OBSERVATIONS

AND

EXPERIMENTS

ON THE

CARCINUS MŒNAS.

BY

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TO

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AND

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PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF EDINBURGH,

THESE PAGES

ARE DEDICATED,

AS A TRIBUTE TO THEIR TALENTS, WHICH HAVE SO BENEFITED SCIENCE,

AND AS

A MARK OF RESPECT AND ESTEEM,

BY

THEIR FORMER STUDENT,

THE AUTHOR.

INTRODUCTORY

REMARKS ON ITS HABITS, ETC.

To every inhabitant on the sea coast, especially where rocks abound, the Carcinus mœnas, or Common Shore Crab, is familiar. But few places can equal the shipwrecking bay and rocky fringed shore of St. Andrews, where these observations were made, for the abundance of this, as well as many other marine productions of a much rarer description. The Carcinus mœnas is alike lord of the sunny pool and shady clefts. Here he may be seen in some still water, whose edges and bottom are mantled with dark Algæ of luxuriant growth, interspersed with lighter tufts of arborescent Sertularidæ, scuttling over a sandy spot, uncovered by the vegetation, and seeking a secure retreat under the shelving rock; and he does so with astonishing rapidity. There, tide being ebb, he is shrouded under some protecting shelf, in dirty mud, scarce a morsel of his body appearing above ground, and oftentimes totally submerged; his dingy coat, on ejection, bearing slight resemblance to the clean mottled green that so closely figures the vegetation and rocks which he haunts. Again, when the tide has far receded, and you tread over the rocks which ocean mostly covers, you meet with many specimens,—in those regions where the Uraster and Solaster hang on the dingy, dripping rocks in fantastic attitudes, now suspended by the tiny ambulacra of one ray, now by more, their gaudy bodies

Remarks on habits and haunts.

contrasting with the dark back-ground of a deep recess, or bunch of Fuci. Here, too, upturned flags reveal rich treasures, Galatheas, Porcelain Crabs, Ophiocomas, Pycnogonons, Nereis, Terebellas, &c., and hosts of young Carcini; and stooping down, you see under the ledge the well-grown Doris lazily indulging his carnivorous propensities, occasionally accompanied by an Aplysia. Ascidians and Anemones abound, and a touch of the hand brings a jet of water from either. It may happen that you are at a part where the soft blue shale affords a favourite site for the Pholas crispata, which here abounds, and whose fleshy siphon betrays the lurking inmate of the circular aperture. Touch the siphon, and it sinks into its wondrous retreat, after emitting a tiny stream of water, which often seems well directed. The cavities themselves, grooved and empty, with a projecting point at the bottom, frequently lie broken by the waves on the sand.

But it would be endless to notice the numerous and interesting structures which here fascinate and instruct the marine Zoologist, for they abound in our rocks and pools. They are only mentioned as the companions of the Carcinus mœnas in those retreats of the deep.

It is in such haunts, then, that you get fine specimens, whose powerful telæ have not acquired those colossal dimensions by one moulting or by two; and numbers, male and female, line the fissures, quite secure from vision, but accessible to the entangling rod. After a storm, especially, great numbers are found crowded together. It sometimes happened, that, at this season (Autumn), you ejected a group of half-a-dozen females without a single male, each bearing its sub-abdominal burden of ova. Again, a large old male might be dislodged from some lonely nook, quite a bachelor crab.

More frequently, however, I found a few together at low water mark; and, if single, it generally had been moulting lately, and was in the condition vernacularly termed 'Soft back.' The females were frequently of a reddish or purplish hue, even where no ova adhered to the abdominal feet. Lastly, the crab may be found wanting one or both telæ, several of his smaller limbs, or may have them in various stages of growth, and, besides being subject to other mutilations, may have several additions—in the shape of a bunch of Sertularia, a group of Balani, numerous white-shelled Serpulæ, or Sponges, clustered on his back.

In activity, the Carcinus mœnas is pre-eminent, his body is not too bulky for his long and powerful limbs. By nature, he is savage, fighting constantly with his own species of a similar sex, and mutilating each other often to a great extent. He hangs on by a tela, when enraged, often to its destruction, but he is more cautious of the one remaining. When in danger, he elevates the telæ, and makes off, if not prevented, with great alacrity, whether on land or in water, and is quick in detecting enemies. This animal stands in marked contrast to another of his kindred occasionally dislodged in the search, the Cancer pagurus, whose motions do not display anything like the remarkable activity of the Carcinus mœnas, nor is his disposition so fierce. The C. pagurus is easily injured and dies, whereas the C. mœnas survives great harm. The latter lives in a glass globe for ten or twelve days, deprived of all moisture, but that which he has in his own branchiæ, or derives from those of a fellow prisoner; the former scarce lives a day or two.

Towards the latter end of October, the weather was cold and frosty, and it could be observed that the activity of the C. mœnas was considerably diminished, especially in the morning, before the sun became powerful. When pulled out of his retreat, his motions were much more sluggish than usual, showing that the cold evidently exercised a sedative effect both on his activity and ferocity.

At Christmas, the animals were in considerable numbers in the same haunts, and, the weather being mild, they were rather active. The females of course still carried their ova, and frequently, too, were accompanied by males in their retreats.

From the foregoing considerations, then, it may be premised—that the nervous system of the C. mœnas is highly developed and concentrated; and the investigation of this, anatomically, brings us to Part I. of the Thesis.

PART I.

OBSERVATIONS ON THE NERVOUS SYSTEM, &c.

THE nervous system of the great Division of the animal kingdom to which Crustacea belong is characterised by generally appearing as a double gangliated chain. In the Crustacea, this bilateral symmetry is well shown in those whose dermo-skeleton presents us with the most regular and distinct segments. It may be generally described as consisting of a series of ganglia, placed on the ventral aspect of the animal, communicating with the cephalic ganglion and each other by a pair of nerve filaments, and supplying the various organs around. The Talitrus exhibits this arrangement. Further up the scale, we find that the ganglia diminish, and do not correspond in number to the segments of the body. The scale of centralization is traced with great distinctness from the Talitrus, before mentioned, through the Oniscus, Phyllosoma, and Cymothoa (where the ganglia have coalesced transversely), to the Lobster, in which the longitudinal filaments are united completely in the abdomen, though still double in the thorax.* The first thoracic ganglion, and the last abdominal, also, are evidently composed of several united; the former being composed of the five pairs of ganglia belonging to the five rings bearing the accessory masticatory apparatus, the latter consisting of the two ganglia pertaining to the sixth and seventh segments of the abdomen. In the Palæmon, the three lowest thoracic ganglia are united, in fact, the nervous system of the cephalo-thorax consists of four closely approximated ganglia. In the Palinurus, the thoracic ganglia are in a single mass, with a cleft for the sternal artery. Through interme-

Nervous System in higher Crustacea.

* Lect. on the Comp. Anat. of Invertebrate Animals, Owen, p. 305.

diate stages, we come to the C. mœnas, where the single thoracic centre is in the form of a ring, and the abdominal filament is rudimentary and single, in consonance with the state of the abdomen itself. The centralization is completed in the Maia, where the thoracic ganglion is without aperture or break, even the nerves themselves bearing evidence of concentration, as several pairs are distributed conjointly to one segment.

Nervous System of C. mœnas.

As it is chiefly on the Carcinus mœnas that the following observations and experiments have been conducted, a somewhat minute description of the distribution and structure of certain parts of the nervous system in this animal may be advantageously placed here.

Mode of preparation.

In the C. mœnas, as already stated, the centralization of the nervous system is far advanced. For examination, the best way of preparing the crab, so far as I know, is as follows :—snip off the legs with powerful scissors close to the body, except in specimens intended for a special examination of the nerves in those organs; divide the carapace to the exterior of the orbits, and connect these two longitudinal fissures by another, which courses transversely a quarter of an inch behind the blunted rostrum. By a few more touches along the back and sides, the whole carapace can be removed from the dorsal aspect. The liver, generative organs, and other soft parts not necessary for the examination, are then to be removed under running water, with the assistance of the forceps. The body is now placed in weak spirit for some days; this is requisite on account of the softness of the nervous texture, which, being at the same time translucent, is much improved by being so hardened, before the minute branches are traced. In the case of those intended for microscopic examination, such preparation in spirit is prejudicial, and I found fresh specimens preferable.

The greater part, then, of the nervous matter in this animal, is found in the Cephalic and Thoracic ganglia, and from these, branches are given off to supply the organs of the special senses, those of locomotion, digestion, reproduction, &c.

The *Cephalic* mass of nervous matter (Pl. I. fig. 1, *c.*) is situated at the anterior part of the cephalo-thorax, over a deep sulcus divided into two by a prominent median ridge, and behind it is a projecting spike to which a strong ligament is attached. This sulcus is marked externally by a pale triangular surface, just beneath the two internal antennæ, and in the mesian line. The ganglion does not lie in contact with the œsophagus, but is distinctly placed anterior to it, the connecting cords with the thoracic ganglion only embracing it. It is about a fourth of the size of the thoracic ganglion, and both are easily distinguished by their opalescent aspect, which arises from the accumulation of nervous matter; and, moreover, in the cephalic, the peculiar arrangement of the latter gives it a nodulated appearance when fresh. With other ganglia, this assumes a yellowish tinge after hardening in spirit, while the nerve tubes have their white opalescent appearance intensified.

Cephalic ganglion.

The nerves given off from this centre are the following:—optic, oculo-motor, nerves for the internal antennæ, integumentary, nerves for the external antennæ, connecting filaments with the thoracic ganglion. The origins of these nerves are not all seen on examining the dorsal aspect of the ganglion, some being placed on the ventral surface; the most conspicuous are the optic and fourth pair.

Branches.

In shape, the ganglion is somewhat oval, the longest diameter being situated transversely, and having a deep cleft posteriorly between the origins of the connecting pillars. Microscopically, the cephalic ganglion is a beautiful object, and well repays observation. White and translucent though it be, fibres, cells, nuclei, and nucleoli, can all be distinctly made out. When taken from a recently killed animal and placed on the field, a mingled array of nerve tubes, nerve cells and granules

Microscopic structure.

present themselves (Pl. II. fig. 1.). The nerve tubes are of the usual structure, pale, translucent and soft, yet of considerable tenacity, and run here and there throughout the whole ganglion. They end in masses of nerve cells, and some can be traced on to unipolar and bipolar cells themselves (Pl. II. fig. 2 *a.*).

The nerve-cells are good specimens, varying in size; some large and filled with granules,—it may be the germs of a new race. They present in most cases a similar appearance to the same structures in vertebrates, having a nucleus and nucleolus. I observed a singular appearance occasionally, viz., that of two nerve cells joined together by a flattened margin, similar to the Desmideæ, and apparently caused by the fissure of a single cell. Groups might also be seen, which, from the flattened sides of the cells composing them, appeared to be the products of the bursting of a well-filled parent cell. Some were in bunches, while nerve fibres coursed through and over them, or were lost in granular masses. Polyclonic nerve-cells were rare, bipolar more abundant, and unipolar common. Most of the fibres seemed to be lost in masses of granular matter and cells, with no distinct connexion. Others were continuous with the poles of the various cells. The primary and simple cell, however, seemed so predominant throughout the whole ganglion, that I could in vain get rid of the notion that it must have some effect on the fibres, without direct continuity.

Crystals. If you examined the cephalic ganglion a day or two after the death of the animal, a remarkable appearance met the eye—in the shape of multitudes of needle-like crystals, scattered over the field of the microscope (Pl. II. fig. 3.). They must therefore have been the result of the decomposition of certain of the nervous elements. In shape, they resembled crystals of margarin, and seemed of fatty origin. These bodies were entirely absent in newly killed specimens, nor did they appear in recent ones kept in alcohol, but I found them occasionally after the lapse of a month or two. They could be detected at once by altering the focus, so as to make them contrast (dark reddish) with the milky colour of the translucent field. Some were shaped like long needles, sharp at both ends; others were truncated at one or both extremities. Sometimes they radiated from a long central stalk like a brush or fan; or again, two opposite radiations met in a point. Acetic acid dissolved them, and so did alcohol. They belonged to the ganglion and were not extraneous structures.*

The first branch of this ganglion that falls under consideration is the *Optic Nerve*, which, proceeding on each side from the anterior horn of the nervous mass, courses obliquely forwards and outwards for about a quarter of an inch; then, coming in contact with the eye peduncles, it enters the tubes of the latter in company with the small muscular nerve afterwards to be mentioned. It does not appear to be increased in size in the Carcinus mœnas after it enters this tube. Passing along the inner side of the horny tunnel, it plunges amongst the soft textures constituting the eye-ball proper, and not much, if any lessened, can be traced to the middle of the same, where it becomes more indistinct. Optic Nerve.

A short description of the *Visual Apparatus* will

* Since writing the above, my friend, Dr. Fraser Thomson, of Perth, while lately examining the structure of crustacean shell, made an interesting observation in regard to crystals in these animals. Having made a section of the dense portion of the claw (propodite) of the Cancer pagurus in the usual manner, grinding it, and removing the canada balsam by ether, he mounted it in distilled water. On examining the specimens shortly after (for he made several), the field was covered with tapering flask-shaped crystals, the sharp extremity being frequently much prolonged. Dense groups of agglomerated crystals of the same shape also abounded, frequently of a circular form and concentric arrangement. Occasionally, a larger and a smaller were joined by the delicate apices, presenting the aspect of a heavily loaded balancing pole. He finds that the crystals dissolve in acid without effervescence (Pl. IV. fig. 4.).

tend to elucidate the distribution of the optic nerve. In the C. mœnas, the eyes, as in allied genera, are supported on pedicles or stalks, and are of the kind termed compound (Pl. I. fig. 2, *a a*.). They are moved in this animal with striking vivacity and acuteness, and are a good index as to the state of the animal and its intentions. Their orbits are wide, and present an admirable curve, whereby the crab enjoys an extensive field of vision, so necessary to his active and marauding habits. In this respect, he stands again in marked contrast with the Cancer pagurus, whose eyes are set in deep and narrow sockets, and are sluggishly moved. While the orbits in the C. mœnas thus admit of great scope of vision, they do not render the organ defenceless, but their exquisite curve, adapting itself to that of the eyeball, permits the latter to sink beneath a protecting ledge.

Orbits.

The organ is complex, and its varied movements are not less so. By a beautiful provision, the most delicate part—the combined corneæ—is almost wholly turned in towards the hard shell, when the eye is retracted; a row of hairs (sometimes absent), in addition, protects the little exposed portion, thus completely shielding it from external injury, while still admitting of useful vision. The force with which the eye is retained, when withdrawn, is very great, and it would seem that atmospheric pressure as well as muscular tension combined to keep it. When turned from their socket, the corneæ are made prominent by a revolving movement; and the more the eye is inverted (towards the middle line), the more prominent does it become, while, at the same time, it is moved in a backward direction.

Shape of Eyeball.

The shape of the compound eyeball is peculiar, and in consonance with the structure of the rest of the animal (Pl. I. fig. 3.). It is a sort of cone, with a deep depression extending round three-fourths of its middle circumference. The peduncle, coming from the junction with that of the opposite side, enters the base of the cone towards the inner side, in a position analogous to the entrance of the optic nerve in vertebrata. The soft parts of the eye are invested by the usual dermo-skeleton, with the exception of the corneæ. These are situated at the outer side of the cone, near the apex, but not quite, a part of the ordinary dermo-skeleton forming the projecting extremity: this has its functional importance, the corneæ being saved from the danger of extreme prominence, whether in protrusion or retraction. The curves of the eye shell are various, and merit close observation. But the calcareous coat of the eyeball is not of one continuous smoothness; there is a remarkable circlet of hairs near the base of the cone, on the outer or convex side, which seems admirably adapted to assist in the sucker power hinted at previously. A short notice of these may not be uninteresting.

(Pl. III. fig. 1.).—The circlet of hairs on the calcareous coat of the eyeball, and also on other parts of this animal, present a most remarkable microscopic appearance, and one which strikes the investigator of the vertebrate forms with astonishment. This peculiarity of structure is not so much in the hair itself (confining this description solely to the hairs of the circlet on the eyeball), as in certain curious appendages which adapt it to its varied functions. The hair is fibrous and pale, with a light coloured central space apparently filled with a semi-gelatinous substance. Its surface is almost everywhere clothed with growths of a fungoid appearance; some presenting the form of a floating mass attached to the surface of the hair by a filiform pedicle; others being of a delicate, filmy structure, not tapering, of pale greenish hue, and having the aspect of pigmy algæ. Many are thickened and roughened with a black cohesive substance, which entirely obscures the normal structure of the hair, allowing it to glance through only at intervals; while the dark parent mass

Circlet of hairs.

appears in striking contrast with the filmy appendages, which glisten as they stretch from it. Numerous other forms cluster round the hair,—bodies of a cellular nature, large and soft, infusorial animalcules and other Protozoa, as well as many anomalous structures. The whole together making up an impervious and adhesive mass of hairs, which, with the mud particles, cannot but form a kind of sucker arrangement by which the compound eyeball may be most powerfully retained in its socket. From its position, the circlet may likewise perform other functions, such as that of an elastic buffer to the delicate organ when rapidly drawn in, &c.

The calcareous cone has within it the visual apparatus and its accessory muscles, as well as the compound corneæ at its anterior part.

Corneæ. The *Corneæ*, as already mentioned, are clustered on the convex side of the apex, and their extent is well defined by the dark pigment which shines through them, lending to their surface a black, glistening, and almost metallic appearance. Microscopically, they present the aspect (Pl. I. fig. 4.) of hexagonal plates accurately united at their margins, and this form, it is well known, admits of the greatest number being clustered in the smallest possible space. They are perfectly transparent, like the analogous structures in vertebrates, consist of several layers, and have apparently the same chemical composition—at least, are acted on similarly by re-agents.

Minute anatomy of eye. Behind the corneæ, by unaided dissection, is a mass of pigment corresponding to each division, and of some thickness; posterior to this—the soft mass of muscles, optic nerve, nutrient arteries, &c. The usual description given in Comparative Anatomy works of the eyes of Crustacea of allied genera is, that "there is a conical crystalline lens behind each facet" (of the cornea), "imbedded in a small vitreous humour, upon which the optic filament expands, and each ocellus is lodged in a pigmental cell, which likewise covers the bulb of the optic nerve."* I traced the optic nerve quite easily through the mass of muscles forward to the vicinity of the pigment border, but at this, and sometimes before arriving at it, numerous branches radiated from the parent trunk, and, when followed, seemed to end in a granular layer, formed by pressure between the glasses. This granular layer was very pale and translucent, and composed of an aggregation of minute cells of somewhat irregular shape, and mingled with granules. It probably was formed originally by pressure on the cylinders, the pigment having been previously dislodged to prevent obscurity.

The pigment is granular, and of a very intense black colour *en masse* under the microscope, but brownish when somewhat isolated. No hexagonal, or other regular cell formation, could be detected. Pigment.

In connection with the external configuration and function of the eyeball, a diseased condition very frequently presents itself, not primarily any defect of the visual apparatus, but total disorganization of structure, and loss of function, caused by the pressure of a foreign body. This condition consists in the introduction and growth of the young of the Mytilus edulis, the Common Mussel, whereby the eyeball is wedged gradually out of its orbit, and ultimately drops off, or, thus projecting, is removed by the tela of an adversary. The Mussels appear to have been introduced in the condition of ova, and lodged in a fissure at the inner angle of the orbit, close to the insertion of the peduncle. In this position, they could not easily be dislodged, while, in growing, it gave them full purchase on the broad base of the conical mass. When small, you might see many, but, after a time, one took precedence, as in polypus of the nares, and, growing apace, appropriated the situation for himself. At first, they caused little interference, but soon the eye protruded; and, as the foreign animal

Introduction and growth of Mussels in orbits.

* Prof. Owen's Lectures on the Comp. Anat. of Invertеb p. 313.

grew, it did so in a most characteristic manner, presenting the convex outer surface on the dorsal aspect of the crab. The ova of the Mussel did not attach themselves to the circlet of hairs before mentioned; and, when the disease was not far advanced, these hairs might be seen still in situ; after a time, however, approximation being denied, they gradually disappeared by friction or other injury. In being thus pushed out, the eye underwent a rotatory movement as well, a rotation from below upwards to the extent of a quarter or half a circle. Whether the animal, while feeding in the water on the ova of the Mytilus, had them, in some of its varied movements, floated into its orbits, the eyes being protruded, I do not know; but the sudden retraction of the eyeball would only fix the intruders more firmly in their seat, behind and inside the cone's broad base. This lesion was frequently noticed, sometimes affecting one eye, at others both. It must have caused considerable pain and annoyance to the crab, and he certainly paid dearly for his destruction of the Mussel ova, if the former supposition is correct. I observed this state in many animals, say fifteen to twenty out of the hundred, (keeping rather under the real number), yet, only in two did I witness an attempt at the renewal of this important organ. In one of these, a pale, horny mass, soft at the tip, sprouted from the eye peduncle, resembling at first sight the interior of the eyeball after removal of the calcareous coating. It was somewhat stiffly attached to the peduncle, and its covering resembled that of the cornea, being, for the most part, pale and translucent (Pl. I. fig. 5, *a.*). Microscopically, the tough, white covering showed a highly wrinkled and transparent texture, enlivened with the cells of a light brown pigmentary portion. At one part, a streaked cellular aspect was visible, possibly the commencement of a new series of corneæ (Pl. II. fig. 5, *a.*). The soft interior presented a developing mass of fibres, cells, and granules. In many, the orbit was found quite empty, the projecting contents having been removed by accident, or the vengeful tela of an irate foe. No Mussels of large size (comparatively) were found in the empty orbits.

While thus describing the injury caused by the Mytilus in the orbit of the eye, it may be stated that they occur also in the sockets of the internal antennæ, and occasionally attached to the abdominal feet in females, and I have found them in the latter position of very large size,—three-quarters to one inch in the long axis, altogether preventing the approximation of the abdomen to the thorax. The ova of the crab sometimes formed a novel setting to the Mussel situated in the latter position. It is curious that an animal, on which, when unshelled or in the state of ova, the C. mœnas feeds with great zest, should thus frequently cause it so much annoyance and serious injury. Mytili in other parts.

The *Second pair* are two small nerves springing also from the anterior part of the cephalic mass, in close proximity to the optic, and which accompany the latter in their course. They enter the tubes of the peduncles, and are distributed to the motor apparatus of the eye-ball in the usual manner. Second pair.

The *Third pair* of nerves arise from the ventral aspect of the ganglion, immediately behind the optic and oculo-motor, and, bending forwards, enter the basal swellings of the internal antennæ, and divide into three branches; one supplying the peculiar organ endowed with motor and tactile sensibility, called the internal antenna; another coursing along the inner margin, and supplying the membranous and muscular structures around the sac; while a third could be traced into the calcareous elevation in the interior of the sac. Third pair.

The Internal Antenna (Pl. III. fig. 2.) in the Carcinus mœnas is of a similar structure with that of its immediate allies, so far as I have examined. It consists Internal antennæ.

of a segmented limb, with a peculiar and delicate arrangement at its extremity, consisting of two jointed appendages; one—strong and bearing beautiful hairs; the other—slender and capable of approximation. The hairs of the larger appendage (Pl. III. fig. 4.) are of a fine golden colour, and have distinct transverse markings, which more resemble the segments of an alga, than the slated appearance of wool: it seemed as if there were gentle undulations, rather than deep notchings. They slope to a point, but it does not taper much. The extremity of the thicker appendage is much finer than that of the more slender, and both are usually tipped with fine hairs. The great joints of the organ are articulated to the distal segments of the limb, and are capable of considerable and varied motions. These two segments (larger) are of the usual structure externally, and are articulated to the basal swelling—so characteristic of this organ—by a long ligamentous connection, which permits them to protrude or sink with great ease; acting, in fact, as a sort of long, elastic buffer and pad, by the shortening of which, the horny segments can be better packed, and by whose elasticity and softness, great and delicate motion is allowed. This, of course, diminishes the power—of little consequence, and increases the delicacy and sensibility—a matter of great moment. It is liberally supplied with muscles and nerves. I traced the nerve by softening the external shell of the jointed limb, but could not detect any peculiar mode of distribution; it seemed to terminate in minute branches to the surrounding textures. In the beautiful antennulæ, no trace of nerve fibre could be seen in the terminal joints, which were filled with a pale granular matter. The hairs at the tip of both, as well as those on their sides, appeared to dip into this substance, and as if their every motion would affect the matter in the interior. May not these hairs resemble our finger nails, in that, though quite insensible

Ending of Nerves.

in themselves, they form a most accurate knowledge of the qualities of surrounding objects by the admirable adjustment of the nervous elements in proximity?

The Basal Swelling (Pl. III. fig. 3.) of this organ presents an interesting structure. Externally, we have a calcareous coating, dense and strong in front and edges, where exposed, but horny and yielding behind; the line of suture between the two being well marked. There is a ridge of pretty strong hairs in front. Beneath the calcareous shell, we find the ordinary soft pigmentary layer of the derma, enveloping a glistening white sac. In the hollow between the latter and the internal edge lie the muscular and other structures pertaining to the limb of the organ. The sac is of an irregular heart shape (like the heart of a turtle), and, when in situ, is firmly attached to the hard walls on its lower and outer surface (Pl. III. fig. 3, *a.*). On its under surface, looking obliquely towards the limb of the organ, is an oblong or somewhat elliptical depression, with a central fissure, which is invariably present in all specimens. This fissure completes a communication between the interior of the sac and the general cavity of the organ. A portion of the sac, too, juts into an irregularity of the external shell. The microscopic structure of the membrane or wall of the sac is beautifully cellular, presenting no distant resemblance to a finely prepared specimen of the cartilage of the ear of a mouse. Every part of the membrane is composed of these cells, and they varied in size only to a slight extent (Pl. III. fig. 5.). Completing the base of the sac, formed by the membrane, is a smooth, hard ridge, running towards the outer margin, where it terminates in a rounded prominence, and becomes continuous with the calcareous coat. The long axis of this ridge corresponds with that of the basal swelling itself. No nervous expansion is visible on the sac, only the cutaneous nerve supplying the integuments and membranes.

Basal swelling.

Cartilaginous sac.

On opening the smooth prominence, it was found exceedingly hard and brittle, and a soft pulpy mass could be pulled from this and the interior of the ridge, which, when subjected to examination, was seen to be composed chiefly of muscular tissue, finely striated, together with the nervous filaments previously mentioned, which seemed to give most of their branches to the muscles. No peculiar formation was seen here to warrant the supposition that this was the important part of the organ, though there was a considerable amount of nervous tissue.

Function of Basal apparatus.

With regard to the function of this Basal apparatus, there remains no doubt in my mind—but that such a complex structure is designed for an important end. Dr. Arthur Farre,* Professor Huxley, and Mr. S. Bates, who have investigated this subject, suppose that it is the organ of hearing. As regards this animal, however, I do not think that it is at all connected with the acoustic organ; another portion of its structure, viz., the base of the external antenna, being devoted thereto. Now, as we have the senses of sight and hearing provided for by other parts, and since no part of the Basal swelling can lead us to think that it has any connection whatever with touch or taste, we are confined to the sense of smell alone. It is pretty certain that the animal is endowed with such a sense, be the organ in which it is placed what it may; but since no other structure in the animal bears so close resemblance to it (an organ of smell), we are again restricted to this. It is certainly in a very modified form, for I could not detect with the unaided eye an external opening; but this will not exclude it from being the analogue of such an organ, and from performing a similar function. The way in which its immediate ally (Cancer pagurus) is caught, also supports this idea; the garbage in the traps being more accessible to smell than sight. In the Carcinus mœnas,

Organ of smell.

* Philos. Transact. 1843.

the superiority in activity and acuteness, when compared with the Cancer pagurus, would of course lead us to the conclusion that the senses are also of greater delicacy, or, at least, of greater acuteness. It is a fact well known to those engaged on our rocky coast in catching the latter, that certain states of the garbage will not entice it, and certainly sight would not discriminate between stinking and fresh bait suspended, at a distance from the animal, in a netted cage.

The rudimentary condition both of this and the succeeding structure render it very difficult to assign to each its proper function; but, in the meantime, I consider that it is the organ of smell in this animal:—
1. Because on the removal of the internal antennæ and their basal organs, the crab was scarcely affected by odours; 2. In the total absence of otolithes; 3. In the presence of another organ having more analogy to an ear.

Fourth pair.

The *Fourth pair* of nerves (Pl. I. fig. 1, *e*.), arising from the dorsal aspect of the ganglion, sweep outwards to supply the tough membranous structures at the anterior part of the animal. They have no further function.

Fifth pair.

The *Fifth pair* proceed from the nervous centre forwards and slightly outwards to the external antennæ, supplying them and the special organ at their base.

External Antennæ.

The basal part of the external antennæ, is firmly anchylosed to the external skeleton, and supports the slender, jointed antenna-proper through the intervention of a flexible hinge, not so lax and delicate as that of the internal antenna. The jointed segments decrease regularly in size to the tip. These are endowed with great tactile sensibility, and their various motions, which indicate the state of the animal, are interesting. In danger, the crab lays them along the lower curve of the orbits, and thus shields them from injury. One of these is frequently, and both occasionally wanting, an occurrence which rarely happens with the internal antennæ.

Auditory apparatus. At the root of the basal portion of the internal antenna, we have a large cavity lined by a soft membrane, microscopically presenting the ordinary pigment cells and granules of the lining membrane of the shell, some peculiarly papillated and translucent fragments, otolithes, and the nerves and muscles chiefly pertaining to the jointed tip. From the two posterior angles of the little triangle, mentioned as the external indication of the cephalic ganglion, jut two ridges, which flatten out a little as they approach the anchylosed base of the external antenna; on this portion is an ovoid and moveable piece of shell, transverse in its long axis, and continuous internally with a calcareous, bifid rod. Any movement in the latter correspondingly affects the lid, which is either elevated or depressed. A somewhat tough membrane connects the margin of the lid to the rim of the cavity, protecting the delicate contents, as well as performing other useful functions. The external end is the more fixed; the internal having much greater freedom of motion (elevation and depression). On dissecting this further, the under surface of the lid is found cup-shaped, and resembling, in its connection with the bifid rod, the stapes of the human ear (Pl. III. fig. 6.). In the cup-shaped hollow of the lid, or between the forks of the stalk, is found a pulpy mass into which nerve fibres can be traced. It would seem, then, that the vibrations in air or water acted through this membrane on the pulpy mass, which, in its turn, communicated its particular state to the cavity at the base of the external antenna. From the nervous expansion on the walls of this cavity, the crab receives such a sensation as enables it to judge of the direction and intensity of the sound. Various experiments and observations may prove that this animal does hear, and since there is no other structure which can by anatomy or analogy be made into an ear, the case is substantiated. By making a noise in the proximity of the crab, hid in

Auditory apparatus.

Function of parts.

some narrow fissure amongst muddy water, and in such a position that sight was useless, you might hear the grating of his shell, as he pushed further inwards from the invader. Or again, when a step approached the room, at night, in which they were confined in a closely fitting vasculum, an immediate commotion of the prisoners resulted; and the same occurred when any sudden noise alarmed them. Observations on hearing.

On removing their eyes, they also showed much more acuteness than such an animal would if hearing were wanting, and, in fact, if it were not tolerably well developed.

Connecting Trunks.—The two nerves connecting the cephalic with the great thoracic ganglion are of large size, much more bulky than the optic nerve, a state which betokens their great functional importance. They do not continue as cylindrical cords, but, whilst encircling the œsophagus, a gangliform enlargement takes place on each side, and a branching of the trunk ensues. This ganglion (Pl. IV. fig. 1, *a*) is easily distinguished as such, and is of an oblong shape. It contains a collection of nerve cells at one side of the mass, and gives off from the under side,—nerves for the mandibles, and from its upper,—a large nerve, which covers the stomach with its ramifications (Pl. IV. fig. 1, *b*, and Pl. II. fig. 4, *a*.). This latter may be termed the *Pneumogastric*. Ganglion on Connecting cords.

Less than one-eighth of an inch behind the œsophagus, we have a considerable nervous cord (a notice of which, in this animal, I have not been able to find in any treatise) connecting the trunks of communication, and steadied by membranous folds of fibrous tissue. This cord does not arise from the œsophageal ganglion, but is placed about a quarter of an inch further back (Pl. IV. fig. 1, *c*.). There is no gangliform enlargement where it meets the cords, and no nerve cells are perceptible; it seems to be solely a commissure of fibres Commissural cord.

between the cords. From all I could observe microscopically, the arrangement of the fibres has, on a small scale, somewhat the appearance of the optic commissure in man. Some of the fibres from the cephalic centre go right on to the thoracic, without crossing at all; others, curving through the commissure, return through the other cord to the ganglion whence they started; while a third set, not so easily made out, crosses from the one cord to the other, still continuing in the pristine direction (Pl. IV. fig. 2.).

Course and termination of cords.

Proceeding backwards under the stomach, the nerves of communication gradually converge through masses of the liver, and, passing beneath a ligamentous archway connecting two jutting portions of the skeleton, come close together, so as to appear as one cord. This takes place just at the posterior part of the ligamentous band before mentioned, and they then plunge into the thoracic ganglion. While tracing these connecting cords backwards, we come in close contact with the nerves for the foot-jaws, which run forwards by their side.

Thoracic Ganglion.

Thoracic Ganglion (Pl. IV. fig. 3, *h*).—The Thoracic Ganglion is an ovoid mass of nervous matter, the longest diameter being antero-posterior, and having in its centre a circular aperture. This shape has given grounds to the appellation "nervous ring;" the aperture, however, is small, while the surrounding nervous substance is of great thickness. It lies on certain parts of the muscular apparatus of the limbs, and has above it portions of the intestinal canal, liver and generative system, amidst which various organs it enjoys comparative immunity from danger. From this great nervous centre radiate on all sides trunks for the supply of the foot-jaws, telæ, limbs and abdomen, giving to the arrangement here a stellate aspect. It is best reached by a dissection from the ventral surface, whether after hardening in spirit, or during the life of the animal. Microscopically, it presents a similar structure with the cephalic ganglion, abounding in nerve cells of various kinds, &c.; but the nerve cords of course are much more conspicuous at the edges, from their great number and radiated arrangement.

Nerves of growing limbs.

The only observation I have worthy of note in regard to the distribution of the nerves of the limbs (for they are simple branching muscular nerves), is their arrangement in the *young or growing limb* of the animal, after the old one has been lost. Thus, when the limb is fully grown, an entire nerve and branches are furnished to it, differing in no respect from those of the original organ. The distinguished naturalist, Mr. H. D. S. Goodsir, who fell a martyr to science in the fatal expedition of Sir John Franklin, carefully investigated the mode of reproduction of the crustacean limbs, and made beautiful drawings of the ordinary and microscopic anatomy of the same; before mentioning our observations, it may be advantageous to give the following quotation from his paper.*—"Immediately on the limb being thrown off, a quantity of blood escapes, which is soon stopped by the retraction of the vessels. After this takes place, we see the small open foramen for the passage of the artery and nerve, which becomes closed almost immediately by means of a slight film which spreads over the whole of the exposed surface. When this surface is examined some hours after the loss, we find that the small cavity of the foramen is slightly filled up with a body resembling a nucleated cell. This cell is the germ of the future leg, and very shortly increases in size, so as gradually to push out the film alluded to above, which is now become a thick strong cicatrix. During the time that this is going on, the whole of the exposed surface had become tense and bulging, but this gradually decreases round the circumference as the central nucleus increases in size, which

Goodsir's Observations.

* Anatomical and Pathological Observations, by J. Goodsir, F.R.S.E., and Harry D. S. Goodsir, M.W.S. 1845, p. 77, Plates VI. and IX.

it does at first longitudinally, and then transversely. As it increases in size, the cicatrix, which still surrounds it as a sac, becomes thinner and thinner, until it bursts, when the limb, which has hitherto been bent upon itself, becomes stretched out, and has all the appearance of a perfect limb, except in size."

Microscopic appearance of nerve at cicatrix.

On dissecting a very young limb, about one-eighth of an inch in length, and quite soft, no new nerve texture was visible, the amputated parent trunk being little altered. It could be traced to the amputated ring, and microscopically became lost in a tough fibrous cicatrix which protected the delicate parts at the end of the stump. When you tried to separate the cicatrix into its constituents with needles, the nerve adhered strongly, and could not be detached without laceration (Pl. IV. fig. 5.). At the extreme portion of the nerve, a granular and faintly cellular appearance was visible under pressure, and the fibres could be traced up to and amongst this (Pl. IV. fig. 6.). As older, though not full-grown limbs were examined, a complete nerve was easily detected; but I have not met with a specimen in which I could see the nerve tissue so long as the limb was soft and doubled, before expansion.

Question of reproduction.

Whether the nervous tissue reproduced itself, or was formed by the general cellular matrix of the new limb, are somewhat delicate questions. If it was not reproduced by the original nerve, but was formed from a special set of cells, we have an example, on a small scale, of what takes place in the fœtus. Special arrangements, moreover, in this case, would require to exist for the exact blending and continuity of the old and new nerve texture, a state so necesssary for the proper performance of its functions.

PART II.

EXPERIMENTS ON THE NERVOUS SYSTEM OF THE CARCINUS MŒNAS.

1. *Removal of Thoracic Ganglion.* This operation was effected by raising the abdomen and snipping out a portion of shell over the ganglion, then clearing it from the superincumbent muscles, which present themselves in this view of the structure (ventral). Before the ganglion was injured, the slightest irritation applied to any external part of the animal caused it to struggle violently; and, as large and active specimens were generally chosen, they were often difficult to hold. The nervous matter, when cleared, is of the usual pale aspect, not contrasting forcibly with the surrounding tissues. The ganglion, being seized with the forceps, was entirely removed by snipping its branches. As each nerve was cut, the limb twitched convulsively for a second or two, and then relapsed into complete paralysis; exhibiting not the slightest motion but such as was caused by the force of gravity. Repeated irritations to the external surface, after a time, had no effect, and the limb remained powerless. If, however, the trunks supplying the limbs were irritated at the point of division, the corresponding limb of each nerve was flexed once or twice, and the distal segment (propodite) oftener and longer. On applying the stimulus (forceps) again to the same nerve, the movements were not distinct, unless it was touched beyond the point formerly irritated: this may be accounted for by the fact, that the forceps probably destroyed the conducting power of the excident fibres by pressure, at the portion first stimulated. The posterior foot-jaws were also deprived of motion, and when displaced, did not return altogether to their ori-

Effects of removal.

ginal position, the inherent contractility of their flexor muscles not accomplishing so much. The smaller foot-jaws, however, retained a certain degree of motion, probably from the circumstance of a ganglion being situated somewhere on their nerves. The mandibles of course were active, and closed sharply when forced open. The abdomen for a time possessed a certain degree of motion (probably from some ganglionic connection also), but, on severe irritation, it too remained extended, its distal segments alone exhibiting slight contraction. No frothy matter escaped from the anterior branchial openings. The lesser or internal antennæ remained in full action, being sharply folded when extended, and undergoing other motions when irritated. When at rest, they were always closely doubled up and drawn in. The eyes were drawn back to the utmost into their orbits, and, when forcibly pulled out, immediately sank back on removal of the restraint, unless their muscles were torn or otherwise disabled. Occasionally the animal would protrude one eye to reconnoitre, but quickly retracted it, if danger seemed imminent. The external antennæ were generally laid along the orbital groove, this being the least exposed and most convenient situation. On irritation, they underwent their usual motions, and generally concluded by being laid along the orbital notch again. If anything, they seemed more languid in performing their evolutions than either the eyes or internal antennæ. Sometimes they remained standing out, as if in stupor, after the shock of so great an injury.

Effects on heart's action.

By the wound made in removing the ganglion, the heart could be seen beating, but irregularly, and always with increased vigour if irritated. Sometimes the contractions ceased suddenly, and as suddenly began again. They occasionally continued, or could be excited, for fourteen or sixteen hours after the operation of removing the nerve centre. The movements of the heart continued for about an equal period, on the whole, after the removal of either ganglion (cephalic or thoracic); at least, they could be excited for nearly the same length of time in either mutilation.

On the whole, then, the general condition of the crab after removal of the thoracic centre was the following:—Loss of sensation and motion in all the locomotive organs (the motions which the limbs afterwards exhibited taking place when altogether removed from the body as well as when adherent); almost complete paralysis of the abdomen, this, however, evincing slight contractions; loss of motion of most of the foot-jaws; impairment of respiration, since no air bells gurgled to denote an active state of the branchiæ; irregularity of motion of the heart, with frequent suspension of function, unless under direct stimulus; integrity of function in the eyes, two pairs of antennæ, and other parts supplied by the cephalic ganglion, except so far as might be accounted for by shock. Summary.

2. *Removal of Cephalic Ganglion.* This is accomplished by cutting out a portion of the shell on the dorsal aspect, over the seat of the ganglion. The muscles of the stomach, cellular tissue, &c., are then removed, and the mass exposed. The animals seemed to suffer great pain on irritating this ganglion, and their struggles were violent. It was excised as formerly, by seizing it and snipping its branches. During the excision, the antennæ and eyes, as might be expected, underwent various jerking movements; although, rarely, the animal lay in a sort of stupor during the operation.

The following effects were evident in most cases after the injury. A general stupor pervaded the animal, which, however, appeared less marked than in the former operation, since it retained the use of its limbs. When the limbs were irritated or injured, the animal could crawl in an opposite direction, and avoid the cause of the pain; but there was a want of control manifested in its actions, a stumbling gait, with the anterior part Effects of removal.

of the cephalo-thorax often depressed to the surface on which it moved, and it frequently turned itself on its back. Sometimes it evinced no tendency to move, except slight contractions of the smaller limbs, and swinging of the telæ to the site of injury, probably from irritation of certain parts supplied by the great thoracic ganglion, as the stomach, &c.; at others, it would crawl considerably. The abdomen was very irritable, as in the normal state of the animal, and, accordingly, it resented the slightest interference. The foot-jaws and the mandibles retained their motion, and so with the respiratory organs, as the frequent escape of frothy air bubbles attested. The larger foot-jaws moved vigorously, while the smaller were rapidly vibrated. The heart continued to beat for a long time, as in the former case. The eyes and two pairs of antennæ were of course deprived of sensation and motion, and the former often remained protruding in a characteristic manner.

Compared with the former injury.

On comparing the one operation with the other, it would seem that, in general, the removal of the cephalic mass had a greater influence on the regularity of the animal's movements than the thoracic, since any motions exhibited after the removal of the latter evinced more want of purpose and control than regularity. More extensive movements could be excited in this, than in the former case, from the large expanse of tissue supplied by the thoracic ganglion.

State after section of connecting trunks.

3. *Division of the two connecting cords.* On cutting these, the animals at once started and moved their limbs convulsively. Some then assumed that peculiar position, with the anterior part of the cephalo-thorax pointing downwards, and carried forward in that situation; others wheeled round and raised the posterior part of the carapace so high as to fall on their backs. A third set, again, moved little after the injury, elevated the posterior part of the cephalo-thorax, bent the forceps underneath it, and denoted pain by biting

at the oral region; then they relapsed into a motionless condition with scarcely a twitch of a limb, the silence being broken only by the gurgling air bells from the branchial apertures. In some cases, especially if the section was close to the cephalic ganglion, the eyes, when pulled out, no longer sank back from slight irritation, and were drawn in only when the optic nerve was injured by direct puncture; in others, the eyes retained considerable power, but were seldom protruded spontaneously. The internal antennæ, when drawn out and pinched, showed contractility; sometimes they were even protruded voluntarily. Irritation of any of the foregoing was followed by no movement of the forceps or smaller limbs. The foot-jaws were in full power, and the feathery margin of one of the small anterior pairs was often kept in vibratile motion. The large posterior pair were also frequently moved in the usual manner, but slowly. The forceps retained most of their power of motion, but wanted precision in regard to direction; the other limbs also lost little of their mobility, being deficient only in the co-ordination of their movements. The abdomen retained full sensibility and motion, and the slightest irritation of this part in either male or female caused the crab much annoyance. The distal segment was frequently put in motion, in the peculiar manner noticed previously.

Tendency of the crab to turn over on dorsum.

A striking effect of this operation was the tendency of the crab to turn on its back, more especially if the maxillary palps were injured by the points of the scissors; and often, although repeatedly put in its normal position, it persisted in turning itself on its dorsal aspect. Some remained midway, standing on edge with the assistance of the large forceps; these formed two points of a tripod, the third being the anterior margin of the cephalo-thorax: others did not accomplish so much, but had intermediate positions. These attitudes were characteristic of this lesion; and occasionally one died and stiffened in the former posture. They frequently jerked their limbs in a peculiar manner some time after the operation, as if a sudden paroxysm of pain compelled them to do so. Wherever these cords were divided, similar effects ensued; most of the divisions, however, took place nearer the cephalic than the thoracic ganglion.

Summary. This operation, then, was followed by these general effects:—Complete loss of regular progression; more or less impairment in the function of the parts supplied by the cephalic ganglion (partly from shock); power, but also stupor, in the parts to which the thoracic ganglion is distributed. That the thoracic ganglion performs the part of a complete nervous centre, when separated from the cephalic, is demonstrated by this operation. Irritation of any of the organs supplied by it speedily brought the defensive forceps to that part, and with considerable certainty of direction. That the cephalic also exerts a certain amount of influence on the thoracic is equally plain, for, though the limbs retained motor power, the animal never progressed one inch, and there was a torpor in all its motions. Pain, too, formed a prominent feature in this operation, as indicated by the frequent motion of the forceps towards the wounded part.

Section of cephalic nerves on one side. 4. *Division of the Cephalic Nerves on one side.* This was done by removing a small portion of shell over the ganglion on the dorsal aspect. The animals generally remained stationary for a time, after the first convulsive movements. In these, it might be observed, that they most frequently ran to the side opposite to that on which the nerves were cut. The eye and antennæ on that side were of course paralysed, and remained motionless. The anterior part of the cephalo-thorax was not much depressed in general, as in removal of the entire ganglion. The crabs defended themselves vigorously. When the limbs were pinched sharply, the animals sometimes wheeled round and round, without progressing much from the spot, in a manner seen in no experiment or operation before. Some, after recovering from the shock of so dangerous an operation, moved about, and generally with the sound side foremost, as before mentioned. When arrested, and turned round with the wounded side foremost, and the limbs on the sound side pinched, they did not stir; but when again placed with the sound side first, they frequently decamped without irritation. When the limbs were irritated on the sound side, their motions were more sudden and lasting, as if that side were the more sensitive.

Bisection of thoracic ganglion.

5. *Bisection of Thoracic Ganglion.* An incision, carried backwards from between the connecting cords, severed the ganglion to the abdominal nerves. After this injury, the crab never crawled, but was thrown into a variety of contortions, the forceps and small limbs being knuckled under, and spasmodically moved. Unable to support the cephalo-thorax, the latter lay flatly on the ground, after the convulsive twitching ceased; life being only manifested now and then by a waving of the posterior pair of limbs. The eyes and antennæ, active at first, soon became sluggish and insensible. Some, on the application of galvanism to the bisected ganglion, pitched off the telæ, when the current was sent to the tips; life soon ceased: the operation appearing to be equally as fatal as the removal of the entire ganglion.

PART III.

EXPERIMENTS WITH GASES.

1. *Chloroform.* The experiments with the vapour of this substance were conducted in a large glass jar with closely fitting top, and the chloroform was either put on a piece of cloth, or poured in loosely.

The first effect observable was the active motion of the crab, which clambered up the jar, and apparently, in some cases, endeavoured to escape from the rag saturated with the liquid (another argument in favour of the presence of an organ of smell). In many of these experiments, the jar was entirely filled with the vapour, and would speedily have anæsthetised a mammal of almost any dimensions. After the chloroform had fairly taken effect, the animal sunk into a paralysed state, every limb hanging loose as if dead. Out of many cases, I select the following, in which large crabs of both sexes were the subjects of the experiments.

In a jar thoroughly filled with the vapour, a crab was immersed for $1\frac{1}{2}$ minute; its motions had not ceased when it was removed. It ran about actively, and then hid itself in a dark corner. The chloroform had little effect. Another was kept in $2\frac{1}{2}$ minutes; when removed, cold affusion caused slight twitchings; by and by it crawled nimbly, and, like the former, sought a dark retreat. After 4 minutes immersion, occasionally one would crawl: the cold douche generally set them in convulsions, out of which they gradually emerged, and recovered completely, as we shall see. Having one afternoon left my room door open, and there being on the floor several crabs supposed to be dead or dying, I got no small surprise when returning up stairs in the dark of the evening to hear a heavy body strike on the rail of the stair close to my face, which was struck with water drops; this was followed by a second and a third crash in the immediate neighbourhood, with a scrambling and crunching (as two had fallen together), which revealed the intruders. It was found, afterwards, that this crab rain was caused by three of the chloroform series, which had been immersed respectively 4, $4\frac{1}{2}$, and 6 minutes, but they had recovered entirely, and only one was the worse of the fall.

The series of phenomena occurring in the experiments with this vapour may be stated as follows.—On first immersion, the animal endeavoured to escape by clambering; foot-jaws, both large and small, in active motion; limbs gradually grew weaker, and respiration embarrassed; eyes staring, or one retracted and the other staring; made great attempts to clear branchial apertures. In 10 minutes, little or no motion, and frequently, though removed, they did not recover. On being violently shaken at this time, there were slight motions of the foot-jaws, and terminal segments of small limbs; sometimes spasmodic twitchings about the 6th or 7th minute. If the chloroform jar was in proper condition, they seldom recovered after the 10th minute, only rarely exhibiting a twitch or two of the propodite in the smaller limbs, after the cold affusion.

This remarkable agent, then, has a precisely analogous effect to what we witness in man and the higher mammalia. Operations of any kind could be conducted on the crabs when anæsthetised, just as in man. Of all the vapours experimented with, this had the pre-eminence, like corrosive sublimate amongst the poisons. It will be observed, too, that the series of phenomena occurring on its application are almost exactly those we see in mammals. We have, first, a period of stimulation; towards the end of this, irregular motions, sometimes of a spasmodic character; and then a state of anæsthesia, which becomes more and more intense, till at last it merges without a sign into death.

2. *Mineral Naptha* (*vapour of*). A jar similar to the former was used, and the liquid poured in freely or on cloth. Their movements at first resembled those in the last experiment, but they soon grew more violent; for the animals evinced an intensity of action, tossing their every limb in convulsive efforts. These motions lasted much longer than in the former case, those of the foot-jaws especially attracting attention, as if the animal wished to clear the anterior branchial apertures from some irritating and offensive substance. It placed the crab in a state of high nervous excitement of a spasmodic or convulsive character. If taken out in half an hour or less, and the cold douche applied, they slowly recovered. When they were kept longer, and especially if there were two together, they threw off many of their limbs; in some cases leaving only a single small one. Their motions were very violent, but of course after such a catastrophe as that last mentioned, they were not so evident. There was generally little sign of life at the end of an hour. On one occasion, some naptha had been accidentally spilt into a large paper box, containing 20 or 30 small sized Carcini; I shall not readily forget the intense horror, the rushing, scrambling, confusion, discarding of limbs, and other tokens of extreme excitement which lasted until they were removed from the baneful compartment. They seemed to regard naptha with especial aversion and dread.

3. *Ammonia vapour*. The jar was filled with the vapour of strong ammonia of the shops, and a large and powerful Carcinus mœnas immersed. For a time, it did not move; and it seemed that the gas had a soothing effect, at least did not cause such pain as to irritate the animal into motion. In a quarter of an

hour the crab moved about, but these and all the subsequent motions did not seem to be the result of so much inconvenience as in the foregoing case. It continued to move until it was taken out at the end of an hour, quite as lively as ever, and using its forceps with fierceness. An accidental and sudden fall put an end to this, and it lay motionless, stunned by an amount of injury which would have been a trifle under ordinary circumstances. It lay with its limbs contracted in a peculiar manner for two or three hours, but afterwards recovered entirely.

This experiment showed some of the preliminary actions of $N H_4 O$ vapour, and that sufficient time had not been given for the gas to develop its full effects. So far as we can judge from this experiment, the ammonia vapour had more of a sedative and narcotic than stimulant and irritant effect.

4. *Hydrosulphuric acid.* This gas was made by enclosing in a perforated tin box some Fe S and H O, $S O_3$; a further addition of a little of the acid could thus always command a supply of the gas: once only was the filling tube used. Some of the general effects were these:—The animals avoided the generating apparatus. There was no violence of motion at any period of their immersion. Change of colour of the dermo-skeleton from the deposition of sulphur.

As an example, the following case will show how little effect this gas has on the crustacean's comfort. A large male was placed in the gas, as in the former experiments. At first, it clambered a little, but its motions were rather sluggish, and it held the telæ in a sloping direction. On shaking the jar a quarter of an hour after (as it was quiet), the eyes were retracted, and the external antennæ moved upwards and downwards, while the usual motions of the limbs and elevation of the forceps followed. Occasionally, one eye would be retracted and again extruded, the other remaining motionless.

No motion of the foot-jaws could be observed, the narcotic effect of the gas seeming to influence them in the first instance. Sometimes there occurred slight clambering, and movements of the terminal joints. On violently shaking the jar half an hour after immersion, the forceps were elevated and the other limbs tossed about, and again all sunk into repose. By and by, the body of the animal assumed a bluish appearance, as the S of the H S was deposited on the dark background of the carapace; the under surface became, for the most part, of a blackish aspect. In an hour or two, it moved little, and only a sudden twitch of one or more limbs, on shaking the jar, indicated life. But, although thus apparently sinking, the animal was by no means destined to terminate its existence so quickly. On the second day, the limbs were twitched spontaneously in the morning, and the telæ moved sharply on irritation. In two days and a half, bubbling commenced at the branchial apertures; when stimulated, the telæ rose feebly, and soon fell again. It was taken out in three days and a half, the jar still strongly scenting of H S; the limbs were slightly moved. On the fourth day, there were still evident traces of vitality, although the animal did not move from the spot. Life's flickering flame became gradually feebler, and it died on the same day.

It was astonishing to observe with what impunity these animals could remain in an atmosphere which terminates with rapidity the life of most creatures. To see a crab surviving after 30 hours immersion, with its branchiæ in full action, is certainly wonderful, but yet not so much so, when we reflect that this being is found flourishing in its native haunts amongst slimy mud, impregnated with putrefying animal and vegetable remains, the dark chaos of which gives forth volumes of this very gas.

5. *Hydrocyanic acid.* Cyanide of potassium was

placed in a perforated vessel in the jar, and the gas sent off by the addition of H O, S O_3. On insertion, the crabs immediately exhibited violent motions, with attempts to escape from the deadly vapour, and spasmodic twitchings of the limbs. After this ebullition, they generally remained quiet for a time. No motion of the foot-jaws. In a quarter of an hour, when shaken, the telæ were feebly raised. The eyes were rapidly drawn in, on the approach of a foreign body. Sometimes the crab seemed quite overpowered, and had no tendency to raise itself. A few made active movements at twenty minutes, without any action of the foot-jaws. In half an hour, there was little motion, even when shaken violently; while the limbs were somewhat tetanically affected, the animal supporting itself on one large and on half of the smaller legs. They generally moved little after the half hour, perhaps only a gentle separation of the external foot-jaws. They died on an average in one hour.

At first, this gas seemed noxious and irritant, goading the crab into desperate action. Afterwards, the narcotico-sedative action enfeebled its once active muscles, and soon severed the hardy life. Alike, then, with the higher, this animal succumbed to the fatal vapour, though there was a considerable interval between the application and the result.

6. *Chlorine* — produced by the action of H Cl on M n O_2, in the same apparatus. At first, they struggled violently, and ran about as from a sharp irritant. The motions of the foot-jaws were slight, became a little more active, and then declined; air bells ejected only once or twice. The foot-jaws often remained apart from each other, at a distance from the body, for a considerable time, and this, together with the swinging of the external antennæ, was characteristic. In a quarter of an hour, irritation caused the animal to move about pretty actively; occasionally there was frothing, but no

movement of the foot-jaws. In an hour, some waved their limbs and foot-jaws after the manner of a sinking animal, but yet, when touched, they made a vigorous defence. It reached the fifth or sixth hour, in most cases, before life became extinct, at least before its external manifestation ceased.

It was remarkable to witness the time these vigorous crustaceans could be immured in a jar containing an amount of chlorine that would speedily have suffocated most other animals. Besides, the gas must have been absorbed in large quantity by the fluids of the animal, and diffused through its respiratory system. At first, the irritation caused active movements, then the crab sank into a quiet state as if powerfully depressed, yet it had much latent energy. It died, slowly exhausted by the irritant poison, but without manifesting much disturbance after the beginning. Motion throughout was not of a convulsive character.

7. *Sulphurous acid.* The jar was filled with this by burning S in a capsule. After the vapour began to get dense, active motions ensued; sometimes convulsive twitchings of the limbs. In ten minutes, there were often rapid contractions of all the limbs, as if from pain, with frothing at the branchial apertures. In an hour and a half, scrambling movements, considerable action of the foot-jaws, and air bells; the larger foot-jaws stuck out from the body, and the external antennæ were swung round. It could be observed, that the action of the foot-jaws increased gradually, thus showing a return of function to the respiratory organs. On smelling the jar, the SO^2 odour was quite gone, nothing but the saltish smell of the crabs remaining. They recovered entirely.

The acid vapour was probably taken up by the fluids of the animal, producing a temporary depressing effect, afterwards negatived by the activity of the respiratory organs. The crabs, however, as might be expected, were more easily injured by external violence, or other gases, than those not similarly circumstanced.

8. *Phosphoric acid.* An active male was plunged in a jar of this vapour, made by burning P in a capsule, and this was repeated twice. After the usual clambering, the limbs became weaker, and it sank into a motionless state, unless irritated. There was no action of the foot-jaws, as the respiratory apertures were shut against the noxious gas. In an hour, its feeble motions indicated pain. The dark surface of the carapace was now rendered grey by a deposit of PO_5. In two hours, bubbling at the branchial apertures, but no motions of the foot-jaws; the limbs twitched sluggishly under strong irritation. Five hours, action feeble; no movement of the foot-jaws; great tendency of the telæ to hang drooping. Seven hours, foot-jaws in action, and frothing at apertures; telæ drooping. The jar had long lost the odour of the vapour, and the crab was removed. It was some time before the animal recovered itself, but in 24 hours it crawled about with as much ease as when inserted, its back white with PO_5, and the terminal segments of the limbs reddened by the action of the acid, dissolved in a little water at the bottom of the jar. It was my companion for many days, running about the room as if nothing had happened to it, and often scrutinising the remains of less fortunate compeers. I missed the crab, and nine months after found him comfortably situated behind a bookcase, mummied and fit for museum purposes, an occurrence by no means unfrequent.

PART IV.

EXPERIMENTS WITH POISONS, &c.

1. *Tartar Emetic.* This substance was introduced in poisonous quantities by various means. First, by raising a portion of shell over the cardiac region. In this, and in the experiments with As O_3, some observations were made on the heart. Every pulsation raised the detached portion of shell, which was carefully replaced over the wound, after the introduction of the poison. Immediately after the operation, the number of beats was 80 per minute; in half an hour, 112; it moved little during this period, but sharply resented irritation. It also emitted a large quantity of frothy matter from the branchial apertures. In one hour, heart's action slightly increased (115); spontaneous motion slight, branchiæ in action. Fully two hours after, heart's beat, 109; in six hours it fell to 69. At the second hour, the crab did not move except when irritated; eyes and antennæ retained their irritability for about six hours. The limbs soon became rigid, and sinking supervened.

Secondly, an aperture was made in the cephalo-thorax beneath the folded abdomen. The crabs moved rapidly when let loose, and then remained still. Their motions soon became sluggish, and they had no tendency to crawl; no frothing. In one hour, they resented interference actively, but did not run: two hours, branchiæ in action; resented interference: six hours, moved telæ when strongly irritated, but did not stir from the spot; small limbs often stretched towards telæ. After this, they gradually became weaker and weaker, and perished often without moving.

When Tartar emetic was injected per anum, in solution and mechanical mixture in water, the crabs moved about as usual on being freed, though scarcely so far. If pinched, they struck with telæ; eyes and antennæ active; no tendency to hide. In half an hour, struck actively when irritated; eyes and antennæ functionally perfect. One hour and a quarter, little defence unless strongly pinched; no spontaneous motion beyond a slight heaving of the cephalo-thorax. Three hours, no voluntary motion; limbs feeble; eyes still retracted on being pulled out. At the fourth hour, the eyes were seldom retracted, the majority being lifeless, not manifesting even a twitch of the internal antennæ.

Injection into the alimentary canal was thus more speedily fatal than insertion of the poison almost in contact with the heart in the one case, and in close proximity to the great thoracic ganglion in the other. It would seem that absorption of the poison was more rapidly perfected by the surface of the canal (accustomed to such work), than by any wound, however appropriate. It must be remembered, that a nearly impervious shell forms the covering of this animal, on removal of which we cannot expect to find a surface very amenable to absorption, if, indeed, it exerts such at all for a time. This may even hold, to a certain extent, although we remove the soft pigment membrane beneath, as was done in every, or nearly every, case. The foreign function at least took some time to develope itself in these wounds, while the alimentary canal set to work at once.

2. *Arsenious Acid.* A square portion of shell was removed from the dorsum, as formerly, and a grain or two inserted. It moved actively; heart's beat 60, and in half an hour 76; but the organ did not seem to carry on its function regularly, as it frequently could not be seen beating at all. Branchiæ in action, without frothing; resented irritation. Internal antennæ jerked. One hour, heart's action, 79. The animal was very active at the end of three hours, in fact, its vigour was

unabated. On seeing so small an effect produced by such a dose of this deadly irritant, I made an aperture in the cephalo-thorax beneath the abdomen, and inserted at least a grain more of the powder. It crawled about as before, and seemed little affected by the further direct application of the poison, when the shock of the fresh injury was taken into account. Six hours, crab very lively, and using forceps keenly. It did not crawl much from the spot after the fourth hour, although, as before mentioned, it was not from want of power. Seven hours, pulsations 59; eyes, antennæ and limbs pretty active. There was no frothing, but only an occasional gurgle from the branchial aperture. After this, it gradually became feebler, and died.

When the As O_3 was injected per anum, the following effects ensued:—The animals were immediately tetanically convulsed, and often sensibility seemed lost, as they crunched at the anterior part of the shell, or anything that came in the way of their telæ. The smaller limbs and telæ then lost power, and there was swinging of the external antennæ; eyes and internal antennæ active. Foot-jaws sluggishly moved. In four hours, some few exhibited traces of vitality in the internal antennæ and eyes. They did not move from their position after the first struggles, and now made no attempt to resent irritation.

This poison applied to wounds, generally considered such deadly practice, was comparatively long in producing its effects. The former substance was more speedily fatal by this method. To see a crab running about, almost unhurt, after the manipulations narrated in the first experiment, was more than curious, and this was but one case out of many. Wherever the wound was made and the poison inserted, invariably the crabs, labelled accordingly, were found amongst the list of effectives, after numbers of their comrades had succumbed to other poisons. The wonder of the experiment where the poison was applied to the vicinity of the heart is somewhat diminished, when we recollect that the crab can live for a long time without a heart at all, as several trials demonstrated.

3. *Bichloride of Mercury.* A grain or so was placed in general in the wounds, which were varied as regards their seat. Sometimes they crawled about after the operation, seemingly labouring under some severe injury. The forceps were often moved irregularly towards the cephalo-thorax, indicative of pain. After the first attempts to escape, the limbs gradually became feeble, and answered their summons to action tardily: this was well seen in the smaller limbs, as they assumed abnormal positions in their abortive efforts to progress. The eyes and antennæ continued active for a time. In a quarter of an hour, in some instances, and longer in others, the animals perished by the virulence of the poison. From the proximity of the wound to the thoracic ganglion, its action might be more speedily fatal in some instances, but its insertion at other points proved that the seat of its application mattered little.

The injection, in the usual manner, of a pretty strong solution of Hg Cl further corroborated its destructive influence on those animals. For a few seconds, the limbs were most violently contorted and convulsed, and the animal raised high on them; then it remained motionless. After the fourth or fifth minute, little trace of vitality could be detected; the eyes, antennæ, and every part of the animal losing life simultaneously.

As an agent of destruction to these animals, corrosive sublimate far exceeded either of the foregoing or any of the succeeding substances, the crabs rarely surviving fifteen minutes after its introduction into a wound, and perishing four times as quickly when injected per anum.

4. *Muriate of Morphia.* By the usual incision in the c.-thorax, beneath the folded abdomen, $M^{ɤ}$, HCl was introduced. It ran actively at first, then rested and

moved alternately. No action of the foot-jaws. One of the experiments with this substance was remarkable in that the crab threw off one of its telæ, a rare occurrence in these operations. The limbs responded to irritation in one hour; not stirring if undisturbed. In three hours, crawled feebly; little action of branchiæ. This seemed a period of slight relief from the action of the drug. After the fifth hour, it did not move much. Lived eight hours.

Injection, in the usual manner, caused the animals to run actively at first, but soon their limbs scrambled and refused to carry them. Eyes and antennæ sluggish. They lived three hours. A comparatively large amount of morphia was used in each experiment.

A period of remission, more or less distinct, could be observed in the experiments with this agent, which, on the whole, proved rather a feeble poison to these animals.

5. *Acetate of Morphia.* ♏ 13 of a strong solution (containing 1¼ gr. in this dose), were injected by a fine syringe in the usual manner. It ran fiercely about, as if in agony, knuckled its legs under it, and bit the foot-jaws. Shortly, the limbs only scrambled and were unable to carry it; foot-jaws moved slowly; slight gurgling. In ten minutes, movements of the limbs when stimulated; eyes and antennæ dull. One hour, limbs bent underneath, raising the body; feeble movements when suddenly irritated; bubbling, and movements of the foot-jaws. By and by, it recovered from this sinking condition, and in four hours, I found it crawling nimbly, with every sense acute; and so far from perishing quickly, it lived for two whole days after the injection.

6. *Cyanide of Potassium.* ♏ 8 of a saturated solution, and often a grain or more of the solid, were placed in the wound. The animals ran actively at first, then were still, often elevating their forceps as if to resist an

attack. In an hour, they resented interference somewhat tardily, and the small limbs were weak and trailing. They frequently had a tendency to remain in one position, perhaps keeping a tela elevated. They did not move out of their position after one hour and a quarter, and soon were unable to crawl. They died on an average in two hours.

As an example of the effects of an injection of ♏ 14 of this strong solution, the following may be taken. The crab was large and powerful, and it ran about, as before the operation. Eyes not very active; came to rest easily. Eight minutes, motion perfect, and it was savage. Half an hour, crawling languidly when irritated, and only for a short distance. Seventy minutes, if strongly irritated, it moved telæ with reluctance; limbs feeble and motion dull. Eyes inactive; no gurgling or motion of foot-jaws. Two hours and a half, slight trace of vitality in eyes; moved both telæ when lesser or internal antennæ were pinched. Died in three hours.

The action of the poison, then, seemed much more feeble than in the case of mammals; with a quantity not much exceeding the above, I have poisoned a powerful dog in a minute, by pouring it down its œsophagus. When injected into the alimentary canal of the crab, its action seemed to be retarded rather than increased in quickness, at least in some cases.

7. *Oxalic Acid.* The wounds were filled with crystals. The crabs seemed to be entirely unaffected, and crawled swiftly about as usual. Sometimes, however, they manifested a tendency to rest at any convenient place, if undisturbed. Generally, bubbling at the branchial apertures. After many hours (eight or nine), they were still active, and defended themselves accordingly. Some lived for a day, others longer, and some even seemed to recover, scrambling off to secret corners, where they were found months after, labelled and mum-

mied. The only observable effect of the Ō was a slight dulling of the animal's activity.

8. *Nux vomica.* Placed in the wounds as before. The crabs crawled actively, and evinced pain by biting at the part. They also showed a tendency to rest if undisturbed,—defending themselves, however, most vigorously when interfered with. Three hours, resenting irritation; bubbling at apertures. Sometimes a peculiar raising of the cephalo-thorax on the tips of the legs was observed. Seven hours, could crawl, and defend themselves when pinched, but motion was seldom apparent otherwise. Neither gurgling, nor motion of the foot-jaws. Traces of vitality could be discovered with difficulty in ten hours, and soon all was over.

9. *Strychnine,*—in solution and mechanical mixture with water, was injected per anum. At first, they made violent efforts, with spasmodic contractions of the limbs. The bubbling at the branchial apertures often commenced immediately, and continued very actively. After these preliminary violent efforts, the crabs generally lay still, often with the smaller limbs elevated above the body. In a quarter of an hour, gurgling; when irritated,—feeble motions. Eyes and antennæ dull. One hour, all retained traces of vitality, and some even crawled. The limbs were frequently spasmodically stretched. In some, the eyes were retracted, when pinched; in a few, frothing. Nothing was observed after this, except a twitch or two.

The tetanic spasms, usually the result of poisonous doses of the foregoing substance and nux vomica, were by no means conspicuous in crabs at least. There were doubtless twitchings, but then they were observed frequently before. In neither did the effects seem those of a virulent poison.

10. *Benzoic Acid.* When the wounds were filled with this substance in considerable quantity, little marked effect ensued. After the operation, the animal

actively escaped from the restraining force, and its motions were quite unimpeded. It was my companion for many days, running here, there, and everywhere, and would have died quite as quickly with the wound only, as with the wound and the Bz O. It seemed, at all events, to be a very inert substance in its action on crabs.

11. *Iodine.* Pure iodine was inserted in scales into the wounds. The animal remained quite active after the proceeding, and there was frothing at the branchial apertures. It had not much effect till the sixth hour, when it could be observed that there was no spontaneous movement, and even when irritated, its actions were sluggish. Eyes and antennæ tolerably sensitive. It lay in a stupor on the floor, but retained vitality for about two days. The animal which was the subject of this operation had a sort of tetanic or spasmodic extension of the telæ, and contractions of the smaller limbs.

In another, the ethereal tincture was sent into the posterior part of the alimentary canal. It ran actively about during that day, and defended itself most fiercely. On the morning of the second day, it was still able to crawl, though its activity was much diminished. Senses still pretty acute. Gradually sinking, it died before the second day was finished. Like the former, the action of the iodine, when introduced by this method, seemed feeble.

12. *Acetate of Lead.* This substance, though inserted into the wounds in quantities varying from one to four grains, or more, produced no distinct effect, the animals running about vigorously, and defending themselves as in ordinary circumstances. The crabs labelled Pb O $\bar{A}$ were the pests of the room for days; many meeting mummy's fates in curious nooks and corners, where they were found months after, duly desiccated. From the salt water in the tissues of the animals, part of the

acetate may have been changed into the chloride, sulphate, &c., but whether this had any influence on the result or not, I do not know; it would appear, from the following experiments, that it had not much, since sea-water must certainly have been more plentiful in the intestine of the animal, than in its other tissues.

Far different results ensued when the Pb O $\bar{A}$ was injected into its alimentary canal. The limbs were strongly contracted, and they made no attempts to crawl. There was little gurgling, and they succumbed so rapidly, that, in half an hour there was only a trace of vitality in the eyes and internal antennæ, and none in the limbs.

These experiments were remarkable for the wide difference resulting between the two modes of application. By the former, it was often inert, but by the latter most deadly.

13. *Camphor*. The solid was inserted into the wounds with marked effect. Motion was much impaired, and they showed little tendency to move from the spot, although they defended themselves vigorously. The small limbs seemed more irritable than usual. Gurgling slight. One crab, while striking at the boot, shortly after the operation, threw off the terminal segment of the great tela, an occurrence, which was not witnessed before, although the crab might be under the influence of poisons more speedily fatal. In three hours, the smaller limbs only moved slightly on irritation, and the telæ could not be used with power. Eyes and antennæ also weak. They perished speedily.

If a solution of camphor in āl was injected per anum, the result in all cases proved speedily fatal. The animals were instantly and violently contorted, and many bit the opposite telæ. In three or four minutes, the eyes got dull and motionless, and the internal antennæ were extruded most significantly; while movement in the limbs was scarcely perceptible. The external foot-jaws were generally protruded in a peculiar manner, not laterally, but pushed from the cephalo-thorax, in front of the maxillæ, half an inch or more, and being stiffened in that position after death. In most of the experiments, similar results occurred, the animal, after a few spasmodic or tetanic convulsions, perishing rapidly.

Camphor, then, proved a deadly poison to those animals, the virulence of whose nature caused conspicuous symptoms and a rapid issue. The presence of the āl in the injection, however, must also be taken into account, though the crab died much more speedily than by the injection of āl alone. On introduction, the camphor must have been precipitated from its solution by the water contained in the intestinal canal of the crabs, and applied to their absorbing surface in the solid form, just as in the case of the wounds.

14. *Alcohol* (*Methylated*). Many experiments were conducted with this agent (upwards of thirty), introduced by injection into these animals. Its effects, for the most part, were the following:—The crabs were generally spasmodically convulsed, and reeled about; sometimes, if irritated, they threw off a limb or two. The motions were desperate, and the bitings of the forceps a common accompaniment; in some, the latter were stretched out stiffly. Eyes and antennæ pretty active; frothing at apertures frequently great. In six or eight minutes, some recovered and were able to crawl about; and often they assumed a defensive attitude, and struck with the forceps where no enemy was near. In a quarter of an hour, when pinched, moved telæ and cephalo-thorax, but seldom stirred from the spot. The posterior limbs seemed weakest, and all were frequently contracted. One hour, eyes active; considerable frothing; motion of limbs slight. Thereafter, the effects of the āl seemed to be mitigated, and, though pernicious, were rather long in producing death. Occasion-

ally, on the approach of a foreign body, the telæ were half raised, but could not be moved further, as if the eye had warned, where the muscle had not power to defend. Some showed a peculiar tendency to turn on their backs, as in section of the communicating cords of the ganglia, though in this case scarcely so well marked.

The crabs did not move far from their position after the second hour; if they did not live so long, it is probable that extravasation accelerated their fate, unless when the dose was too great. Eight or nine hours, eyes feebly responded to irritation; slight motion of limbs, with waving of the posterior pair. Some lived a few hours after this, and a small number even to the second day, but the average period at which death occurred was the twelfth hour.

Care must be taken in these experiments not to confound true and successful injection with injection and extravasation, which latter accident swept off its victims in a minute or two, with desperate convulsions.

The alcohol seemed to act primarily as a powerful stimulant and irritant, throwing the crab into the most violent convulsions and tetanic spasms, which looked as if about to prove fatal at once. This was followed, however, in general, by a partial recovery, and then they subsided into a state of repose during the rest of their hours, as if under a depressant. The violence of the motions on the recurrence of extravasation may be easily accounted for by the anatomy of the parts, the smallest escape of this baneful substance being applied directly to the great thoracic ganglion. It is a curious fact, that some crabs, often powerful ones, with the same quantity of alcohol that perhaps produced the foregoing results in weaker, died very speedily after the first convulsions.

15. *Nitric Ether.* It was administered by injection per anum. Immediately the crabs were sent into a state

of violent contortions, knuckling the limbs underneath, turning over on the dorsum, and biting the opposite telæ, or anything near. There was active frothing at branchial apertures. They did not crawl far, and the small limbs seemed incapable of regular progression. Senses preter-naturally acute. They moved little, only slight startings of the limbs being observed. In four hours, eyes and antennæ pretty active; unable to crawl. Some lay in a pool of frothy matter, with the anterior part of the cephalo-thorax depressed. Seven hours, limbs subject to a spasmodic twitching; senses pretty acute, especially that of sight; gurgling at apertures; totally powerless as regards progression. The frothing and gurgling continued for some hours after this, and could be excited in a few at the sixteenth hour. They lived about a day after the injection.

16. *Oil of Turpentine.* After the injection of this, the animals rushed wildly about for a second or two, as if unhurt and fierce, and then remained motionless. Opposite forceps were bitten, with wriggling, and occasional upheaving of the cephalo-thorax. Sometimes the legs were drawn in spasmodically, and knuckled underneath, then the cephalo-thorax rested on the telæ, inversion frequently supervening, with desperate motions of the limbs; or again, it might stand on the tripod of the forceps and rostrum, with the small limbs sticking out in all directions. There were motions of the foot-jaws, and often gurgling at the branchial apertures; eyes and antennæ active. In ten minutes, vermicular motions of the limbs, and peculiar positions. When turned on their dorsum, a few contracted their limbs with a spasmodic jerk. Twenty minutes, little or no motion, the most sensitive parts being the eyes. Some showed little evidence of life after this; a few emitted froth from the branchial apertures. After they were incapable of progression, a smart rap on the dorsum would frequently cause the eyes to roll wildly about.

This substance appeared irritant and depressant, the latter action predominating.

17. *Creosote.* Three small crabs and one large were chosen, the doses injected being respectively three, four, five and six minims, according to their size. The three smaller were most summarily disposed of, being seized with spasms of the limbs, and every joint twisted in various directions. Every now and then, a series of extreme twitchings occurred, but they never moved from the spot, and perished in ten minutes. The large crab, with a dose of ♏ 6, ran about actively on being freed, but it easily came to a stand. Gradually, progression failed, and in half an hour it was quite unable to crawl. Sensibility of eyes and antennæ diminished; jerking of limbs. After the affection of the limbs, the frothing became very great, and it bit the foot-jaws. In three-quarters of an hour, eyes and antennæ very sluggish; feeble motions of limbs, when irritated. It soon died.

The narcotico-acrid qualities of this drug were well illustrated in these animals.

18. *Mineral Naptha.* This was introduced, first, by snipping the mandibles on both sides, and sending it into the stomach by means of a glass pipette. Immediately the crabs ran actively, and appeared to be unaffected. However, they soon rested, and in about a quarter of an hour, peculiar spasmodic motions of the limbs ensued, while progression in most cases was impossible. In half an hour, though strongly irritated, only slight motion of limbs. No action of foot-jaws from the beginning. Death soon followed.

Secondly, naptha was introduced by the usual method of injection. The animals drew up their limbs spasmodically, remaining so for a few minutes, and then, relaxing, they crawled about with considerable alacrity. In a quarter of an hour, there was no attempt at progression; swinging of posterior limbs. Three-quarters of an hour, eyes and antennæ almost insensible; small limbs quite powerless; sometimes slight motion of the large pair of foot-jaws. One hour, life extinct.

By either method, mineral naptha thus seemed equally destructive. It will be remembered that the vapour of this substance killed in one hour also, so that this would appear to be the pretty exact duration of life after its application. Its irritant properties caused pain to be manifested in no small degree in almost all the experiments, whether as vapour or liquid. Latterly, it exercised a sedative effect, which terminated only in death.

19. *Collodion.* When poured on the maxillæ and into the mouth, this material had very perceptible results. The crabs rushed swiftly about for a short time, and then rested, or else began tumbling on their backs at once. Contractions and waving of the limbs occurred frequently; rarely bubbling at the apertures. If the animal was not very powerful, it seldom moved much from the spot, but lay as if under some severe shock, evincing life only by the occasional twitchings of the limbs. Some died in two or three hours, but some lived much longer, and seemed to recover, if powerful, from the first destructive effect of this compound liquid.

On injection, the following effects ensued. The crabs were instantly seized with contractions of the limbs, and sometimes wheeled round and round; eyes and antennæ active. They crawled about shortly afterwards; bubbling at branchial apertures continued for a long time. Some twitched the terminal segments of the small limbs; while others lay motionless, and, on lifting them, their limbs hung paralysed. A few died in four hours, but most lived for a day or two, though, perhaps, they remained stationary. The gurgling and frothing, on the second day, told of the animal's partial recovery.

Collodion seemed irritant at first, having a peculiar effect on the motions of the limbs, then proved in most cases a slow poison. It was decomposed into ether, and flakes of what was gun cotton, by the HO in the intestinal canal. The former was probably the active ingredient, and some of the motions of the animals resembled those following the introduction of alcohol.

20. *Colchicum* (*Acetous extract*). This was introduced into wounds in two specimens. They, though apparently not much affected, did not crawl far, and, even when irritated, did not move many inches from their original position. Bubbling at branchial apertures. In two hours, the eyes responded actively to irritation; motion in the external and internal antennæ failing. No action of the foot-jaws. They were unable to move from the spot, at least made no attempt to do so. Four hours, only traces of vitality on irritation, and one soon died. The other lived an hour or two longer. The sedative action of the colchicum was most conspicuous in these experiments.

21. *Atropia*. This was injected in the usual manner into three crabs. One ran about as if nothing had happened, and was exceedingly fierce in using his forceps, striking at any approaching object with great alacrity. The eyes and both antennæ unusually active. Another was convulsed at first, but by and by also used his forceps actively, though he did not move far from the spot; eyes and antennæ active. The third, with the latter parts in a similar state, crawled more than the former. In one hour, the first was active still, and moving about in all directions; the second and third more sluggish, but still with vigorous action of the telæ. The two latter were obviously depressed, with no tendency to crawl unless irritated. In all three, there was bubbling and frothing at the branchial apertures, and this was carried on with intermissions. They continued to live for many hours. In 16 hours, two were dead, while the other (first) exhibited most motion

in the eyes and antennæ. It also soon followed the others.

The Atropia was used in the form of a solution in water, mechanically mixed with an excess to increase its strength. If we may judge from these three cases, its action on crabs did not seem to be very virulent. A stronger solution, in other medium than water, might have had different results, although, from the mechanical mixture, the strength of the liquid was much increased.

22. *Cannabis indica.* The acetous extract was placed in the usual wounds, generally on the under part of the cephalo-thorax. The animals manifested no spasmodic action, and their motions did not seem to be materially weakened. Eyes and antennæ active; no, or slight, gurgling at branchial apertures; no motion of the foot-jaws. In one hour, active as before, and in most, gurgling had commenced. They continued in a similar state for many hours, only a slight depressing action being visible. One died in sixteen hours; others lived two days. When turned on their backs, some (especially females) were liable to spasmodic actions of the small limbs; but it must be remembered, that, in the various experiments, they were more liable to this than males, many assuming a contracted state without irritation or injury.

When the Tincture was injected per anum, the symptoms were somewhat similar, and the crabs generally survived till the second day.

This substance proved rather a slow agent of destruction to these animals. There were no spasms till near the death of the crabs, and at this time they would probably have occurred independently of any such administration.

23. *Stramonium.* The acetous extract was pushed into the wounds of two crabs (male and female). There appeared, at first, no visible effect, the animals crawling about as before. Then their action became slower, and

they had little inclination to move. No gurgling or frothing. Eyes and antennæ weak, the internal protruding characteristically. Two males were then similarly treated, and the effects were as follows.—In one, which was gurgling before the operation, gurgling continued. Six hours after, the animals were sluggish and little able to move, and the foot-jaws were much more irritable than either the eyes or antennæ; no movement at branchiæ. Two died in five hours, one in eight hours, while the other (a female) retained a trace of vitality next day (twelve hours after).

This poison, then, was moderately active, and produced a fatal torpor when applied to the crabs as above. No pain seemed to be caused by the stramonium.

24. *Hyoscyamus (Tincture of).* This was injected p. anum. The crab, when freed, was active and fierce, and shortly, bubbling began at the anterior branchial apertures. In an hour, I found it running about, and striking fiercely if touched. Five hours after, the limbs were quite useless for progression; gurgling; eyes and antennæ active. It remained in the same spot, and the only motions it afterwards exhibited were feeble wrigglings of the limbs, and separation of the foot-jaws. It died in twelve hours.

25. *Digitaline,* in solution, and mixture in HO, was injected as usual. The limbs were immediately contracted and doubled up; frothing commenced and became intense; eyes and antennæ dull. They seemed in great pain. Some scarcely moved from the spot, and held that peculiar position — with the forceps knuckled in, and supporting the elevated body. A few crawled a little, but were readily arrested, their limbs being weak and unfit for steady progression. In half an hour, there was no spontaneous attempt at motion, beyond occasional swinging of the foot-jaws: frothing had entirely ceased. They soon sank, and all died within the hour.

This poison thus proved very speedily fatal by injection; its action doubtless accelerated by its comparative solubility in water. A striking feature, in most cases, was the frothing from the anterior branchial apertures.

EXPLANATION OF DRAWINGS.

Plate I.

Fig. 1. View of the cephalic ganglion and its branches from a dorsal dissection: *a*, external antenna; *b*, compound eye of one side; *c*, cephalic ganglion; *d*, optic nerve; *e*, one of the fourth pair of nerves; *f*, mandibular muscles attached to calcareous spike; *g*, connecting trunks in front of the œsophagus; *h*, œsophagus; *i*, calcareous curved spike supporting membrane; *k*, pneumogastric nerve; *l*, commissural cord, behind which the connecting trunks are lost in masses of liver, &c.; *m m*, branchial whips, with their margin of fine hairs; *o*, branchiæ; *p*, heart; *r*, amputated limbs; *s*, abdomen.

Fig. 2. *a a*, eyes in retraction; *b*, internal antennæ; *c*, external antenna; *d*, circlet of hairs; *e*, eye-peduncle; *f*, basal swelling of the internal antenna.

Fig. 3. External shell of compound eye: *a*, corneæ; *b*, protecting point of dermo-skeleton; *c*, circlet of hairs.

Fig. 4. Magnified hexagonal corneæ.

Fig. 5. Somewhat enlarged drawing of one of the specimens, having—what appeared to be—a reproduced eye: *a*, growing eye; *b*, eye-peduncle of the same side.

Plate II.

Fig. 1. Microscopic view of the cephalic ganglion of a recently killed specimen; fibres, cells of various forms, pigment, &c., all speak for themselves.

Fig. 2. View in cephalic ganglion, where, by careful dissection in a fitting preparation, I tried to trace the ending

of the nerve fibres: *a*, group of unipolar and bipolar nerve cells.

Fig. 3. Drawing from cephalic ganglion of a crab which had been dead 30 hours. The crystals contrast strikingly (by focussing) with the translucent cells and fibres.

Fig. 4. The pneumogastric branch (*a*) magnified as it leaves the parent trunk; the arrangement of the fibres is shown, but few cells are visible in this view.

Fig. 5. Microscopic appearance of a small portion of the horny translucent coat of the growing eye shown in Plate I. fig. 5: *a*, cellular aspect, probably an attempt at corneæ; *b*, columnar pigmentary portion.

Plate III.

Fig. 1. Hairs from the circlet on the outer side of the eyeball; this appearance is often characteristic.

Fig. 2. Internal antenna enlarged: *a*, beautiful terminal antennulæ; *b*, ordinary joints of the limb; *c*, elastic and mobile connection at base; *d*, basal swelling; *e*, ridge of hairs.

Fig. 3. Dissection of the basal swelling of the internal antenna, in the same position as in fig. 2; the cartilaginous sac is seen at *a*, with its elliptical depression sloping to a central fissure.

Fig. 4. The terminal apparatus of the internal antenna: the beautifully segmented larger one, with its golden bristles, is easily recognized; the smaller has a few lateral hairs at the joints.

Fig. 5. Cellular structure of the cartilaginous sac enclosed in the basal part of the internal antenna.

Fig. 6. The cap and bifid stalk of the auditory apparatus, cleared of muscles, &c.; it resembles the human stapes.

Plate IV.

Fig. 1. Enlarged view of the connecting cords: *a*, œsophageal ganglion; *b*, pneumogastric branch; *c*, commissural fibres behind œsophagus.

Fig. 2. Course and relation of the commissural fibres (*c*) more clearly shown.

Fig. 3. Ventral dissection: *a a*, internal antennæ; *b*, great pair of foot-jaws; *c*, amputated limbs; *d*, connecting cords; *e*, nerve to the tela; *f*, nerve to the foot-jaws (great pair); *g g g*, nerves to the small limbs; *h*, thoracic ganglion with its central aperture; *m*, abdominal nerve; *n*, generative apparatus (male).

Fig. 4. Crystals from a microscopic preparation of the propodite of the Cancer pagurus by Dr. Fraser Thomson; see foot note, page 13.

Fig. 5. Nerve passing to cicatrix of growing limb (tela), in which it is lost.

Fig. 6. Microscopic appearance of the cicatrix: fibres, granular matter and pigment.

THE END.

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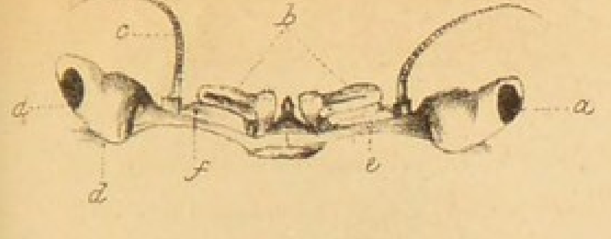

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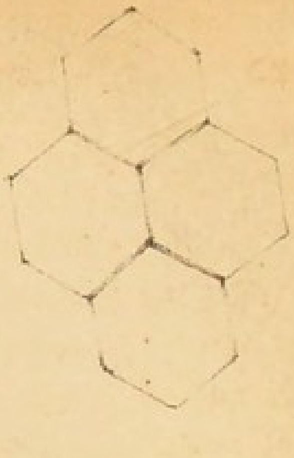

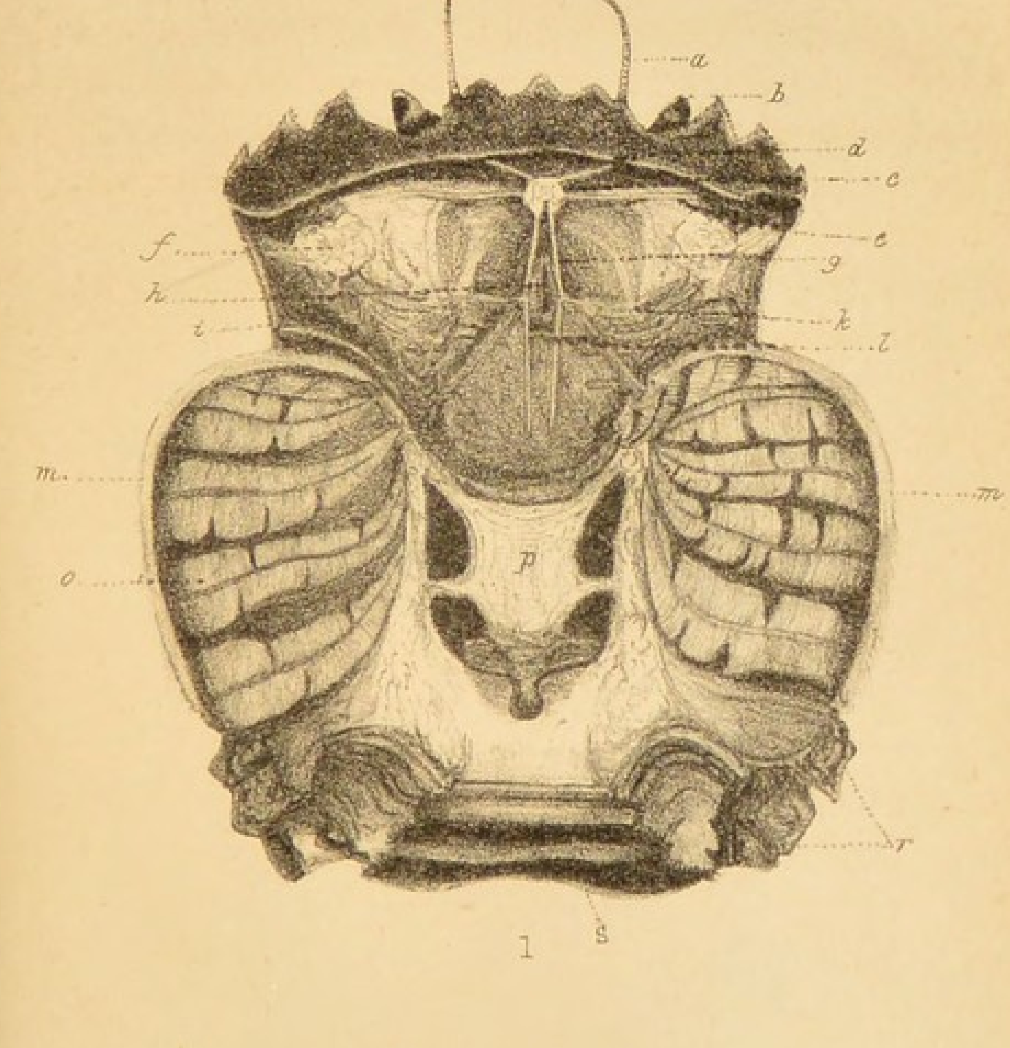

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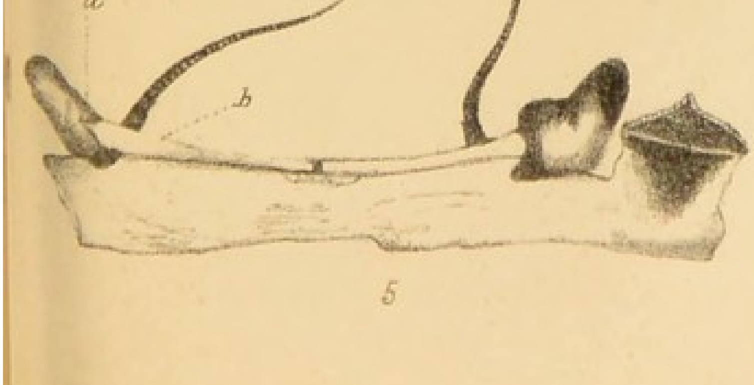

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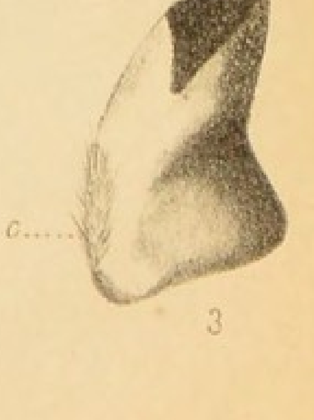

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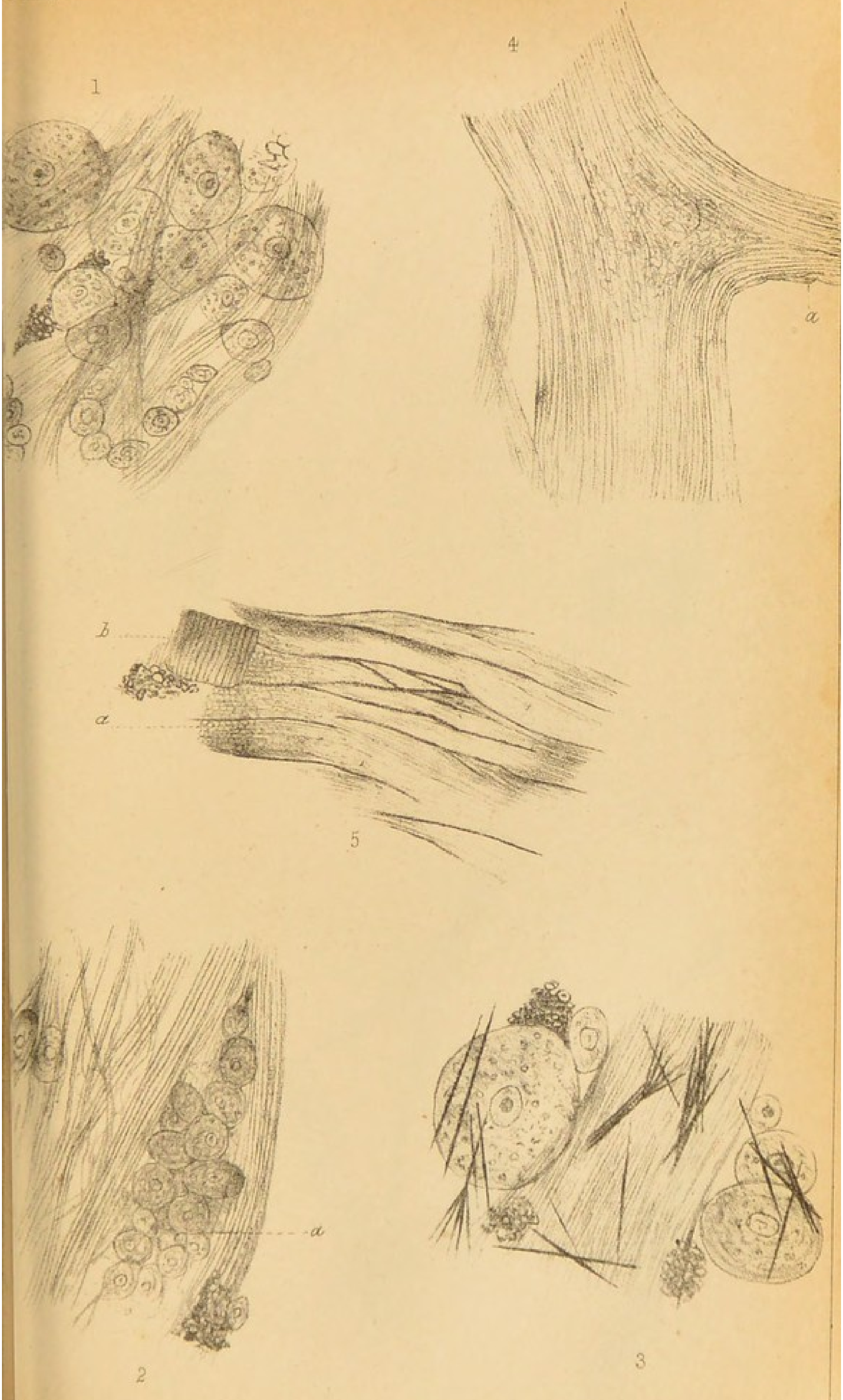

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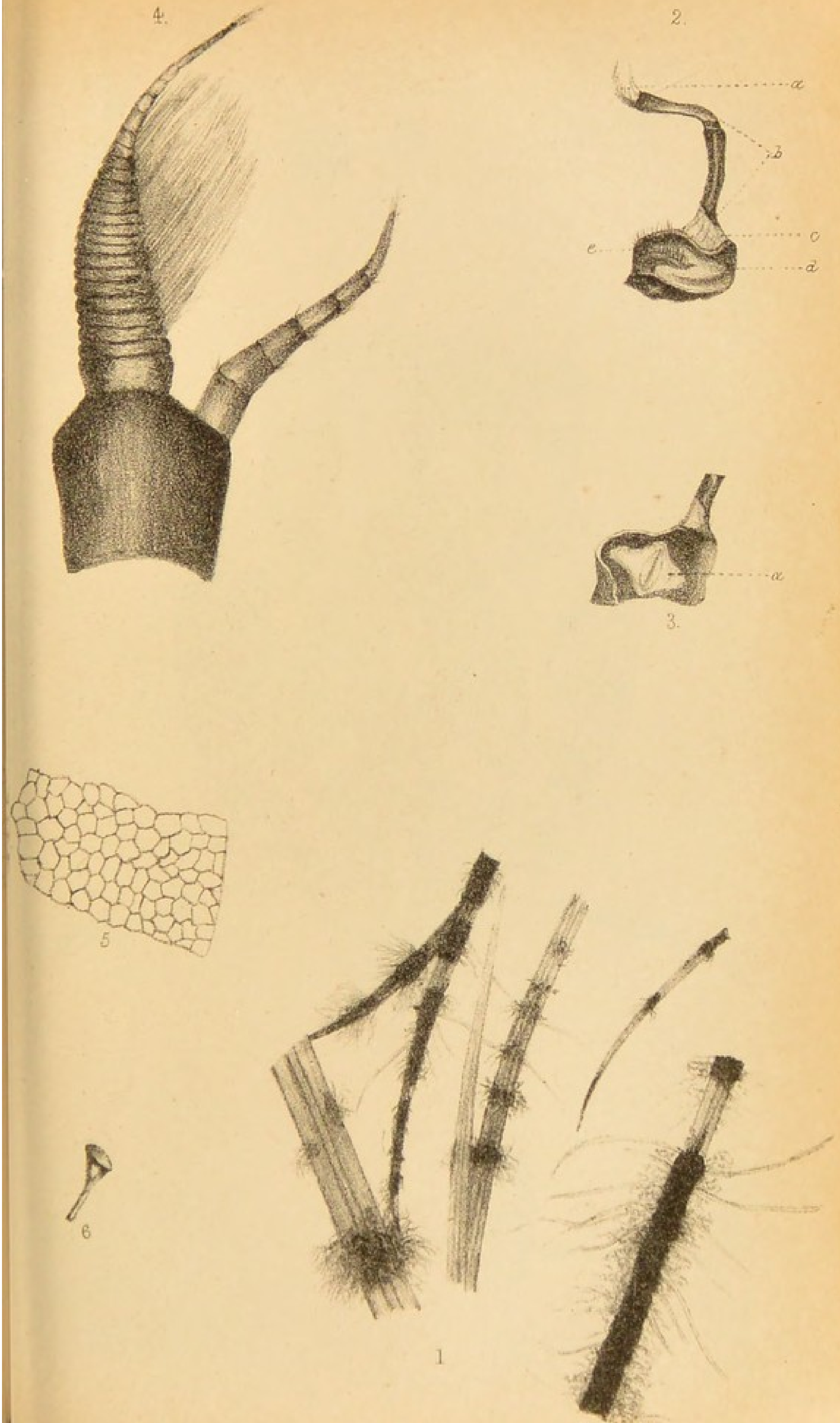

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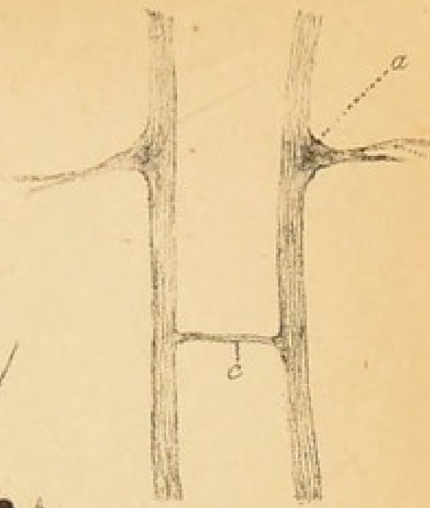

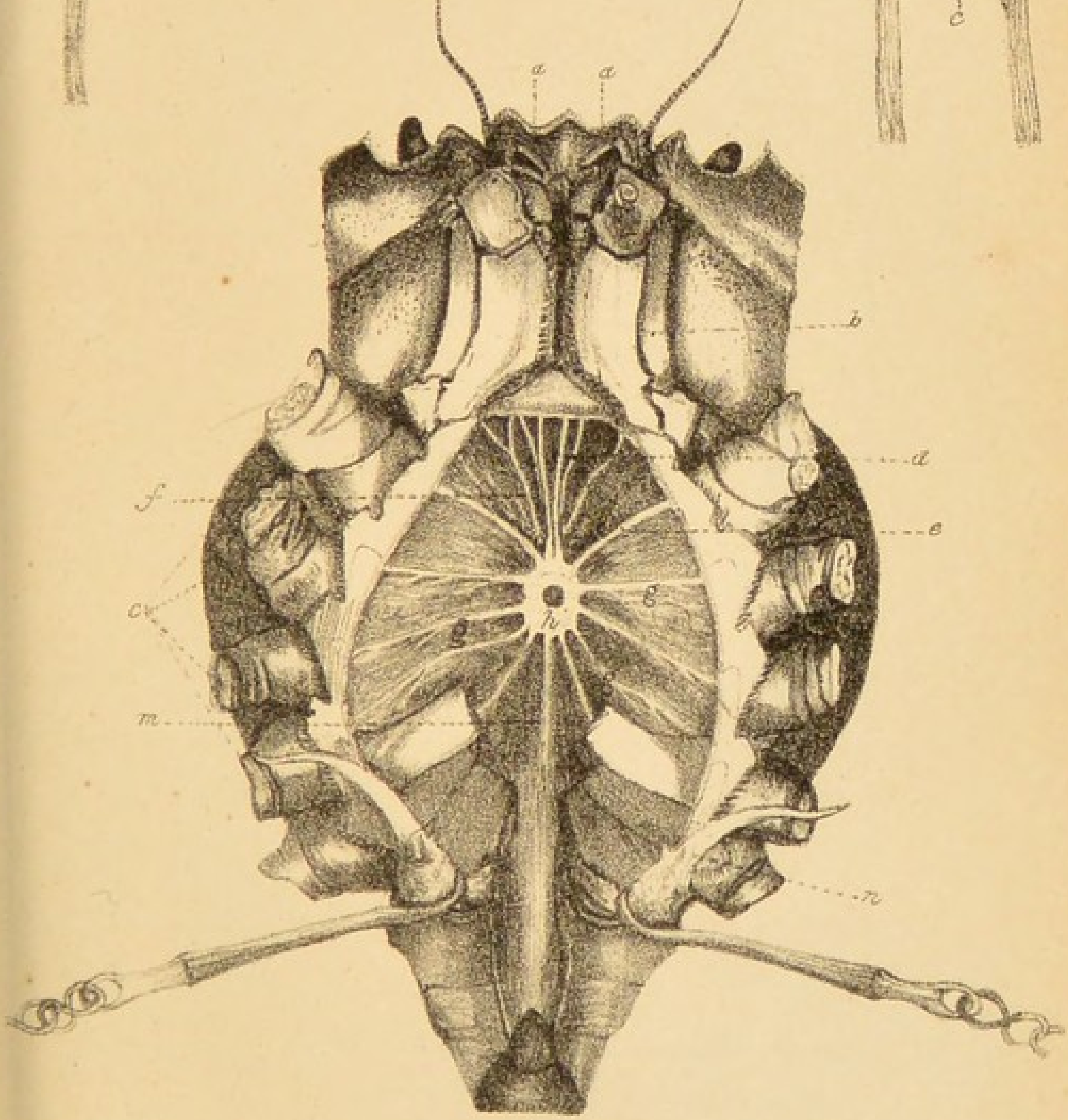

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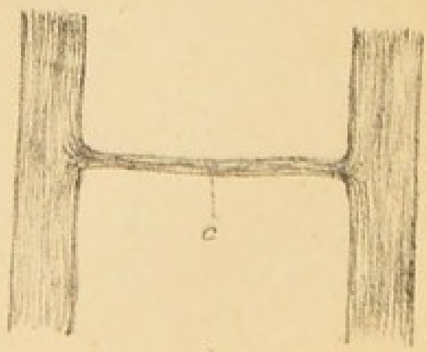

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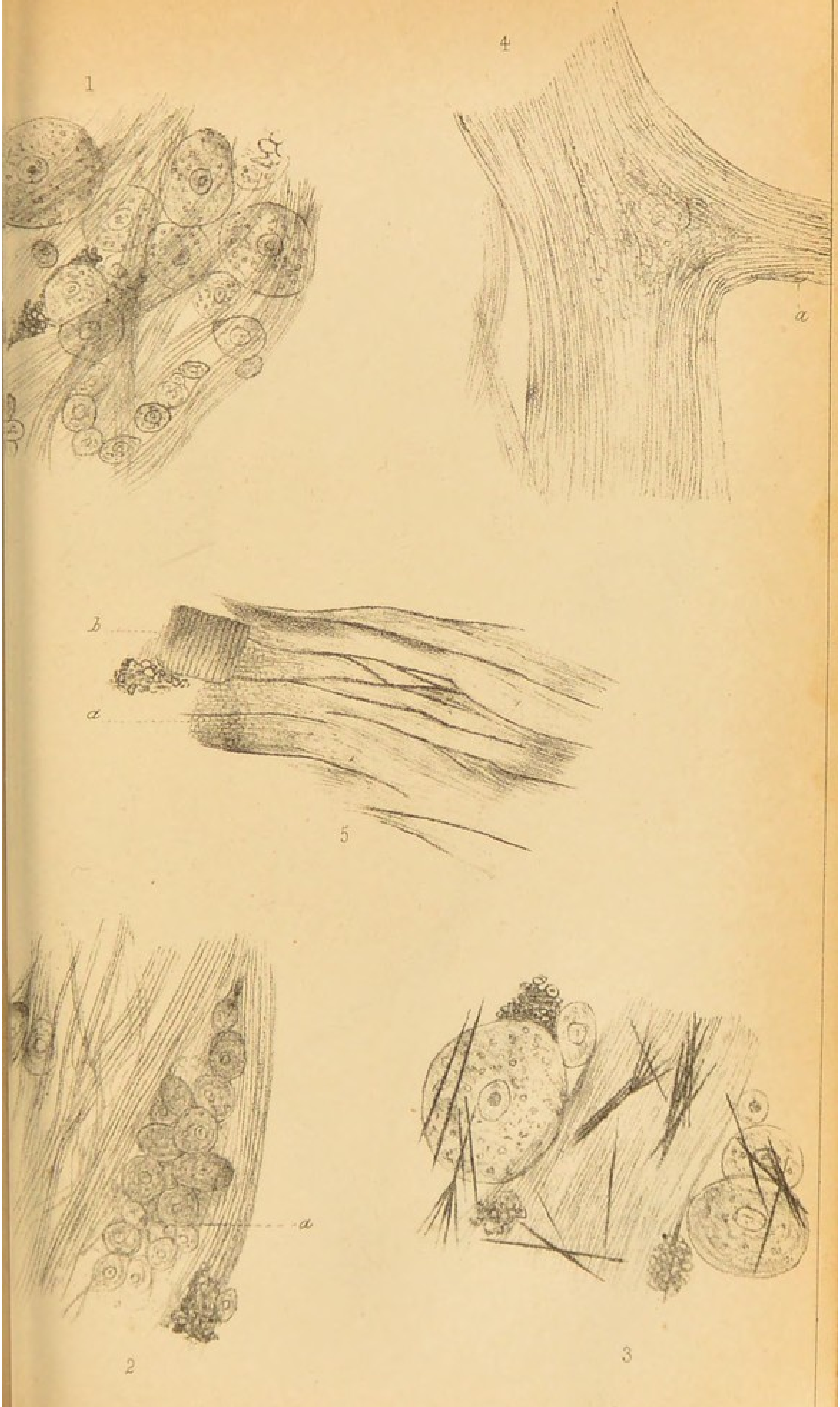

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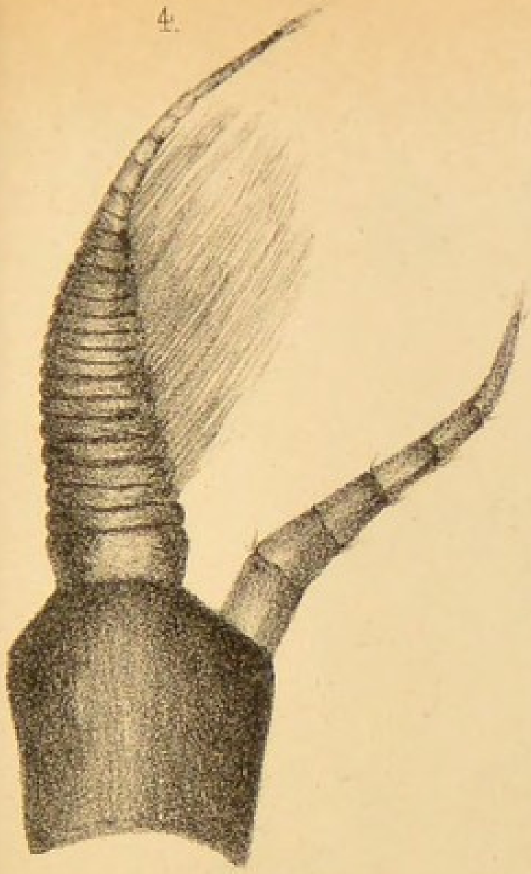

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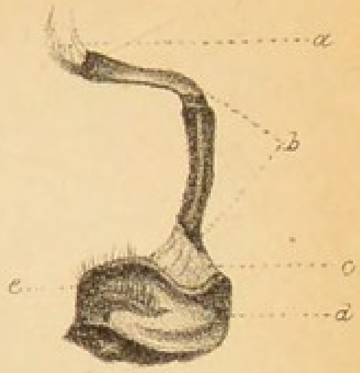

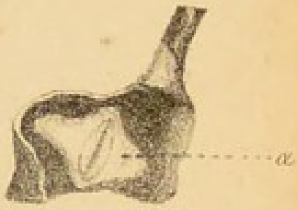

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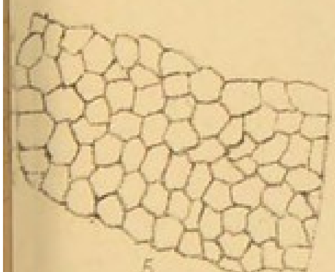

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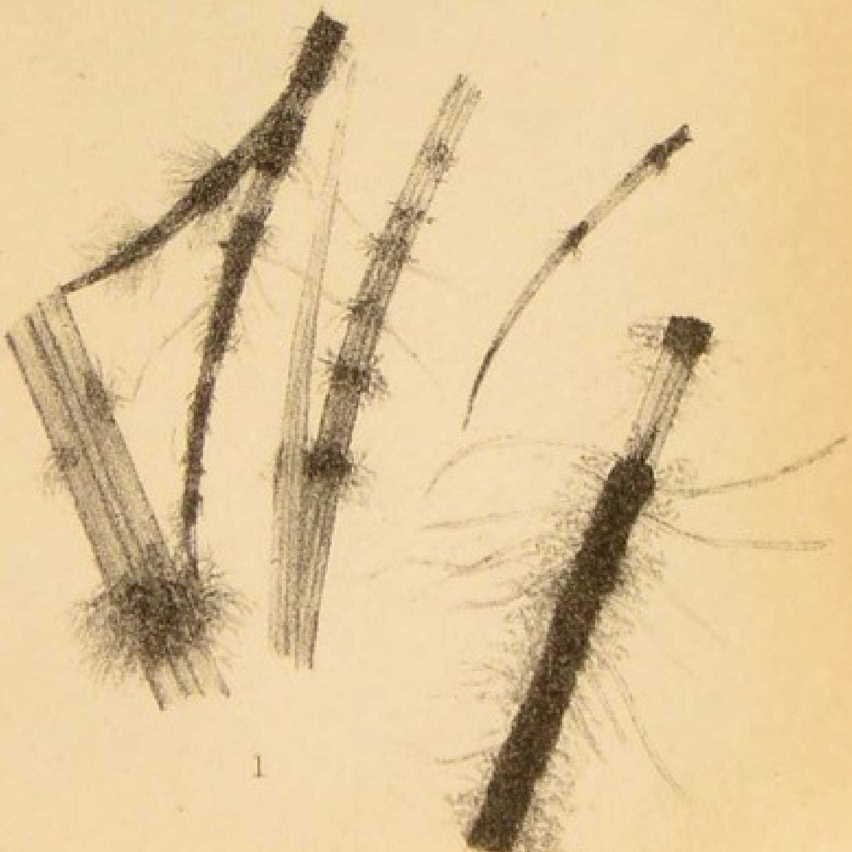

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Pl. IV.