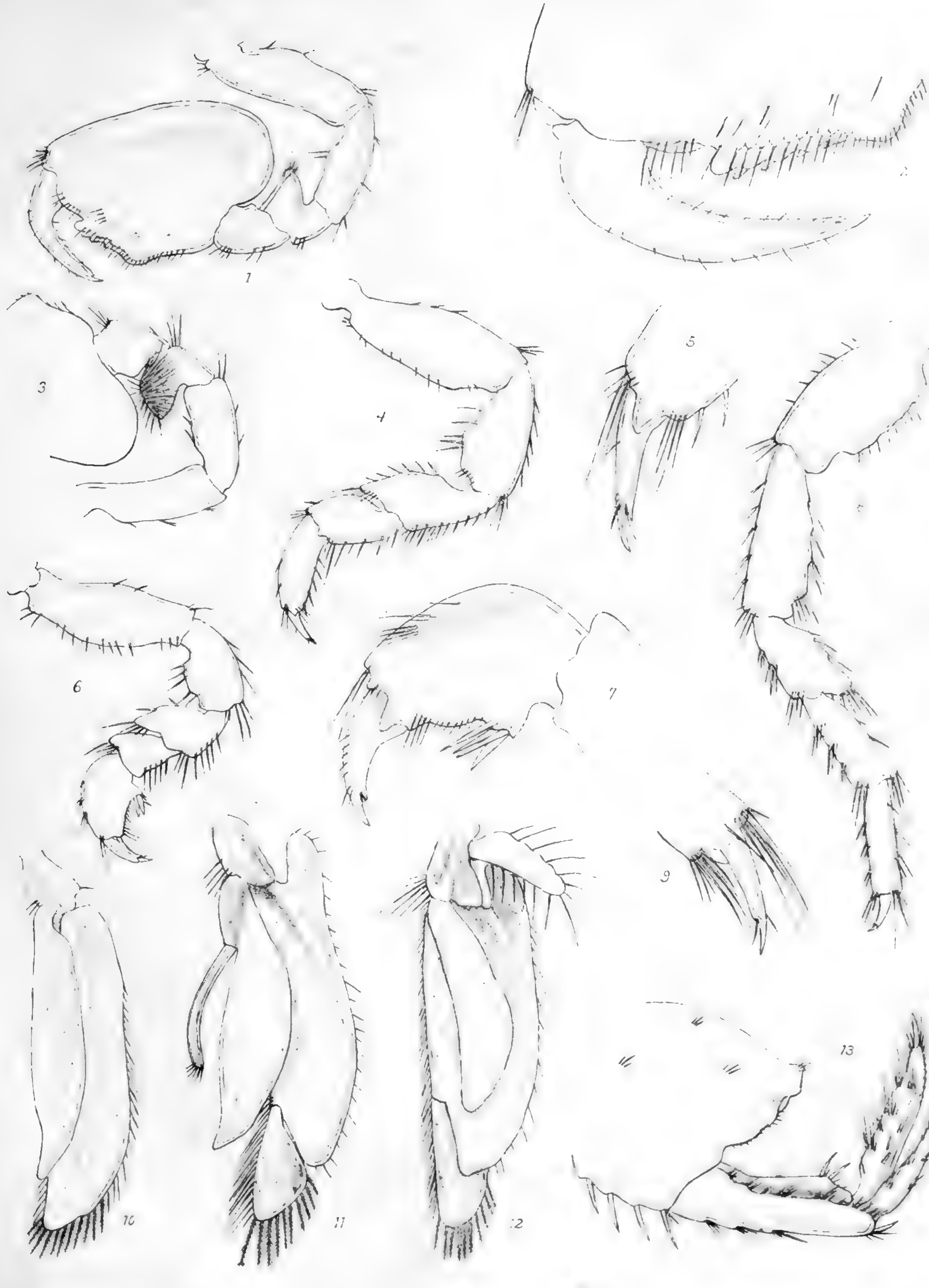
PHREATOICUS ASSIMILIS, *Chilton*, sp. nov.



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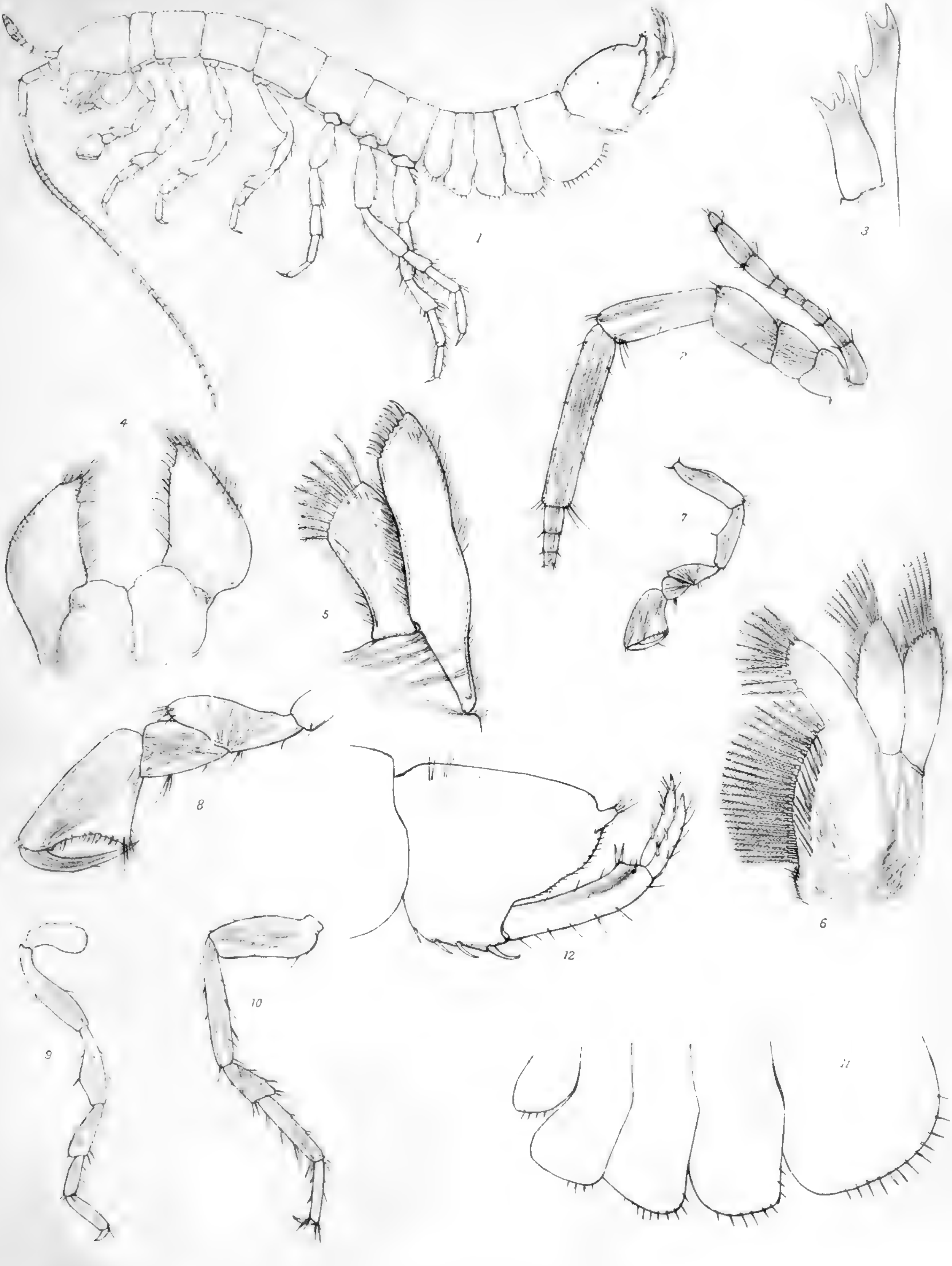
PHREATOICUS ASSIMILIS, *Chilton, sp. nov.*



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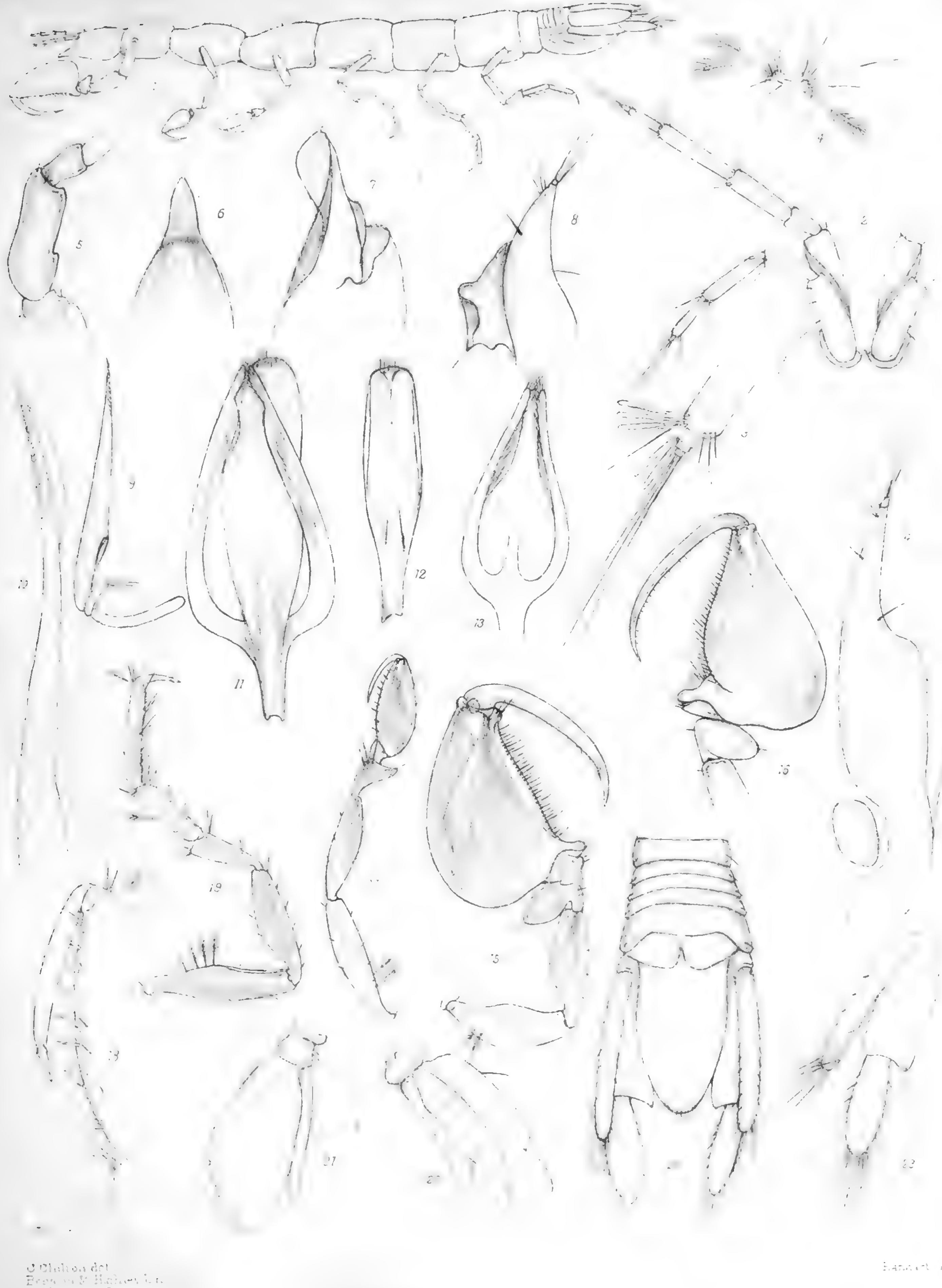

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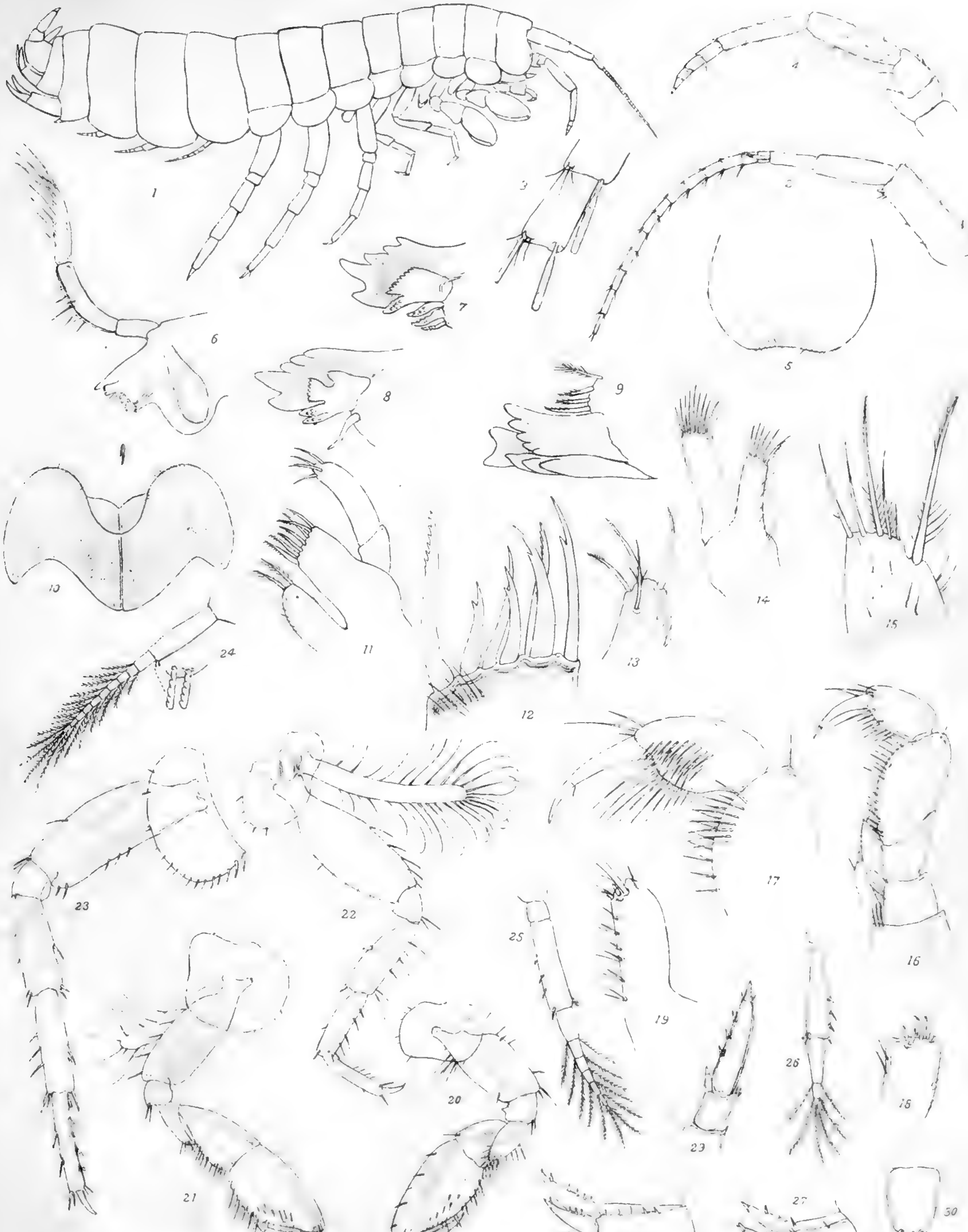
CRUREGENS FONTANUS Chilton.



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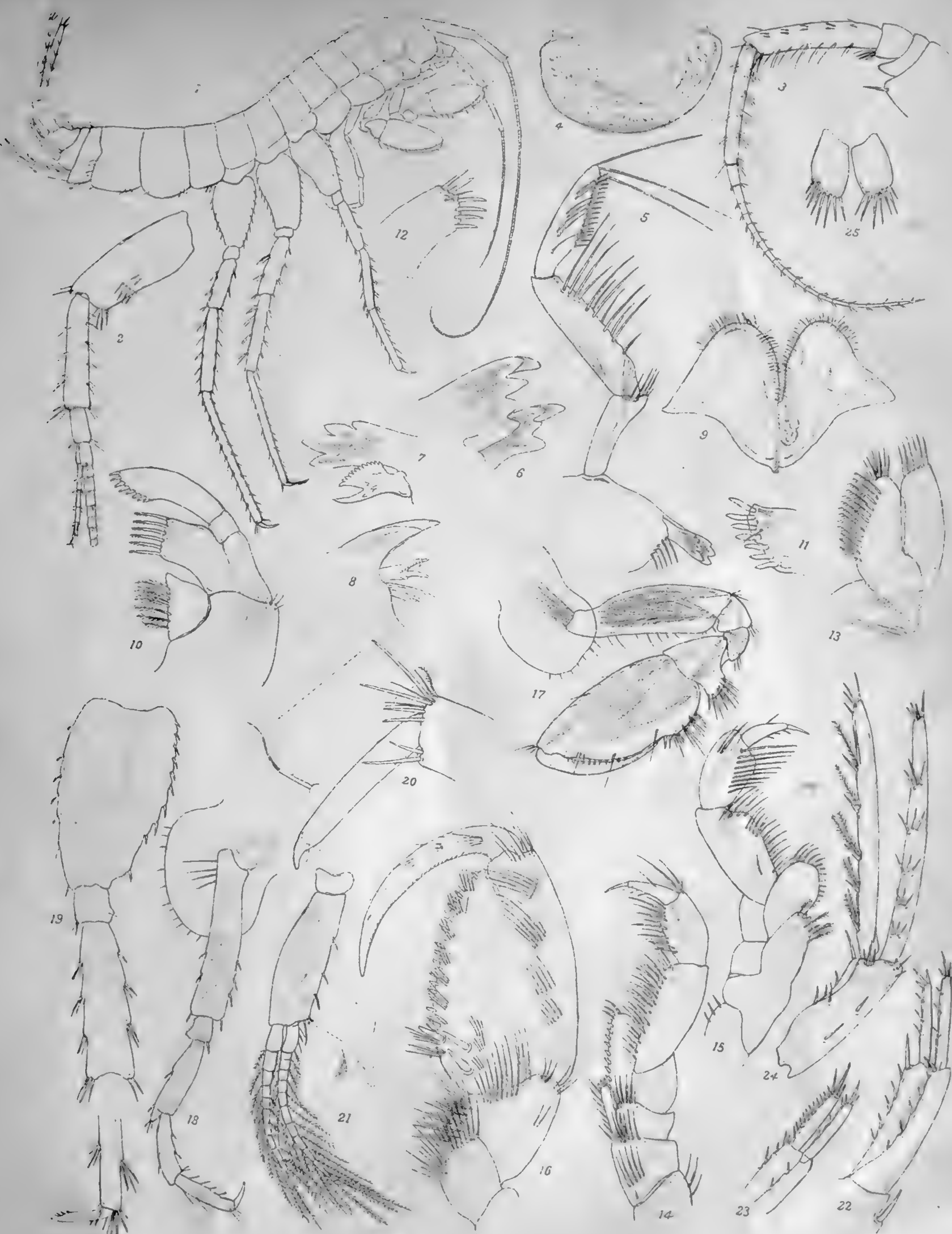
CRANGONYX COMPACTUS, *Chilton*



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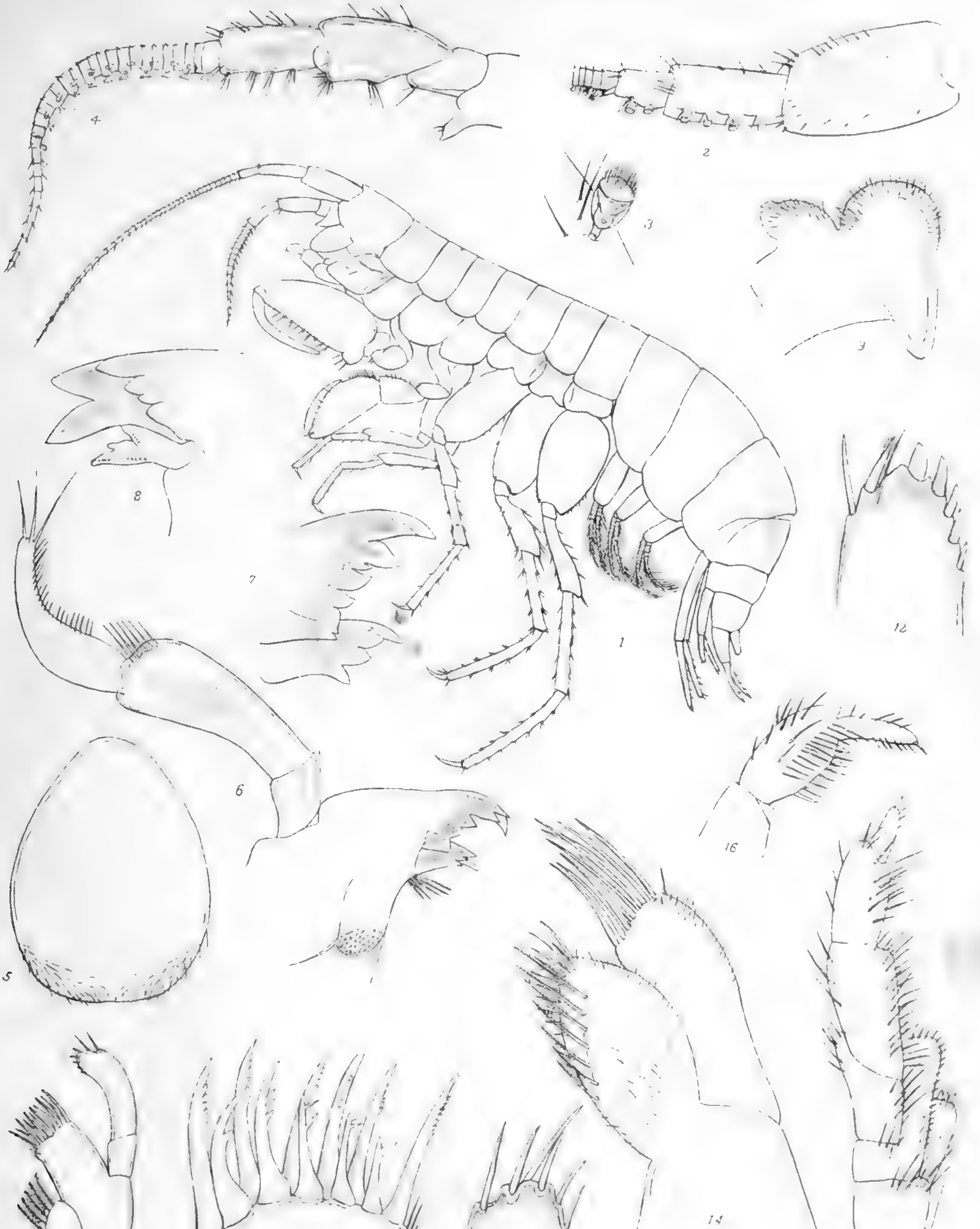
GAMMARUS FRAGILIS, *Chilton*



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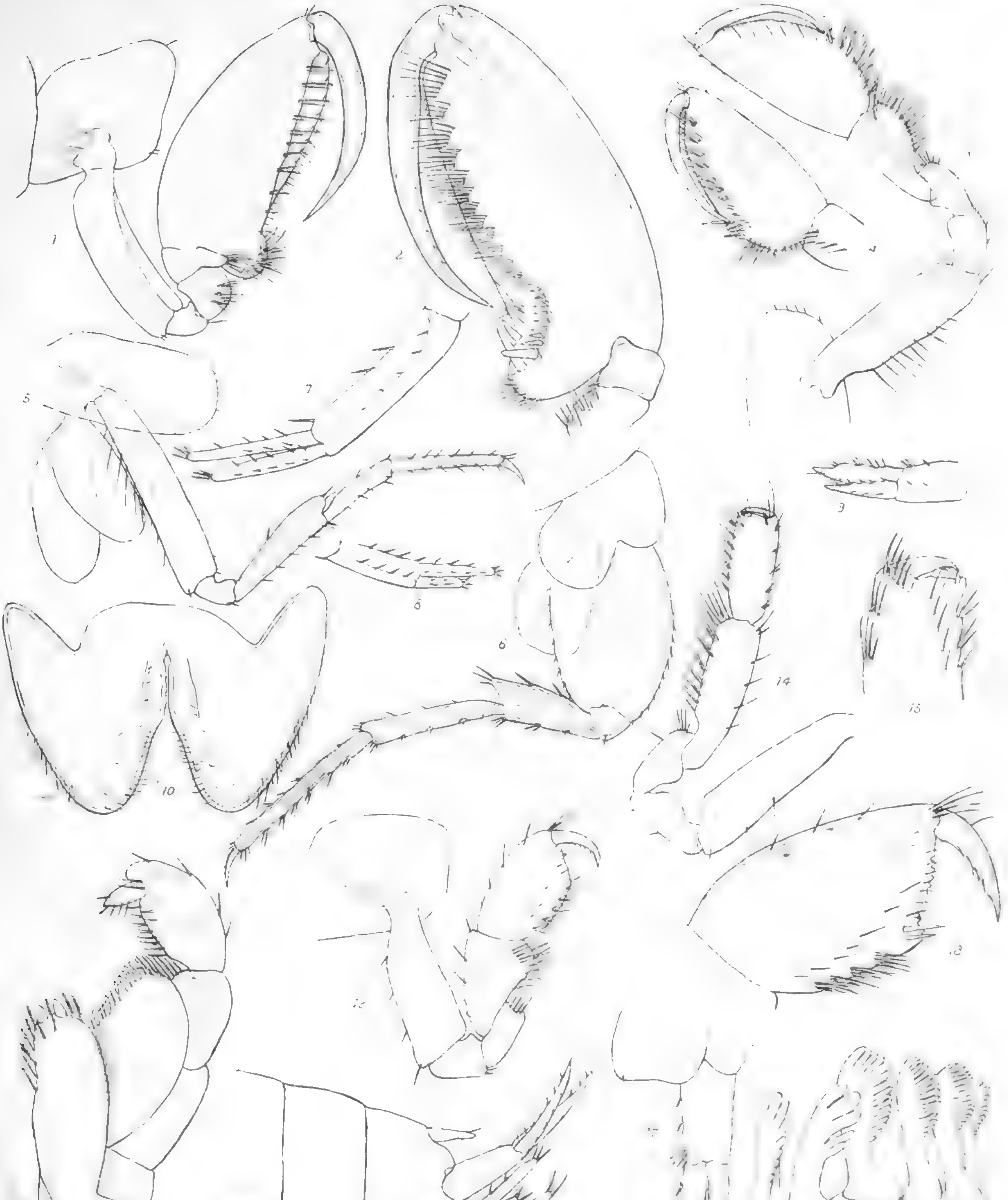

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Part	V.	1890	0	6	0	0	4	6
Part	VI.	1891	0	12	0	0	9	0
Part	VII.	1891	0	6	0	0	4	6
Part	VIII.	1892	0	8	0	0	6	0
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