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NATURAL HISTORY.

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TWELVE PLATES.

appear to pour out more sap than the south. The checking influence of nocturnal cold was again distinctly visible here.

10. On the 10th of March a young sycamore stem (*Acer platanoides*), 3 feet high and ½ an inch in diameter, was plentifully watered with solution of ferrocyanide of potassium. On the 15th it was taken up, root and all. When dissected, the reagents showed that absorption had not commenced in the stem. At the base alone, weak, bleared blue spots were produced on a cross section. In one place the colour was deep and sharply-defined enough to admit of microscopic examination: this proved that the walls of a few streaked and spotted tracheæ were coloured blue.

11. A white birch, with a trunk 1 foot in diameter, was tapped 1 foot above the ground, on the west side, on the 4th of March; up to the 11th nothing flowed out. On this day a new orifice was made in the west side of the stem, at a height of 7 feet. Up to the 14th neither gave off any liquid. Only a few sucking flies appeared to indicate that the sap was beginning to rise.

It is worthy of notice, how much later the bleeding occurs in the birch than in the sycamore.

12. On the 7th of March, at three o'clock, a sugar maple (*Acer saccharinum*), with a trunk 1½ foot in diameter, was tapped:—

A, orifice 1 foot from the ground, south side.

B, orifice 5 feet from the ground, south side, but 1 inch further to the east.

About eight days previously several small branches had been cut off further up the stem; some sap ran down from the wounds. The fluid exuding from the borings was collected, and gave the following results:—

March	7.	3½ o'clock, at A,	3 cub. in.;	at B,	1½ cub. in.
—	..	5½	3½	....	7½ ....
—	8.	8	16¼	....	a few drops.
—	..	2	8¾	....	4 cub. in.
—	..	5½	11	....	4 ....
—	9.	7½	6½	....	none.
—	..	2½	17	....	7¾ cub. in.
—	..	5½	7½	....	2½ ....

March 10.	$7\frac{1}{2}$ o'clock, at A,	3 cub. in.;	at B, $1\frac{1}{2}$ cub. in.
—	.. $1\frac{1}{2}$	38(!)	.... 11 ....
—	.. 5	9	.... 4 ....
— 11.	7	$13\frac{1}{6}$	.... $\frac{1}{4}$ ....
—	.. 2	9	.... $1\frac{1}{2}$ ....
—	.. $5\frac{1}{2}$	$5\frac{1}{4}$	.... $\frac{3}{4}$ ....
— 12.	7	4	.... $\frac{1}{2}$ ....
—	.. 2	17	.... $3\frac{1}{8}$ ....
—	.. 5	$4\frac{1}{2}$	.... $\frac{1}{2}$ ....
— 13.	$7\frac{1}{2}$	$6\frac{1}{2}$	.... a few drops.
—	.. 2	$15\frac{1}{2}$	.... 1 cub. in.
—	.. $5\frac{1}{2}$	$4\frac{1}{2}$	.... a few drops.
— 14.	$7\frac{1}{2}$	$13\frac{1}{2}$	.... ditto.
—	.. 2	23	.... $2\frac{1}{2}$ cub. in.
—	.. $5\frac{1}{2}$	1	.... none.
— 15.	$7\frac{1}{2}$	none.	.... none.
—	.. 11	5	.... $\frac{1}{5}$ cub. in.

From this it follows that the efflux, or fulness of sap, is greater in the lower part of the stem than further upwards. This phænomenon is not hydrostatical (as a barrel emits a more powerful stream from a hole nearer the bottom, than from one at the top, on account of the higher pressure of water), but depends on the force of the water making its way *upwards*, as is seen by a comparison with Experiment No. 1. It is also again seen what an obstacle the nightly cold is. Lastly, a comparison of the temperatures of the air in the sun, which I observed, shows how much the ascent of the sap is *favoured by the heat of the air*.

From the following table, especially from the two last columns, it is seen that on the whole the outflow runs parallel with the temperature. The 10th of March alone forms an exception, evidently on account of the unusually favourable weather on the 9th, the after-influence of which is seen here.

SUMMARY.

	Sum of the Temperature of the Air in the Sun. At the Hours	Sum of the Temperature of the Air in the Sun. Degrees of Fahrenheit.	Amount of Heat per hour.	Efflux of Sap per hour.
Mar. 7. from $3\frac{1}{2}$ to $5\frac{1}{2}$ A gave $5\frac{1}{2}$ cub. in.	4 and 5	63·5 and 54·5 = 54°	27°	$1\frac{3}{4}$ cub. in.
— 8. ... 8 ... 2 ... $8\frac{3}{4}$ ...	9, 10, 11, 12, 1, 2 ...	45·5—47·75—47·75—52·25—72·5—81·5 = 155·25	25·825	$1\frac{1}{2}$ ...
— ... ... 2 ... $5\frac{1}{2}$ ... 11 ...	3, 4, 5	83·75—72·5—63·5 = 123·75	41·25	4 ...
— 9. ... $7\frac{1}{2}$ ... $2\frac{1}{2}$ ... 17 ...	8, 9, 10, 11, 12, 1, 2	45·5—47·75—52·25—77—86—88·25—88·25 = 261	37·25	$2\frac{3}{7}$ ...
— 10. ... $7\frac{1}{2}$ ... $1\frac{1}{2}$ ... 38 ...	8, 9, 10, 11, 12, 1	41—43·25—45·5—47·75—50—56·75 ... = 92·25	15·375	$6\frac{1}{3}$ ...
— 11. ... 7 ... 2 ... 9 ...	8, 9, 10, 11, 12, 1, 2	41—41—43·25—43·25—43·25—43·25—61·25 = 92·25	13·176	$1\frac{2}{7}$ ...
— ... ... 2 ... $5\frac{1}{2}$ ... $5\frac{1}{4}$ ...	3, 4, 5	70·25—61·25—43·25 = 78·75	26·25	$1\frac{3}{4}$ ...
— 12. ... 7 ... 2 ... 17 ...	8, 9, 10, 11, 12, 1, 2	38·75—38·75—42·125—43·25—47·75—53·375—68 = 108	15·428	$2\frac{3}{7}$ ...
— 13. ... $7\frac{1}{2}$ ... 2 ... $15\frac{1}{2}$ ...	8, 9, 10, 11, 12, 1, 2	43·25—44·375—46·625—46·625—52·25—50 = 104·625	14·946	$2\frac{3}{14}$ ...
— ... ... 2 ... $5\frac{1}{2}$ ... $4\frac{1}{2}$ ...	3, 4, 5	47·75—47·75—45·5 = 45	15	$1\frac{1}{2}$ ...
— 14. ... $7\frac{1}{2}$ ... 2 ... 23 ...	8, 9, 10, 11, 12, 1, 2	45·5—50—63·5—79·25—77—74·75—74·75 = 240·75	34·391	$3\frac{2}{7}$ ...
— ... ... 2 ... $5\frac{1}{2}$ ... 1 ...	3, 4, 5	65·75—46·625—43·25 = 59·625	19·875	$\frac{1}{3}$ ...
— 15. ... $7\frac{1}{2}$ ... 11 ... 5 ...	8, 9, 10, 11	36·5—41—62·375—55·625 = 67·5	16·875	$1\frac{1}{5}$ ...

The specific gravities of the effused fluid exhibited the following scale. They were determined in a narrow-neck globular bottle, of about 1 oz. capacity.

Rain water,	1st filling	. . .	25·660 grammes.
... ...	2nd ...	. . .	25·661 ...
... ...	3rd ...	. . .	25·665 ...

Sap of the Sugar Maple.

	Orifice A.	Orifice B.
March 7. 3½ o'clock	25·877 gramm.	
— 8. 4	25·875	25·918 gramm.
— 9. 2½	25·871	
— 10. 2	25·861	
— 11. 2	25·889	
— 12. 2	25·883	25·918 ....
— 13. 2	25·890	
— 14. 2	25·896	

According to this, the specific gravity increases pretty rapidly, and the sweetness of the sap also is readily detected by the tongue. The *upper* part of the stem contains a *less aqueous* sap than that near the soil.

The *reaction* of the exuded fluid was neutral to blue litmus and to turmeric paper in a fresh condition on the 8th of March; on the 9th slightly acid, as also on the 15th.

The *amount of sugar contained* was tested by adding solution of potash, a few drops of solution of sulphate of copper, and boiling; after a long-continued boiling only was a very small quantity of copper reduced. Some ammonia was set free in this operation. When the mixture was merely allowed to stand at ordinary temperatures, not the least copper was reduced in two hours. It was therefore cane-sugar.

13. A birch (*Betula pubescens,* Ehrh.) was tapped in two places at half-past two o'clock on the 8th of March. The base of the trunk was 1½ foot in diameter.

A, orifice 1 foot from the ground.
B, ... 7 feet ... .

Both orifices 1 inch deep. Quills were cemented in and the effused fluids caught. On the upper part of this birch a few small branches had been cut off, from which some sap exuded, which, however, did not run down to the bottom. The following quantities flowed out:—

March 8.	Up to 4 o'clock	at A, $9\frac{1}{2}$ cub. in.;	at B, 7 cub. in.	
— ..	.. $5\frac{1}{2}$	 7	 4	..
— 9.	.. $7\frac{1}{2}$	.... $39\frac{1}{2}$	.. .... $8\frac{1}{4}$	..
— ..	.. $2\frac{1}{2}$	.... $23\frac{3}{4}$	.. .... ?	..
— ..	.. $5\frac{1}{2}$	 9	 6	..
— 10.	.. $7\frac{1}{2}$	.... $5\frac{3}{4}$	.. .... $1\frac{1}{7}$	..
— ..	.. 2	.... $18\frac{1}{6}$	.. .... $15\frac{1}{3}$	..
— ..	.. 5	 7	.. .... $12\frac{1}{2}$	..
— 11.	.. 7	.... $13\frac{1}{2}$	.. .... $4\frac{1}{2}$	..
— ..	.. $2\frac{1}{2}$	.... $9\frac{1}{3}$	.. .... $\frac{1}{3}$?	..
— ..	.. $5\frac{1}{2}$	.... $3\frac{1}{2}$	.. .... $6\frac{1}{5}$	..
— 12.	.. $7\frac{1}{2}$	.... $5\frac{3}{4}$	.. .... $7\frac{1}{2}$	..
— ..	.. 2	.... $19\frac{2}{3}$	 38	..

As there was no fixed result here, the holes A and B were bored out again to remove any accidental obstruction.

March 12.	Up to 5 o'clock	at A, 5 cub. in.;	at B, 9 cub. in.	
— 13.	.. $7\frac{1}{2}$	.... $9\frac{3}{4}$	.. .... $31\frac{1}{2}$	..
— ..	.. 2	.... $4\frac{3}{4}$	 33	..
— ..	.. $5\frac{1}{2}$	 2	 12	..
— 14.	.. $7\frac{1}{2}$	.... $6\frac{1}{2}$	.. .... $39\frac{1}{2}$	..
— ..	.. 2	.... $3\frac{1}{3}$	.. .... $39\frac{1}{2}$	..

A was closed up, and a new hole C bored near it.

March 14.	Up to $5\frac{1}{2}$ o'clock,	from C, 5 cub. in.;	from B, $1\frac{1}{4}$ cub. in.
— 15.	.. $7\frac{1}{2}$	.... $\frac{8}{9}$ ..	.. none.
— ..	.. 11	.... 3 ..	.. 4 drops.

Thus, from the 8th to the 11th of March more flowed from below; from that time the proportion was reversed, perhaps in consequence of the more powerful *swelling* of the lower (*wetter*) *wood* at A, and a contraction of the orifice resulting from this. After a new hole was bored, the proportion was as in ordinary cases (compare Experiments 20 and 21).

The specific gravities of the fluids from A, B, and C, exhibited the following scale:—

March 8. Spec. grav. of A,	25·705 gramm.;	of B, 25·715
— 9.	25·690	
— 10.	25·712	
— 11.	25·728	
— 12.	25·722	
— 13.	25·718	.. 25·717
— 14.	25·714	.. 25·719
— 15. Spec. grav. of C,	25·732	

According to this, there was increase at A from the 9th to the 11th, then from the 12th (through a fall of snow on the 11th) decrease; on the 15th increase (through the preceding warmth, and resulting evaporation of moisture from the earth ?); at B increase. The sap from the lower orifice was not so dense as that from the upper.

The *reaction* of the fresh sap was neutral to blue litmus and turmeric papers on the 8th and 9th of March; on the 15th slightly acid.

On the 8th and on the 15th the taste was indistinctly sweetish and earthy; but chemical testing demonstrated the presence of *grape*-sugar, when the fluid was warmed with solution of potash and sulphate of copper, since a red powder was rapidly thrown down.

14. A birch (*Betula pubescens*, Ehrh.) 1½ foot in diameter was tapped in various places, in order to discover whether more fluid was effused from the upper or lower part of the stem. This took place on the 14th of March, at three o'clock.

A,	East side,	1½ foot high,	gave in 5 minutes	335	drops.
B,	..	8 feet	....	120	..

A and B were then closed.

C,	North side,	2 feet high,	gave in 5 minutes	118	drops.
D,	..	8 ..	....	80	..

The lower orifice therefore gave more than the upper.

The fluids of A and B were neutral with test-papers.

15. Repetition of the preceding experiment in another birch of the same species and of the same size. Experiment made after three o'clock on the 14th of March.

A,	N.E. side,	1 foot from the ground,	gave in 5 minutes	93	drops.
B,	..	9 feet	....	103	..

A and B were closed, and two new holes bored.

C,	North side,	1 foot from the ground,	gave in 5 minutes	63	drops.
D,	..	9 feet	....	51	..

Here also the lower orifice usually emitted more than the upper. The striking and frequent anomalies which appeared here, as in Experiment 13, will appear abundantly explicable when we reflect what an important influence a very small difference in the condition of the orifices (in regard to depth, diameter, quantity of fragments of wood remaining in, &c.) and the unequal expansion of the wood must have; a difficulty which I could not master. Here, therefore, useful results could only be obtained by a number of observations.

II. The Summer Sap.

The circulation of the sap during the summer, at the period of the greatest activity of the leaves, displays at once much agreement with and many striking differences from that of the early spring, among the latter of which stands above all the circumstance that the trees hitherto mentioned no longer bleed from wounds inflicted on them, although, as a little reflection must reveal, the quantity of fluid actually passing in the stem is far greater; a fact also demonstrated by direct observation.

In summer, as in spring, there exists a rapid ascent of the crude sap; in addition to this, a descent of unelaborated fluids after every shower of rain; and, lastly, a descent of the elaborated fluids from the leaves into all parts of the plant.

Since there apparently exists no means of tracing accurately the mode and course of the last phænomenon directly, I have restricted myself to the first, namely to the roads which the unelaborated fluids traverse in their ascent and descent in plants; but the results obtained could not but give ground for the deduction of many conclusions as to the behaviour of the elaborated saps. The following pages therefore will be devoted to the investigation of the paths by which the crude summer sap ascends or runs down under conditions as natural as possible, and afterwards also under various abnormally arranged conditions, especially when wounds have been made in the plant.

A. The Ascending Sap.

1. *With* NORMAL *absorption of the Sap by the Root.*

For the purpose of tracing the course of the sap, the earth round the plants to be experimented on was watered with dilute solution of ferrocyanide of potassium; after which cross slices of the plant were tested for that solution with a mixture of acetate of iron and hydrochloric acid. It is not advisable to make these experiments on plants standing in the open ground, since the fluid is here spread about too much and too unequally; hence the absorption becomes very uncertain, or even fails to take place at all, as I have experienced several times to my discomfort in vines, plums, and sycamore trees. I therefore preferred such plants as had been kept a longish time in pots, taking only such as exhibited a full activity of vegetation.

Euphorbia terracina, L.—Watered on the 5th of June; taken up by the root on the 8th. The saline solution was detected in the inner layer of the bark (the liber), and in a few tracheæ or spiroids of the outer layer of wood. Watered on the 15th; withering on the 24th; taken up on the 25th; the saline solution could be detected last, as far as 2½ inches above the collar of the root, in the striped spiroids of the outer layer of wood and in the liber, in which it ascended farthest. These vessels were only partially filled with the saline solution; the majority still contained air and did not react.

Since in these and several similar cases, not only the cellular tissue, but also—in direct opposition to the preceding observations on the Monocotyledons—the air-vessels took part more or less in the conduction of the sap, the first object was to clear up the contradiction.

The Monocotyledons used in my investigations, whatever their other differences, were almost without exception furnished with tuberous or bulbous rhizomes. The conjecture was not far-fetched, that the predominant subterraneous stem-structure, the whole character of which is, moreover, accumulative and retentive, retarded the conveyance of the fluid into the upper portions of the stem, and thereby exerted essential influence over it. Hence arose the question, whether, in the Dicotyledons also, varied conditions in the conduction of the sap would occur according to the rapidity of the absorption, according to superabundant or scanty watering, &c.

a. *Accelerated absorption of the Fluid.*

Balsamina hortensis.—The root was carefully freed from earth and immersed in a large vessel full of solution of the ferrocyanide; then the stem was cut across obliquely at a height of 8 inches, and sucked with the mouth. After the sucking had been continued for half an hour, reaction occurred at this point;

the solution had penetrated into several of the large and small spiral vessels of the stem, and still more had ascended in the delicate parenchymatous tissue surrounding the vascular bundles; the pith and remaining portions of the cellular tissue had taken no part. When the lower end of a fragment of a balsam stem 3 inches long was dipped in ink and the upper end sucked, the ink rose *instantaneously*. From this is evident how considerable an obstacle the uninjured epithelium of the root opposed to the forced penetration of the fluid in the preceding case.

Balsamina hortensis.—The plant was allowed to stand dry from the 14th to the 19th of June, until the withering stem had collapsed considerably. The soil was then well watered with 14 cubic inches of dilute solution of the ferrocyanide, which was wholly retained by the mould, as in a sponge (the plant stood in a pot 5 inches high and 4 inches in diameter). On the 21st it began to wither, the leaves exhibited spots and died, while the stem was still partly elastic. On the 23rd the plant was analysed. All parts had absorbed. In the cellular tissue of the pith and rind, the *intercellular spaces* or passages, especially, were found deep blue, so that the rind-cells which contained a red sap, presented red spots enclosed in blue frames; in the pith the whole of the *cell-contents* were coloured blue in many places. The *vessels*, striped as well as unrollable spirals, together with the immediately adjacent prosenchyma, were almost without exception dyed deep blue; air-bubbles were met with in very few, but sometimes even in those vessels which contained blue fluid.

b. *Retarded absorption of the Fluid.*

Oxalis tetraphylla.—Watered very slightly with the saline solution from June 25th to July 27th; the plant was exposed to the atmospheric moisture in the open air. About this time the leaves began to lose their colour and wither.—Analysis. The bulb is composed of two distinctly separated circles of scales, from the interior of which springs the leaf-stalk. The solution was principally met with in the periphery of the inner portion of the bulb; and the elongated *cells* at the surface of the separate fleshy scales, but not the spiroids, had also absorbed it in very small quantity.—Leaf-stalk. This contained a loose circle of five vascular bundles; the salt had ascended in the prosenchymatous cellular tissue surrounding these, but not in the tracheæ themselves; the latter were filled with air. The cortical layer had also conducted, and indeed in the intercellular passages.

Euphorbia terracina, L.—Treatment as in the preceding case; taken up at the end of four weeks. The solution had ascended in small quantity, especially in the inner cortical layer, the liber. No saline solution in the vessels of the wood.

Hibiscus Trionum.—Watered with 1 cubic inch of the saline solution during heavy rain; taken up after three days. Only the root had absorbed up to this time, and chiefly in the central layer of wood, where the prosenchymatous cells in the vicinity of the vessels were coloured blue in spots: the tracheæ took no part.

These experiments showed that when small quantities of liquid are absorbed by the root, the sap of herbaceous Dicotyledons ascends, just as in the Monocotyledons above described, in the *cellular tissue,* and with especial ease in the delicate prosenchyma surrounding the vessels; while when the absorption is hastened and superabundance of fluid present, the *vessels* also take part in the conduction of the sap, at the same time proportionately parting with the air they contain.

2. *Behaviour of the Ascending Sap in* ABNORMAL *absorption.*

Salix alba.—Absorption through the exposed *wood.*—A young leafy shoot 10 inches long was stripped of its bark for 2 inches at the bottom, and dipped 1 inch in the solution; 2 inches of bark were also removed at the upper end, and this part rolled up in blotting paper. Then, to prevent drying, a glass tube closed at the upper end was passed over the upper half of the shoot. After one day the paper was already moist and reacted strongly blue; after six days the shoot was analysed; it was filled in all parts with the saline solution, especially, however, in the wood-vessels which were gorged with sap up to the very top; much salt had crystallized out on both surfaces of the leaves, especially at the bases. Here, with the mouths of the vessels of the wood standing open, a rapid ascent was observed not only in the longitudinal direction, but also *horizontally,* into the blotting paper in contact only with the alburnum.

Salix alba.—A young leafy shoot 12 inches long was stripped of its bark for 2 inches at the bottom, and dipped 1 inch in the fluid; 1 inch below the top (the upper oblique cross section of the shoot) an annular piece of bark 3 lines wide was removed. Protected from drying as before. After six days the salt was found to have ascended into the very apex, and indeed into *all* parts, but most strongly in the medullary sheath. This contained dark blue dotted vessels and unrollable spirals. Only the epidermis of the upper piece of bark gave no reaction.

S. alba.—A piece 12 inches long was cut out of a young leafy shoot, 2 inches of bark removed at the bottom, and dipped 1 inch into the solution. In the upper part a little ring of bark was cut out, and the whole allowed to stand *without* protection from evaporation. After six days, all parts, up to the top of the shoot, even the externally dry, exposed part of the wood which had been laid bare, gave a reaction. At the extreme point the vessels of the medullary sheath no longer took part, but the inner prosenchymatous cells of the wood reacted deep blue.

From these experiments it is seen how little share the bark takes in the conduction of the sap, and how readily a horizontal movement of the sap takes place from the gorged young wood into the bark.

S. alba.—Absorption through the *bark.*—A piece 12 inches long, of a young leafy shoot, was taken and the bark slit up 2 inches from the bottom drawn back, and the exposed cylinder of wood, 2 inches long, removed; then the lower end (merely bark) was dipped 1 inch into the solution. After six days the shoot was found remarkably dry, from insufficient supply of fluid.—Analysis. The whole of the stripped piece of bark, even the epidermis, reacted strongly. The wood had likewise absorbed fluid from the bark into *all* parts at the lower end, but not uniformly; particular vessels and cells did not react at all. —Cross section 2 inches higher up. The bark and medullary sheath had absorbed most, the pith least. At 3 inches distance from the lower end of the wood, the salt was found only in liber and wood; the epidermis and pith no longer reacted.

Consequently, under favourable circumstances, a movement of the fluids in the bark, and *horizontally from the bark* into the wood, undoubtedly occurs, although to a very slight extent.

The isolating power of the epidermis against moisture is worthy of notice.

B. The Descending Sap.

It seemed advisable in this case also to examine the different conditions separately, since it must be influential whether the fluids ascend from the uninjured roots before descending from the peripherical parts of the stem, or make their way down directly from the leaves, or from the points of cut shoots, &c.

1. *The Descending Sap when absorbed through the* LEAVES.

To warrant this experiment on physiological grounds, it suffices to refer to the fact of such a condition occurring in nature in every fall of dew or rain, wherein it in fact constitutes a condition essential to the well-being of plants.

Salix fragilis, L.—On June 7th a large uninjured leaf was immersed in the solution, and on the 10th the shoot which bore it was cut off.—Analysis. In the outer part of the shoot *all* the systems reacted; nearer the base at length only *isolated tracheæ* of the wood, and to the greatest distance on the *side of the twig on which the leaf arose.*

S. fragilis, L.—Experiment as before, with the modification that the larger shoot which bore the absorbing twig was notched deeply on the corresponding side. In three days the solution could be traced in the absorbing twig, farthest in the dotted vessels of the woody layer, and above all in the unrollable spirals of the *medullary sheath.* In the main shoot the fluid had descended over the boundary between the inner and outer layers of wood, *but not beyond the notch.*

S. fragilis, L.—Fresh leaves of a young twig were immersed one after another for several days in the solution, until a large quantity of it had been absorbed. The main shoot which bore the absorbing twig was ringed 3 lines broad down to the wood, and the ring of bark removed.—Analysis after twelve days. In the peripherical part of the absorbing twig all systems had again absorbed, but only the medullary sheath conducted far down; from this the fluid had passed out to the cicatrices of the partly fallen leaves, while the buds in the axils of these, at that time without any vascular connexion with the medullary sheath, were wholly passed over. It had descended a good way in the interior of the wood of the *main shoot*, and here again at the *boundary between the outer and inner layers of wood* (but especially in the *latter*), while in the bark and liber it had *not reached* the ringed portion, much less passed beyond it. The fluid had, moreover, not merely descended, but also *ascended*, in the main shoot, and in the *same region* of the woody system. In the absorbing twig itself it likewise passed into the leaves situated below the absorbing leaves, and could readily be detected in the unrollable spiral vessels of their petioles. It must be observed that the two layers of the wood differed very much in their whole character; the outer was gorged with sap and evidently still in active process of development (June 27th), while the inner was white and dry, and therefore much better fitted to convey the crude juices. It therefore only remains remarkable, that the fluid which penetrated most easily in the *medullary sheath* of the twig, *left the neighbourhood of the pith in the main* (older) *shoot*, and passed to vessels situated further out. I observed the same in *Salix acuminata*, Smith, in which the solution was traced through three communicating generations or systems of branches. The still green absorbing twig behaved as above; the shoot from which this arose possessed three layers of wood; in this also the fluid had descended chiefly near the pith. The second shoot passed into (or arose from) a third thicker branch in the wood, in which four layers could be distinguished, and here the fluid had passed down at the boundary between the inmost and the next succeeding layer of wood, and not next the pith. It perhaps would not be erroneous to attribute this circumstance to the difference of the annual course of growth, assuming that the fluid always kept to one and the same tract, to vessels of the same age, in passing from the youngest shoot into the older. At all events this is not contradicted by the observed occurrence of *several* layers of wood, for I have seen distinctly (in *Salix alba*) that at least three succeeding systems (or generations) of shoots may be developed in one and the same year, the lowest and thickest containing two clearly distinguishable layers of wood, which however were indicated even in the last and thinnest (in the beginning of July). In order therefore to obtain a surer basis for the decision of the differences of age in the young systems of branches, I examined the condition of that small *vascular bundle* which diverges at certain points from the medullary sheath, and runs into the petiole of the leaf which subtends the bud. Subsequently (in the succeeding year), these vessels, which are torn off externally at the fall of the leaf, are covered up and buried by degrees by the new wood formed in the young shoot (produced by that axillary bud); but they may still be discovered, even in old branches, if carefully sought. In the above case, in *Salix acuminata*, it was found that the saline solution had descended in the old main shoot, as mentioned, between the innermost and next succeeding layer of the wood, and thus *externally* over that little vascular bundle (originally going to a leaf) belonging to the inmost layer of wood.

Balsamina hortensis.—The solution absorbed by the leaves could in three days be traced upwards in all parts and farthest, and downwards in the vessels and the (wood) prosenchyma accompanying them; the *latter*, however, had conducted very much more fluid, since in cross sections the colourless large vessels were ordinarily perceived surrounded by a delicate ring of very small blue cellular points. In another case also, when the plant had absorbed very little of the solution, it was observed that this had descended principally in the internal cortical layer, and in the prosenchymatous cells in the vicinity of the vessels, not however in the latter themselves.

While, therefore, the tracheæ conducted most readily in woody plants, in the succulent balsam the neighbouring prosenchymatous cells were decidedly overcharged. Perhaps the cause lay in the prosenchymatous cells of the woody plants being in many cases filled with air (which is not the case in the balsam), whereby, of course, the passage of the solution from cell to cell through the, moreover dry, membranes might be rendered more difficult.

Lactuca sativa.—The solution absorbed by the leaf during eleven days was contained in especial abundance in the spiral vessels and their surrounding prosenchyma, on the corresponding side; on the other side of the stem, however, only in the prosenchyma surrounding the vessels, and in the lower parts of the stem the same. Here, moreover, the rind and the pith also had conducted, the pith principally in the cells at the boundary of the medullary cavity.

Euphorbia terracina, L.—After four days' absorption through a leaf, the solution was traced in the entire stem, chiefly in the wood cells and isolated tracheæ (unrollable spirals and dotted vessels), which latter also contained a few *air-bubbles at the same time.*

Tropæolum majus.—After five days' absorption the solution was found inside the intercellular passages of the rind and pith, still more in the prosenchyma of the wood, and most of all in some tracheæ.

Cucumis Melo.—After one day's absorption all the intercellular passages, for several inches upwards and downwards in the stem, were found filled with the saline solution, while the fluid cell-contents themselves did not react; particular portions of the (wood-) prosenchyma, and above all some of the large tracheæ, had also absorbed.

The size of the vessels here permitted a decision, for this and all other cases, of the question whether the blue reaction so often observed in the interior of the exposed tracheæ might not result from the process of preparation, in short from the cutting of the sections, since the knife might indeed readily spread reacting fluids from the neighbouring prosenchymatous cells into the open mouths of the vessels. If such were the case, if therefore the reaction in the interior of the vessels were exclusively caused by an unavoidable smearing at the time of the analysis, the blue vascular points arising from the reaction would not, at all events, always occupy the same place in a succession of transverse slices from a stem where the course of the vessels was exceeding straight. *But this actually took place,* and it follows beyond doubt that the tracheæ can in some cases take up and carry forward fluids.

Vitis vinifera.—Here again it was found that the fluid proceeded both downwards and *upwards* from the absorbing leaf into the shoot bearing it, and in both cases in the same situation, namely, chiefly in the medullary sheath and in the portions of cellular tissue enveloping the liber-bundles on the inner side; apparently somewhat more had descended externally, and somewhat more ascended internally.

Cucurbita Pepo.—This time a *tendril,* instead of a leaf, was immersed in the solution, but it absorbed very little, probably in consequence of continued wet weather. Analysis showed that the fluid had ascended in the prosenchyma accompanying the vessels, but not in these themselves.

From these and similar experiments it follows that in the absorption of fluids through the leaves, they are conveyed most readily by the tracheæ or the prosenchyma closely surrounding these; in plants gorged with sap more readily in the latter, and the reverse in dry woody plants. But even in the most succulent vegetables, only a somewhat longer continuance of the introduction of the fluid, or a greater quantity of it, is requisite to cause it to pass very readily into the air-tubes, and at length into all parts. It would therefore be erroneous to assume that any particular anatomical system is exclusively charged with the conveyance of unelaborated fluids in the ascending or descending direction. It was above all seen, that the tracheæ do usually convey air in summer, but very readily become temporarily more or less, or even wholly filled with fluids which displace the air. In fact, chemical reasons led me to consider the existence of the gas in the spiral vessels and spiroids as nothing more than a result of the absorption of crude fluids from the soil, which, ascending in the higher and warmer layers of the plant, at once give off almost unaltered the gases dissolved in them, these being diffused through those communicating passages, and so gradually evaporated outwards and upwards without doing any mischief. In this point of view the vessels would be regarded as 'tubes of safety.'

It merits some attention, that, as the last experiments prove, no parts take so little share in the conduction of the solution downward as the layers of the bark. I therefore took occasion to investigate the capability of the bark to convey fluids by a direct experiment. This was done by removing every other passage but the bark from the descending fluid.

Salix vitellina.—On the 19th of June a fresh pendent twig $1\frac{1}{2}$ line in diameter, had the bark slit up for the length of 1 inch at the side, 5 inches from the end; the bark was turned back and the wood within completely removed for a length of 2 lines; then the bark was returned into its place, rolled up in a living leaf to prevent drying, and the shoot strengthened by a splint. Lastly, a leaf situated below the excised wood was immersed in the solution. After twenty-four hours the fluid had advanced very little in the pith, but elsewhere in all parts (bark and liber included) as far as the cross-section of the wood, but not beyond this even in the bark. The result was similar after absorption for four days. Even after seven days' absorption, the solution had not made its way over the bridge of bark; indeed this did not itself react, although it was in part perfectly fresh and living. In this case, moreover, the whole of the lower outer part of the twig was densely filled with the saline solution; even the badly conducting pith of the lower portion of wood reacted distinctly; the medullary sheath and the peripherical portion of the wood reacted most strongly, especially on that side of the wood corresponding to the absorbing leaf. From this it is evident that a far stronger penetration of the fluids than that which occurred here, is requisite to overcome the *resistance* which liber and bark oppose to the descending sap (see Sect. 4 below).

This observation rendered it necessary to apply the saline solution immediately to those parts to which the business of conveying the sap down is most frequently attributed, in order to bring the question nearer to a decision.

2. *The Descending Sap with direct absorption by the* CAMBIUM *layer.*

Salix acuminata, Sm.—In a branch $1\frac{1}{2}$ inch thick, the bark was slit up, separated to a certain extent, and a piece of filtering paper, many folds thick, soaked in the solution, inserted under it, the wound being then loosely bandaged. After one day (June 15) it was found that the salt had *neither ascended nor descended beyond* the exposed portion of the wood; it had only penetrated extremely superficially even in the liber which lay directly upon the paper, and not at all into the rest of the bark or the wood.

Salix arbuscula, Whlbg.—Bark slit up for 2 inches; branch $1\frac{1}{2}$ inch thick: otherwise as above. After four days, only those parts directly in contact with the paper reacted; the salt had not passed beyond in any direction; the paper was still moist.

Salix hippophaëfolia.—Branch 1 inch thick; bark slit up as in the preceding, but the fluid was actually dropped in on the 18th and 19th of June. On the 20th it was found that the solution had not gone beyond; even the layer of sap-wood was scarcely penetrated $\frac{1}{8}$th of a line deep.

Salix arbuscula.—Branch $1\frac{1}{4}$ inch in diameter. Repeatedly wetted, as in the preceding case, during eight days: result almost the same. The solution had only advanced 1 line beyond the exposed spot, and quite uniformly upwards, downwards, and to the side; the sap-wood reacted $\frac{1}{4}$ of a line deep. When the experiment was continued for eighteen days the result was the same.

Consequently there is no layer in the whole tree less favourable than the cambium for the conduction of the sap. In opposition to the views of many inquirers, this part, being in the most active condition of development, most energetically arrests the fluids.

It is clear how unfitted the bark is for the transport of fluids; they occupy a longer time there than in most other parts, in changing their place. And in this experiment, we must not be led away by the results of what are called the "magic rings*" on trees. For if a thickened border is formed on them at the upper cut edge, this only proves that the sap in general has a descending motion; not, however, that this *does not take place far better and more easily in the totally uninjured woody layer.* When we reflect that even in the oldest trees a continual incrustation of the cells, a continual increase of that transformation of the saps, goes on deep in the interior of the wood, the result of which is the concentric growth of the *heart-wood*, at the expense of what is at first sap-wood, it is seen at once that it would be a great mistake to regard the wood, on account of its solidity, as lifeless and unengaged in the conduction of the sap.

3. *The Descending Sap in absorption by the* ROOT.

Salix alba, L.—A piece $1\frac{1}{2}$ foot long, of a shoot $\frac{1}{2}$ an inch thick, was placed in the ground on the 24th of February, and kept at a moderate temperature, so that roots were formed, and by the 20th of April leaves had already burst out. On the 6th of June the rooted portion was carefully split up the middle, from below upwards, and one of the halves immersed in solution of the ferrocyanide, the other in a vessel of pure water standing close beside. On the 14th all the leaves were dead, the roots still fresh and healthy. On the 4th of July the height of the fluids in the two vessels was not perceptibly altered, whether the levels were previously alike or different, as counter-experiments

* Made by removing a ring of bark running all round the tree.

proved; therefore no siphon action had been exerted. On this day the twig was analysed. The solution had not only ascended to the upper end in the one part, but also *descended* in the other part (at the water side), and indeed just to the surface of the water; it had penetrated farthest of all in the vascular part of the outermost *wood*, which, at the upper part, was in contact with the absorbing half of the shoot; in the liber and bark it fell about 1 inch short of this, while the inner wood, the medullary rays, and the pith, did not react. The surrounding water exhibited no reaction, which, it may be remarked in passing, does not speak much in favour of the hypothetical "root-secretion." The half dipping in the saline solution, when examined upwards, reacted most in the medullary sheath, and in the (two) outer layers of wood; also, however, in the liber and bark; while the inner (third) layer of wood and the pith had not conducted so far. At the upper free and undivided extremity, the branch reacted only at one side, that corresponding to the vessel containing the saline solution; therefore the solution had not passed round by the top to descend into the other half (to the water), but had gone over (in extremely small quantity) horizontally from wood to wood further down.

When the experiment was stopped sooner, in other cases, it was found (June 12th) that the solution had merely ascended, and not descended; in another piece of a shoot, the solution had descended half way in the water-half by the 15th of June. In one case, when the experiment was kept in action longer, the solution had descended $\frac{1}{2}$ an inch down below the level of the water in the half dipping in the latter,—not, however, to the highest of the little roots; here also the water exhibited no reaction; in fact, the portion of the inner layer of wood here laid bare by splitting the shoot had *not* conducted.

Whether, in these cases, the absorption of the saline solution took place through the roots, or also through the lowest exposed portion of the inner layer of wood, it is certain that here again the liber and bark were decidedly less concerned than the tracheæ of the wood, in the descent of the sap. It is seen that the descending sap, when it ascended from the *roots* and penetrated horizontally from wood to wood, avoided the *medullary sheath*, while it was shown in previous experiments that it very readily passes into the latter when it is brought into the plant by the *leaves*; a circumstance which is doubtless to be explained by the intimate anatomical connexion between the vessels of the medullary sheath and those of the petioles in young shoots.

4. *The Descending Sap after direct absorption by* CUT SURFACES OF THE WOOD.

Salix vitellina.—The end of a pendent young leafy shoot was cut off, and the lower peripherical portion stripped of bark for 2 inches; the part thus laid bare was immersed 1 inch in the solution. At 2 inches further up in the same shoot, the bark was slit up at the side, and the cylinder of wood cut out for a length of 2 lines; the bark being returned to its place, and the wound wrapped in fresh leaves, the whole shoot was supported by a splint, to keep it in a fixed position. After four days the shoot had absorbed the fluid as far as it dipped in it. In this case the saline solution had *passed the bridge of bark*, had advanced $4\frac{1}{2}$ inches beyond the vacancy in the wood, and into *all* parts; furthest, however, in the bark and wood, principally in the medullary sheath and the peripherical part of the wood. Repeated experiments gave the same result, but sometimes the liber, sometimes the wood, had conducted a little farther. Consequently, here, where a forced entrance of the fluid had accomplished the passage through the bridge of bark, the solution had again penetrated in the horizontal direction through the wood above this bridge, and sometimes even advanced further in it than in the bark itself.

S. alba.—A portion $1\frac{1}{2}$ foot long of a leafy young shoot was stripped of its bark for 2 inches at the upper end, and dipped, with its wood wrong end upward, 1 inch deep in the solution. Then 1 inch of bark was peeled from the other free end, and a closed glass tube turned down over it to prevent desiccation. After seven days the fluid had ascended through all parts; whence, comparing this with the cases mentioned in section A 2, it results, that in absorption by exposed layers of wood, *it makes no difference* in the conduction of the sap whether the *shoot* is immersed in the fluid *upright or in a reversed position.* In this case also, some salt had crystallized out upon the leaves. When the free end of the wood was enveloped in blotting paper, the latter absorbed a great deal of the solution (in the horizontal direction from the wood) even when the bark much lower down was unaffected. Or if only a ring of bark was cut out on the upper part of the shoot, this interruption was no hindrance to the advance of the solution; it was found at the end, both in the wood and in the bark. The epidermis did not give a blue reaction even after remaining one hour in contact with the salt of iron.

Salix acuminata, Sm.—The question investigated in this case was, how far a *horizontal* conduction of the fluids can take place under favourable circumstances in the *wood itself*, through layers of different ages. For this purpose the point of a small twig was cut off, at the end of June, and the open end immersed in the solution. The main shoot (6 lines thick) which bore the foregoing was so notched circularly in four different places, that there was no immediate communication with the vessels of the stem in any place: the wounds were enveloped in fresh leaves. After eight days it was found that the solution had advanced exclusively in that side of the main shoot which corresponded to the absorbing twig, and indeed only *as far as the notch* which interrupted the vascular communication 4 inches further up. Here also the outermost layer of wood and the liber had conducted principally, and not the cellular intermediate layer of the bark. From this we see what difficulties are opposed to the assumption of a horizontal movement of the sap through the medullary rays; although, at the same time, a horizontal movement of the saps in the young wood, *generally*, under very favourable circumstances, as in the experiments of Hales (*l. c.*), cannot be disputed.

Postscript.—With regard to the behaviour of the milk-sap, which I had an opportunity of observing in several *Euphorbiæ*, in *Sonchus oleraceus*, &c., in reference to the conduction of sap, I am led to assume, from all that I could notice, that it takes *no part whatever* in this, whether the fluid penetrate into the plant through the leaves or through the roots, setting aside all the anatomical reasons against a circulation of the milk-sap, the most decisive of which is, that in the majority of plants the milk-sap passages have no continuity or general distribution. [A.H.]

ARTICLE II.

Upon the Male of Argonauta Argo *and the* Hectocotyli. *By* Professor HEINRICH MÜLLER *of Würzburg.*

[From Siebold and Kölliker's *Zeitschrift für Zoologie*, June 1852.]

AMONG the many perplexities presented by the sexual relations of the Cephalopoda, we have had to reckon, even up to the present time, the statement of the majority of observers, that they had found none but female Argonauts. I believe that in the present essay I for the first time describe the perfect male Argonaut, as one of the arms of which the so-called *Hectocotylus Argonautæ* is developed. The *Hectocotyli*, which, from the first, Cuvier called "truly extraordinary" creatures, will none the less deserve that title.

It is well known that Kölliker* has endeavoured to show that the *Hectocotylus* of the Argonaut, described by Delle Chiaje† and afterwards by Costa ‡, is the male of this Cephalopod; that the newly discovered *Hectocotylus Tremoctopodis* also is the male of *Tremoctopus violaceus*, D. Ch.; and Von Siebold § has assented to his views.

More lately Verany ||, in his work upon the Cephalopoda, communicated some very important discoveries with regard to the *Hectocotylus* of an Octopod. He found, that among five specimens of a peculiar species which he had previously named *Octopus Carena*, in three the third arm upon the right side was longer and stronger than the others, and was provided with a vesicle at its extremity. The fourth specimen had in the same position a short pedunculated vesicle; and the fifth possessed simply the peduncle without either arm or vesicle. Filippi noticed that the longer arm, which in one instance was observed

* Annals of Natural History, 1845. Linnæan Transactions, vol. xx. Bericht von d. Zootomischen Anstalt zu Würzburg, 1849.

† Descrizione, iii. p. 137, tab. 152.

‡ Annales d. Sciences Nat. 1841, p. 184 and pl. 13.

§ Vergleichende Anatomie, p. 363.

|| Mollusques Mediterranéens, 1ère partie, Genoa, 1847–51.

to drop off on being touched, resembled the *Hectocotylus Octopodis* of Cuvier*, and Verany concludes from thence that this *Hectocotylus Octopodis* is a deciduous arm bearing male organs which are probably periodically developed. With regard to the *Hectocotyli* of the Argonaut and of *Tremoctopus* on the other hand, Verany believes that they cannot be arms of the corresponding Cephalopoda.

These statements rendered the subject of the *Hectocotyli* far more difficult than ever. It could hardly be believed that the *Hectocotylus* of the *Octopus* could be really distinct in its nature from the two examined by Kölliker; and yet upon the other hand, there were many reasons for hesitating to apply the conclusions drawn from the former to the latter. The *Hectocotylus octopodis* differs in many respects from the others; its sexual relations are less certain, while those of the Octopods to which it was attached, either in the mantle or as an arm, are wholly unknown; and finally, the positive assertions of Madame Power and Maravigno (see Kölliker, *l. c.*) seemed to prove that the *Hectocotylus Argonautæ* was developed as such in the ova of the Argonaut.

While at Messina, in the past autumn, I was very desirous of repeating the observations of Madame Power; but notwithstanding the examination of many thousand ova of all the Argonauts which I could procure, I merely found embryos of the ordinary form more or less developed; never those vermiform young, whose description had led to the belief that the *Hectocotyli* were developed in especial bunches of ova.

At last, at the end of September and in the beginning of October, there were brought to me, among many very small Argonauts which had not yet acquired a shell, a few of a quite peculiar form. Their cephalic extremity presented a little sac, which projected between the arms, as the animals swam about with their peculiar retrograde movement. On closer inspection† one could perceive seven arms, which all terminated in points like the six lower arms of other Argonauts of the same size. The

* Annales d. Sc. Nat. 1829, p. 147, pl. 11.

† The relations of the parts were clearest when the animals fixed themselves during life, within a glass, so that one could look from without straight down upon the oval surface of the head; or after death, by placing them in a waxen pit so as to obtain a similar view.

two upper and the two lower arms were longer than the lateral ones; of the latter on the right side three only were present; while on the left side there existed, in all the specimens which I received, in the place of the lower lateral arm, the sac in question, supported by a short and delicate pedicle, as if it were constricted. The pedicle arose from a small depression between the second and fourth arms and the mouth, from which the sac could be easily drawn out a little. The membrane which unites the base of the arms of the Argonaut passed upon the left side from the second to the fourth arm, without immediately investing the sac, whose position was somewhat internal to it.

The sac itself was not so long as the arms in the smallest specimens, whilst in the larger it equalled or exceeded them in length. In shape it was not exactly round, but somewhat elongated and compressed in such a manner that the diameter in a radial direction from the mouth was greater than in the line of the two neighbouring arms. The colour, like that of the rest of the body, was intensely reddish brown when the chromatophora were dilated, more greyish when they were contracted. Only on the inner, oral side was there a white streak without chromatophora, which however did not extend over the whole length of the sac.

In all cases a Hectocotylus Argonautæ *lay coiled up within the sac.* It was curved towards the side which bears the suckers, so that the back of the thick part corresponded longitudinally with the internal convexity of the sac. The part described by Kölliker as a silvery sac, forms at this place, immediately under the skin of the sac in large specimens, a ridge-like elevation visible externally, through which a whitish tint often glistens. The thinner part of the sucker-bearing body is bent back along the inner convexity of the sac towards the base, and the filiform appendage lies between them in multitudinous convolutions.

This position of the *Hectocotylus* is frequently obvious from without, especially during the lively movements which it often makes; and still more clearly on the opening of the sac, when it uncoils itself from its narrow cell under the eye of the spectator.

The relation of the *Hectocotylus* to the capsule in which it lies, and the change which the latter undergoes after its eversion, are very remarkable.

I may here observe, that in one case the sac burst before my eyes, along the inner, oral side, in consequence of the violent movements of the *Hectocotylus*, when the process about to be described took place in exactly the same manner as in other specimens which were artificially opened.

It is observed, in the first place, that the thick end of the *Hectocotylus* is fixed to the pedicle of the sac or forms it; next, that the membrane of the sac is perfectly distinct from the filiform appendage and from the neighbouring parts of the sucker-bearing body; but that, upon the thick portion of the body, while it leaves the sucker-side free, it is attached along the back behind the suckers, and forms the covering of the silvery sac above mentioned.

The so-called pigmented testis capsule of Kölliker, however (as it is observed in the *Hectocotyli* which are found free upon female Argonauts), does not yet exist, and is subsequently formed from the membrane of the sac.

As soon indeed as the appendage and the thinner part of the body, which usually become twisted upon their axis at the same time, are evolved, the thick part bends forcibly back in the opposite direction to the previous curvature, that is towards the back. By this means the longitudinally cleft membrane of the sac is inverted, so that its inner surface comes to be exterior, and the edges of the torn part are turned back towards the back of the *Hectocotylus*, which is now concave. The previously external pigmented layer of the sac now lies in the pit between these edges, and when the latter have united, there is left only a small cleft, a process which can naturally not be directly traced. We have just such a pigmented capsule formed as has been already found in the dorsal crest of *Hectocotylus Argonautæ*.

In this way we readily account for the singular fact, that a colourless layer is constantly found upon the exterior of the dorsal crest, while the layer of chromatophora lies internally upon the so-called capsule of the testis.

The membrane of the sac then belongs to the future *Hectocotylus*. This was seen most clearly in that specimen in which, as has been already noticed, the sac opened spontaneously; for upon touching the *Hectocotylus* frequently it detached itself from its delicate pedicle so as to carry away the inverted sac with it.

However, as the cleft in the sac had not extended quite so far as the insertion of the pedicle, the first suckers still remained hidden by the pigmented sac, whose borders began to be reverted only opposite to the fourth sucker.

The case here cited hardly allows us to doubt that the *Hectocotylus* once formed is intended to become detached from the rest of the animal; as might indeed already be concluded from the fact that all the *Hectocotyli* seen by Delle Chiaje, Costa and Kölliker, to which I can add thirteen others, were found separated and associated with female Argonauts. Hence also it would seem to be probable that the detachment of the *Hectocotylus* is preceded by the bursting of the sac; though I have found no specimen in which when captured the *Hectocotylus* had already made its exit from the sac. When and in what manner the separation of the *Hectocotylus*, and its transport to the female, go on; whether any act of copulation, for instance, takes place, were points upon which I had no opportunity of making any observations.

I will now first consider a few points with regard to the external and internal structure of *Hectocotylus Argonautæ*, and I will then compare the *Hectocotyli* of *Octopus* and *Tremoctopus* with it. For the most part I have only to confirm Kölliker's observations, though of course my interpretation of them must be somewhat different. The name "*Hectocotylus*" may very well be retained, without any implication of independent animality.

Hectocotylus Argonautæ.

As to external form, there were two portions to be distinguished in all the *Hectocotyli*, whether free or enclosed in sacs, which I examined: the one thick, and carrying suckers; the other called by Kölliker the filiform appendage, thin and suckerless, but directly continuous with the former.

In the free *Hectocotyli* the body and its appendage sometimes attained the length of an inch or more each; in other cases, each was some lines shorter. A few of the *Hectocotyli* which were just set free from the sac had this latter size. In three specimens, in which the body and head of the whole animal, as far as the base of the arms, were about 4 lines long, the sucker-bearing portion of the *Hectocotylus*-arm measured 8–10 lines, and the appendage about as much more. In an animal of 3 lines long, each part of the *Hectocotylus*-arm was a few lines shorter. The smallest specimen which I met with measured 2 lines to the base of the arms; body and appendage of the *Hectocotylus*-arm each 3–4 lines. The length of the uninjured sac was about 1 line in an animal of 2½ lines; on the other hand, it was 3 lines in a specimen whose body, as far as the arms, was 4 lines long*.

At the thick end of the detached *Hectocotyli* is the point, where the constricted axis must finally have divided; it is drawn a little towards the dorsal side, while the first suckers project somewhat forward. No trace of any rent is to be seen, but the surface is quite smooth as if cicatrized, and the fringe which unites the suckers upon their dorsal side is also present between the oblique anterior pair, so that the one series of suckers passes in a continuous curve into the other.

The point of transition of the thicker body into the filiform appendage is sharply marked in all the free *Hectocotyli* and in the larger enclosed ones. The suckers with the fringe which unites them cease suddenly, the axis of the body becoming thinner and passing into the appendage. In the smallest specimen before mentioned, on the other hand, the transition was far more gradual. The suckers in the posterior broad part of the body, which did not measure more than ·15 of a line across, became gradually smaller and more rudimentary, and finally appeared as mere transverse elevations; when they ceased the diameter of the body was still 0·1 of a line.

The membranous lobes described by Kölliker at the origin of the suckerless part of the body were present in all free *Hectocotyli*; but it could generally be clearly observed that there is properly speaking only a single lobe, which in its highest part crosses the body of the appendage transversely, and then passes gradually upon each side into a slight fold. These two folds run along the appendage for a considerable distance: in one case, the most elevated portion of the lobe was prolonged into two elongated processes. The height of the transverse portion

* An eighth specimen, in which both the body and the unopened sac surpass the above dimensions, is in the possession of M. Verany, who immediately recollected it on seeing my specimens. It had previously been brought by Krohn from Messina.

varied from an inch to more than half an inch (1 *bis über* $\frac{1}{2}''$). The fibrous tissue of which the lobe consists is contractile, and frequently moves very vivaciously by itself. In the yet attached *Hectocotyli* the lobe was in the same way more or less developed, and was wanting only in the smallest specimen. This is unfavourable to the view that the lobe is a residue of the torn sac; which might otherwise suggest itself, especially since the strong resistant epithelium which externally coats the appendage is absent upon the lobe. The edges of the lobe were generally smooth and did not appear torn.

Of the tentacular cirrhi which Costa (*l. c.* fig. 2[a] *e* and *f*) depicts at the anterior end of the *Hectocotylus*, I could never find any trace, and I am inclined to believe that they were some accidentally adhering foreign bodies, since nothing could be lost or torn away, in the *Hectocotyli* otherwise perfect, which were taken out of the sac.

Such specimens as the latter are also important for the determination of the interpretation which is to be put upon the dorsal pigmented capsule * and the position of the appendix in it. Kölliker has called this capsule the capsule of the testis;—inasmuch as in one specimen he saw the filiform appendage enter it through a cleft in the back, and become connected therein with a coil of seminal canals, to which he gave the name of 'testis.' I believe that the presence of semen there is accidental, and that another interpretation must be given to the position of the appendage. It has been already stated, that there exists no capsule in the *Hectocotyli* while still included in the sac; the appendage is always free, and nothing is to be seen of any seminal canals. In the free *Hectocotyli* the capsule was indeed always formed, but in many instances it was quite empty, the appendage also lying outside it. In other cases the appendage passed, in the manner depicted by Kölliker (pl. 1. fig. 9 and pl. 2. fig. 17), through the cleft of the dorsal ridge into the pigmented capsule, but lay free therein, no seminal canals being present.

* The chromatophora here exhibit in free *Hectocotyli* the same movements as elsewhere. The radial muscular fibres are clearly recognizable, contracted or relaxed according as the chromatophora appear large or small. Muscular fibres are also found in the deeper layers of the cutis in *Hectocotyli* as elsewhere among the Cephalopoda, *e. g.* in the dorsal ridge.

This could be seen partly upon opening the capsule, partly from without during the movements of the *Hectocotylus*. The appendage not only twisted about in the capsule, but crept alternately out and in, so that even the thin part of the sucker-bearing body, as far as it would go, became hidden in the capsule. The *Hectocotylus* then crawled about in a very peculiar manner with this inserted part, which formed about the middle of the body, directed forwards. On the other hand, if the *Hectocotylus* were disturbed by touching, it not unfrequently drew its appendage quite out of the capsule, and could then be no longer distinguished from the first form which has been mentioned.

It appears then, that the appendage makes the pigmented capsule its residence either from being accustomed to its previous imprisonment in the sac, or as a sort of presentiment of its proper position *.

The exceptional occurrence of seminal canals in the capsule of Kölliker's *Hectocotylus* is explained, if we consider the route which the semen must take to be poured out.

Kölliker has exactly described the course of the vas deferens between an aperture in the neighbourhood of the point of the appendage and a thick silvery sac which lies under the pigment-capsule. He called that sac a penis, or finally, vesicula seminalis; assuming that the semen passes out of the capsule (testis) along the appendage, then into the ductus deferens along the back, and finally out of the silvery sac at the thick end of the *Hectocotylus*.

However, in the most free *Hectocotyli*, and even in the largest of the included ones, we find this sac completely filled with semen. Sometimes this distension extends into the ductus deferens to a greater or less extent, and evidences itself to the naked eye even, by an intense white streak along the back and appendage of the *Hectocotylus*. Lastly, on one occasion a *Hectocotylus* passed a whole coil of a thread, about ·06 of a line thick and consisting of spermatozoa, from the aperture of the appendage, and the thread remained attached to it, so that the appear-

* Considering the occurrence of gills in *Hectocotylus Tremoctopodis*, we might ask whether that form developes a digestive organ, for which Cuvier took the capsule in *H. Octopodis*. At present however we have no evidence upon the point.

ance figured by Kölliker (pl. 2. fig. 19) arose: only the appendage was free, while in Kölliker's specimen it was inserted in the pigmented capsule.

We may hence assume that the semen during ejaculation passes from the thicker sac towards the point of the appendage*. It agrees very well with this conclusion, that a copulation very probably takes place during which the appendage represents the penis (*vide infra*). Kölliker's *Hectocotylus* therefore only committed an *error loci* when it deposited its semen in the pigmented capsule. The presence of an investment to the seminal coil which Kölliker found in the pigment-capsule, is not, as I believed at first, any argument against its secondary deposition there, for a structureless layer was also very visible in the free seminal cylinder, at least in some portions of it. It is perhaps only analogous to the structureless mass which is to be found elsewhere in the sexual canals of the Cephalopoda, and is deposited around the semen when excreted. In a second instance I could find no such investment.

Since the pigmented capsule upon the back of the *Hectocotylus* could not be the testis, the latter was to be sought for elsewhere. At first, I was tempted to consider the silvery sac as its representative; since not only was this full of perfect spermatozoa in all free *Hectocotyli*, but also in that *Hectocotylus*-arm already referred to which had burst its sac after its spontaneous detachment. Nevertheless it was surprising that in other *Hectocotylus*-arms just taken out of their sac, the silvery capsule had not its white colour, and neither perfect semen nor any stages of its development were to be perceived therein.

Subsequently I convinced myself that there is unquestionably a testis in the abdomen of the animal which carries the *Hectocotylus* as an arm. Behind the gills and venous appendages a great part of the mantle-cavity is taken up by a capsule, whose free lower wall is very remarkable on account of its isolated chromatophora scattered over as hining golden ground. Behind,

* In most cases I could not exactly make out the place of the aperture, though in the two upper thirds of the appendage the ductus deferens is usually easily recognizable, and even far forward has a diameter of 0·05 of a line when it is not collapsed. On one occasion I succeeded in pressing the semen from the silvery sac to within two lines of the point where the ductus deferens only measured 0·03 of a line.

it adheres to the mantle. In the capsule lies a white mass which consists of little cylinders or cæca which are united at one extremity: their length is about 1 line, their thickness 0·06–·1 of a line. A clearly-defined tunica propria could not be distinctly recognized in these spirit specimens for each cylinder, but expanded membranous coverings could be frequently observed between them. In the cylinders themselves large pale cells lay at the periphery; the interior was in one case occupied by masses which consisted of numerous granules of about 0·002 of a line in diameter, and which had frequently a delicate process in an oblique direction with regard to the axis of the cylinder. In a second specimen there could be no doubt that these lumps were forms of the development of the spermatozoa. There lay in the same position more or less developed bundles of spermatozoa, whose somewhat wavy threads had the same oblique direction with regard to the axis of the little cylinder. This appeared, consequently, to be quite a fibrous streak. The length of the single bundles was about 0·08 of a line.

In these two animals provided with full testes, the generally white and distended capsule of the *Hectocotylus* was colourless and collapsed. In a third animal again, which had carried the detached *Hectocotylus*-arm filled with spermatozoa, the shining golden capsule was indeed present, but it was empty. If we connect all these facts together, it becomes very probable that the semen is produced in the testis, and that it is then transferred into the *Hectocotylus*, although I could not recognise with certainty this portion of the ductus deferens, which must lie under the skin of the head.

The silvery capsule, then, would be neither penis nor testis, but vesicula seminalis; and so long as the *Hectocotylus* remains connected with the rest of the animal, the essential distinction from other cephalopod males must consist in this, that the aperture of the ductus deferens, instead of lying in the mantle-cavity, is placed at the end of the peculiarly-developed arm.

The structure of the silvery capsule harmonizes very well with this interpretation. It is, as Kölliker has shown, very muscular *, and in its interior there lay in all the free, and in the largest of the

* The muscular fibres are distinguished from those of the rest of the body by a peculiar development, a point to which I shall recur elsewhere.

included *Hectocotyli,* the coils of a thread of 0·06–0·08 of a line in diameter, consisting of perfect spermatozoa. I have not seen the aperture of this organ, stated to exist by Kölliker at the extremity of the thick end of the *Hectocotylus.* If the semen be actually passed out of the testis into the capsule, such an opening must exist at one period or other; but it probably becomes closed behind the deposited semen before the detachment of the *Hectocotylus* takes place.

The spermatozoa of the Argonaut consist of a very delicate thread, at one of whose ends is a somewhat thicker fusiform body. They are therefore analogous to those of *Tremoctopus,* but smaller, since they measure, as we see especially in the bundles, only 0·08–0·09 of a line in length, of which we may consider the body to form 0·01 of a line. In general the bodies lie grouped together, and from them the threads pass nearly parallel, like the cilia of a colossal ciliated epithelium. On one occasion almost every bundle of bodies was spirally twisted. This occurred in the appendage of a *Hectocotylus* which I found in the ovarian capsule of a female Argonaut. In this one case I saw a lively movement in the spermatozoa, the groups of which formed regular progressive waves like the sea after a strong breeze.

What is there in the muscular tube which forms the axis of the Hectocotylus? is a most important question.

Since we know that the *Hectocotylus* is developed as an arm, it may be surmised, *à priori,* that the structure of the whole axis will nearly resemble that of other arms, as indeed Kölliker has already shown it does, so far as the muscular tube is concerned. In fact, there lies in its interior a chain of ganglia, which answer to the suckers. We see them best in longitudinal sections which have been placed in solutions of chromic acid or corrosive sublimate, and the single ganglia may be separated and demonstrated as far as the root of the filiform appendage. From this point the muscular tube may be very readily traced to the extreme end, but it is difficult to make out what it contains: certainly not the vas deferens; for this, as Kölliker has shown, is only attached superficially. In fresh specimens I saw a few times a clear tube-like streak, which gave off lateral branches as well in the axis of the sucker-bearing portion as in that of the appendage, in which it measured only ·012 of a line; but of its nature I can say nothing. The thickness of the whole axis measured in one case at the end of the seminal capsule 0·39 of a line; towards the end of the sucker-bearing portion 0·3 of a line; in the beginning of the appendage 0·15 of a line; at the end of it 0·03 of a line. The inner tube measured at the same points 0·24, 0·18, 0·08, and 0·025 of a line.

The development of the *Hectocotylus* as an arm, while it explains the presence of a ganglionic chain, equally accounts for the absence of any special organs of sense. But on this ground the sensibility of the skin is very considerable.

Since the muscular tube is filled by the chain of ganglia, the supposition that an intestinal canal exists there, which Kölliker himself considered doubtful, must be given up; at least I have perceived nothing of the kind.

With respect to the circulation, I can unfortunately give no information as to the connexion existing between the *Hectocotylus* and the rest of the animal. In the separate *Hectocotyli* the investigation is beset with difficulties, since they are for the most part very restless, and wind and twist about in the most determined manner. Yet a progressive wavy motion can readily be observed in the trunks which lie upon each side of the back and are immediately continued into the appendage. In one instance I could distinctly perceive that this somewhat slow movement passed upon the right side (the appendage being supposed to be posterior and the suckers below) as far as the extreme point of the appendage, and then returned in the opposite direction.

After each wave towards the point, however, there succeeded not merely a centripetal one upon the other side, but centripetal movements frequently arose, which commenced from the point of the appendage. In other cases I met with a different rhythm in the longitudinal trunks of the one and of the other side, and a few times it appeared to me as if in the same vessel the movement went on sometimes in one sometimes in the other direction, as in the Tunicata. However, two vessels lying close together might readily cause a deception in this case.

Whether any distinct central organ of the circulation or heart exist, I cannot as yet decide.

There occur indeed considerable dilatations in the vessels;

especially in one specimen, in which I found after the circulation had ceased, a sacculated space ·15 of a line long by ·018–·08 broad in one of the longitudinal vessels of the back, somewhat behind the extremity of the seminal capsule. At both ends of the dilated portion more delicate lateral branches were given off. Somewhat further behind upon the same vessel, and in a corresponding position upon that of the other side, there was a rounded expansion of ·05–·06 of a line in diameter. If these dilatations are to be called hearts—in which case they might be considered to undergo a further development—we must suppose that such exist in many places, which would agree with the general arrangement in the Cephalopoda.

But it may well be that these spots had merely remained accidentally dilated after death, for the narrower parts of the vessels were evidently contracted, and one of them, further on in the thick part of the body, was evenly dilated to 0·05 of a line. The differences in breadth, which may be successively observed in the same place during life, are again very considerable. A vessel between the axis and the seminal capsule measured in its condition of expansion 0·05 of a line, and contracted to ·02 of a line.

This rhythmical expansion and contraction of the larger vessels goes on in somewhat different modes. Frequently one portion of a vessel is suddenly distended by the wave propelled by the contraction of that portion which lies immediately behind it, and then collapses again. At other times one part is slowly distended by the blood which streams in gradually, especially out of the smaller vessels, and at last contracts with a jerk, whereby the vessel in consequence of its elongation becomes much bent.

The independent share of single portions of the vascular system in the centripetal movements of the blood is very clear here as in other parts of the Cephalopoda, *e. g.* the gills.

More or less rhythmical and swift contractions are seen to drive the blood from the smallest venous twigs into the larger trunks; these help it on further either by an immediate contraction, which is a continuation of that of the smaller branches, or only after they are more dilated by the repeated contractions of the latter. That this venous movement is nowise propagated from the arteries, is clear from the circumstance that single ramifications often pulsate rapidly, while the neighbouring ones are either still or move at a different pace. These relations are especially recognizable in those ramifications which come off from a transverse branch of the longitudinal trunks, between every pair of suckers, and spread in the membranous fringe connecting these.

Here, as in many other places in the Cephalopods, one may readily convince oneself of the existence of capillary vessels.

Concerning the development of the male Argonaut I can state nothing, since I unfortunately obtained no more ova advanced in development, after I had discovered the *Hectocotylus* to be an arm; and inasmuch as I had not previously paid sufficient attention to the form of the arms, in the expectation of finding the totally different vermiform embryos described by Madame Power. Indubitably, however, the male embryos are not to be found in especial bunches of ova, but have been frequently seen among the female ones by Kölliker and myself, although from the similarity of their form no further notice has been taken of them. One is the more justified in this supposition, since the sac with the *Hectocotylus* appears to be relatively smaller the younger the animal, and from its shape might be easily confounded with the yelk-sac.

In some preserved ova of the Argonaut far advanced in development, I believe that I can recognize the arm of the *Hectocotylus*.

The statements of Madame Power and of Maravigno quoted by Kölliker (*l. c.* p. 84) contain truth and fiction; but they may be thus interpreted. What are denominated *Hectocotyli* three days old are without doubt *Hectocotyli*; the description of them which is given, no less than the statement that only two or three are developed in the maternal shell, accords very well with this view. For if we procure Argonauts with advanced ova, in a short time we see the hatched young swim about in innumerable multitudes. The statement that the seven other arms spring out as buds from the vermiform animal while it is assuming the form of the common Argonaut, leads one almost to believe that Madame Power saw entire male Argonauts with *Hectocotylus*-arms everted from their sacs in the shell of the female Argonaut.

If this were demonstrable from the original manuscript, it would afford an important evidence in favour of the immediate transportation of the *Hectocotylus* from the whole male upon the female Argonaut.

In the following pages I will bring forward for comparison all that is to be said concerning the two other known kinds of *Hectocotylus*, for it is precisely the very striking differences and similarities of the three *Hectocotyli* with one another, that promise in course of time to afford an insight into the meaning of the separate organs and the nature of this singular creature as a whole.

For this purpose I refer to the description by Kölliker of the *Hectocotylus Tremoctopodis*, and to that of the *Hectocotylus Octopodis* by Cuvier and Verany. Although the identity of the species of *Octopus*, in which Cuvier and Verany found their *Hectocotyli*, is not demonstrated, yet the *Hectocotyli* are so nearly related that they may well be considered together.

Hectocotylus Octopodis.

As Kölliker has shown, the *Hectocotylus* of the *Octopus* is distinguished from that of the Argonaut not only by its greater size, but because at one extremity instead of the filiform appendage there is a vesicle containing a filament; in other respects the two forms essentially agree.

Upon comparing the figures of Cuvier and Verany, we find that the "solid cylindrical body" which Cuvier indicates as the origin of the silky thread is the muscular axis; the supposed nervous threads of Cuvier are the vascular trunks, which in *Hectocotylus Argonautæ* take on a similar appearance in spirit; the sac (*e*) filled with the coils of a white thread is the thicker seminal capsule; the canal (*h*) is the ductus deferens upon the back; the "stomach" (*d*) corresponds with the pigmented dorsal capsule of *Hectocotylus Argonautæ*. The position of the aperture of this capsule alone differs, since in *Hectocotylus Argonautæ* it remains at the posterior end, while Cuvier has depicted it at the anterior (*f*). According to this figure and Cuvier's statement that this opening (which he calls a mouth) in the fresh state is slit-like and leads into the pigmented capsule, as well as from the analogy of *Hectocotylus Argonautæ*, I cannot agree with Kölliker (pp. 79 & 80) that this aperture belongs to the seminal capsule. Whether a second aperture for this exists at the anterior end is not certainly determined by Cuvier himself, and he does not state that Laurillard had seen the semen poured out anteriorly. The connexion which, according to Cuvier, exists between the thread (*i*) everted from the terminal vesicle, on the one hand with the axis of the body, and on the other with the canal (*h*), which, coming from the seminal capsule, is evidently analogous to the ductus deferens in the Argonaut, is singular.

If with Kölliker we may be permitted here to suppose an error on the part of Cuvier, who only examined spirit specimens, I should imagine, keeping in view the fact that Verany found a filament with a free and pointed end in the terminal vesicle of the *Octopus*, that the latter was overlooked by Cuvier. If this be the case, the analogy between the filament exserted from its vesicle and the filamentous appendage (penis) of *Hectocotylus Argonautæ* becomes striking.

It would then require to be made out whether and how this appendage makes its exit from its vesicle, and we might conceive similar relations to those which I shall subsequently show obtain in *Hectocotylus Tremoctopodis*. In the latter case the presumed error of Cuvier would be easily explicable. The abovementioned differences in the position of the pigmented sac might also be connected with the difference in the position of the appendage, since in *Hectocotylus Octopodis* the supposed appendage is perhaps never meant to pass into that pigmented capsule as in *Hectocotylus Argonautæ*.

From the structure of the *Hectocotylus Octopodis*, especially the presence of the silky thread in the capsule, *e*, and the assertion of Dujardin (*Helminthes*, p. 131) that the white thread consists of spermatozoa, the male nature of this *Hectocotylus* also may be concluded.

Its development is probably quite similar to that of the *Hectocotylus* of the Argonaut.

Verany and Filippi (see above) have already proved that the *Hectocotylus* of the Octopod arises as one of its arms. Verany has observed in the same place a sac, which, according to the figure in which chromatophora are indicated, appears rather to be analogous to the sac of the male Argonaut than to the vesicle which otherwise terminates the *Hectocotylus Octopodis.* The pigmented capsule upon the back of the latter again is evidence of a process of eversion similar to that of the Argonaut; and in the specimen of *Octopus,* which M. Verany had the goodness to show me, the pigmented spot upon the back of the *Hectocotylus*-arm appeared very similar, if I do not err, to that upon the back of the *Hectocotylus*-arm of the Argonaut when just everted from its sac. Here also then the eversion of the *Hectocotylus* from its sac precedes its separation. Whether the pigmented capsule is already developed in one of Verany's specimens I know not. It is interesting that Cuvier describes one of his *Hectocotyli* as the arm of the *Octopus.* Four out of five individuals were found in the mantle of the Octopod; "the fifth had attached itself to one arm of the Poulpe, and had changed it into a kind of sac in which it had imbedded its head, whilst the rest of the body remained free externally (p. 150);" and "it has almost destroyed the arm, and appears to replace it so completely that at first it might be taken for the arm itself" (p. 149). It is hardly to be doubted that the animal "qu'un parasite dévore" was a male *Octopus,* which carried a *Hectocotylus* newly freed from its sac, but not yet separated. The last link of the series finally is formed by that *Octopus,* in which Verany found merely a short stump in the place of the *Hectocotylus*-arm, which in all probability had already fallen off.

Considering the general resemblance of the *Hectocotyli* of the Argonaut and of the *Octopus,* it is very remarkable, that, according to Verany, in all cases the third arm of the *right* side is the abnormally developed one in *Octopus,* whilst in the Argonauts it always is the third arm of the *left* side. Cuvier does not state in the place of what arm his *Hectocotylus* was fixed.

It is much to be regretted that Cuvier has given no information as to the sexual organs of the Octopods which carried the *Hectocotyli* in their mantle or as an arm, and it is the more desirable that such Octopods should be closely examined, since their more considerable size will without doubt allow a more easy and better determination of many points than the small Argonauts permit.

Hectocotylus Tremoctopodis.

The third kind, the *Hectocotylus Tremoctopodis*, is intermediate in size between the two others; in form, however, it differs far more from the *Hectocotylus* of the Argonaut than from that of the *Octopus*. Nothing is known of its development.

However, besides the structure of the muscular tube of the body already pointed out by Kölliker, that of the suckers, and the presence of genuine chromatophora, we have one very important point of resemblance with the *Hectocotylus Argonautæ* in the presence of a longitudinal series of ganglia.

This ganglionic chain, which has already been recognized by Von Siebold, passes from the anterior end of the *Hectocotylus* to the commencement of the capsule in the abdomen. The single ganglia are so disposed that one lies upon each of the alternating suckers; they are thence closely appressed. If we make a longitudinal section, not perpendicularly between the suckers, but horizontally, we obtain precisely the view given by Kölliker, pl. 2. fig. 14. It is therefore obvious that the conical masses of granular substance described by him, at p. 74, were these ganglia.

The doubts as to the presence of any intestine expressed by Kölliker are quite just in this case. The opening which he also gives as doubtful, at the anterior extremity of the body somewhat towards the back, was perhaps only the end of the axis whose already attenuated tube here terminates—the inner layers contributing to form a blind end round the last ganglion, while the outer layers united with the skin form a more or less distinct knob*.

If in many cases an opening is actually present, this would indicate even more than the mode of termination which has been described, and which agrees with that of the thick end of the *Hectocotylus Argonautæ*, that supposing the *Hectocotylus* of the *Tremoctopus* to be developed as an arm like the others, this is its attached end.

The structure of the opposite end renders this conclusion

* Von Siebold also has concluded from the want of such an aperture that there is no digestive organ in *Hectocotylus Tremoctopodis*, and Cuvier affirms that in *Hectocotylus Octopodis* the axis has no opening anteriorly.

probable; the ovate or pyriform capsule in the abdomen being similar to that which in *Octopus* is certainly placed at the free end of the *Hectocotylus*-arm.

Besides, both in form and position that abdominal capsule is analogous to the membranous lobe on the appendage of *Hectocotylus Argonautæ*.

Among eighteen *Hectocotyli* of *Tremoctopus*, twelve had the abdomen constructed as Kölliker has described it. In six, however, the capsule of the abdomen had a cleft upon its dorsal side; this commenced close behind the last sucker of the left side (the suckers being supposed to be below and the capsule behind), and extended somewhat obliquely as far as the commencement of the delicate process into which the capsule is prolonged; the latter lay consequently wide open, and it could readily be seen that it was empty; that is, that it contained neither the convolutions of the seminal capsule nor the ductus deferens, which in other cases are found in the closed capsule*. Upon careful examination, however, the cleft is, even in all ordinary *Hectocotyli*, to be seen as a streak occupying the direction indicated. There is a ridge upon the right side; pale, more or less closely adherent, and capable of being raised. It can be observed then that the subjacent layer, upon the left side, passes for a certain distance under the other, and appears to be as it were rolled up at its anterior end.

In *Hectocotylus Tremoctopodis* this cleft then always exists, and it would be interesting to know whether it also occurs in the capsule of *Hectocotylus Octopodis*.

When the cleft is open and the capsule is empty and relaxed, it has a considerable resemblance in external character to the membranous lobe of *Hectocotylus Argonautæ*, which also at times forms a deep pit. Both organs exhibit a lively undulatory movement.

In order to comprehend more exactly the relative position of the capsule, it is previously necessary to show that the penis of

* I presume, that at least in most cases the capsule has been burst after the *Hectocotyli* were taken, by contact with fresh water or the like. In three *Hectocotyli* of the ordinary form which I had thrown into a dilute solution of chromic acid, I also found after a few days the capsule open and the contents fallen out.

the *Hectocotylus Tremoctopodis* is analogous to the filiform appendage of *Hectocotylus Argonautæ.*

Of the six specimens in which the cleft in the capsule was open, three were particularly distinguished by having no penis visible externally. It was not torn off, as might have been concluded from the absence of the opening out of which it generally passes *; but it lay spirally coiled up under the skin inferiorly behind the last suckers, and, indeed, more towards the right side. It was very short, but relatively thick. Here then it was clearly evident that the penis is the immediate continuation of the muscular axis, which could not be so well demonstrated in specimens with a long free penis. Close behind the last suckers, the end of the thick part of the axis, which contains the last ganglion, lies in such a manner in the lower wall of the capsule, that it can be seen through the dorsal cleft above mentioned as a knob somewhat projecting from the inner surface of the capsule. From this the muscular tube bends down to the lower side of the *Hectocotylus* and forms the penis, which here lies coiled up under the skin, instead of as usual passing forward and becoming free in the neighbourhood of the third to the fifth sucker.

Where the axis bends down, the longitudinal vascular trunks pass into the penis †. Immediately beyond this flexure the ductus deferens, generally convoluted, comes from the left side to the anterior side of the penis into which it penetrates. The larger convolutions which this duct frequently makes at the base of the penis produce the transverse ridge, which may be frequently observed in many *Hectocotyli* between the body and the capsule upon the lower side.

If now we consider the place of the cleft capsule, keeping in mind this relation of the penis to the axis, its position upon the back of the axis (where the thicker part passes into the thinner) is quite analogous to that of the membranous lobe in *Hectocotylus Argonautæ.*

* In one specimen the semicircular edge which usually surrounds the aperture behind was faintly indicated, perhaps in preparation for the subsequent exit.

† Whether at an earlier period the contents of the axis also are continued into the penis, I cannot decidedly say.

If then the abdominal capsule of *Hectocotylus Tremoctopodis* is analogous with this lobe, and perhaps also with the terminal vesicle of *Hectocotylus Octopodis,* we must give up its supposed analogy with the pigmented capsule of the two other *Hectocotyli*; and the *Hectocotylus Tremoctopodis* seems to possess nothing comparable therewith.

On the other hand, the presence of a free penis by no means constitutes an absolute difference from the other *Hectocotyli.* It is its position chiefly which distinguishes it from the appendage of *Hectocotylus Argonautæ,* and the circumstance that the ductus deferens lies in its interior, whilst in the latter it is only attached externally to the prolongation of the axis. If it were certain that the filament which we find in the terminal vesicle of *Hectocotylus Octopodis* had the same signification, and is not a mere seminal tube, the analogy of the three *Hectocotyli* in this point would be complete.

In the other portions of the sexual apparatus, the testis and the ductus deferens, such an agreement cannot at present be demonstrated.

Kölliker has named 'testis' a vesicle which generally completely fills the abdominal capsule. The cleft outer capsule readily separates again into two layers, the outer of which is similar to the general cutaneous investment: under the epithelium there is a fibrous network with numerous vessels, whose capillary loops may be seen in the delicate terminal prolongation. The second layer consists, like the subcutaneous tissue of the back, of muscular bundles, which especially affect a longitudinal arrangement. Upon the inner surface it supports a layer of delicate polygonal cells. Below this again comes the so-called sac of the testis, which may be easily separated. Its wall has a peculiar checkered (*carrirtes*) appearance; two layers of fibres are visible, which cover one another very regularly like the fibres of a tissue, at right angles, or often at somewhat oblique angles. The fibres are when isolated somewhat rigid, but oftentimes not dissimilar to muscular fibres. Elsewhere, however, they can be hardly separated at all, and in many places almost structureless layers occur.

In the interior of this vesicle there was always contained the thread described by Kölliker, which consists almost entirely of perfect spermatozoa. In this case a special investment is frequently not to be discovered, as Kölliker and Von Siebold (*Vergl. Anat.* p. 411) state; in a few instances, however, the greater part of the thread was surrounded by a distinct structureless membrane.

Its existence was clear in places where it stretched over gaps in the contents, or where it was quite empty, and also in places where it was torn, and the masses of spermatozoa had swelled up and made their way out. Whether this investment is a true membrane which subsequently disappears, or whether more probably it is rather an accidentally deposited homogeneous mass, I will not attempt to decide; only it is to be noted that this investment was not to be found in a few other portions of the same seminal cylinder.

The one end of this filiform seminal mass is connected with the bulb which forms the commencement of the ductus deferens (ductus ejaculatorius, V. Siebold) described by Kölliker. One part of it lies coiled up with the seminal cylinder in the checkered vesicle, the other part stretches on into the penis.

This peculiar ductus deferens* appears to consist of a substance essentially identical throughout, but varying very greatly in consistence and form in different localities. It is a yellowish or colourless, sometimes tough, sometimes more brittle, but elastic mass, which frequently, *e. g.* in the interior of the bulb, is tolerably soft, but at other places is of almost horny hardness and friability. Histologically, it appears sometimes structureless, sometimes marked very beautifully with parallel striations. The striæ are either immeasurably close or 0·004 (frequently 0·001–·002) of a line apart, and exhibit transitions from the most extreme delicacy to very marked lines.

They have the greatest similarity with those which we see in the wall of the *Echinococcus* vesicles. The structureless mass appears to pass into more slightly or more strongly marked layers which determine the partly longitudinal, partly transverse striation. This often takes on very strange forms when the parts are torn, doubtless in consequence of the folding and tear-

* I retain this term, although the part does not seem to be quite analogous to the organ so named in *H. Argonautæ*.

ing. The substance is little altered by a diluted solution of caustic soda.

The innermost coat of the ductus deferens is generally formed by a layer which strongly refracts light, and when it is stretched looks like a tubular brittle glassy membrane.

Elsewhere when collapsed it has the appearance of a longitudinally fibrous cord, which is easily torn transversely into fragments, and only the local dilatations (for example from 0·02 of a line in diameter to quite smooth clear vesicles of 0·2 of a line in diameter) show its tubular character. One portion is frequently invaginated for a certain distance in a funnel-shaped expanded portion behind it, whereby a swelling is produced. In other places the innermost layer forms the spiral band mentioned by Kölliker. This exhibits considerable elasticity, and its coils are often very close, often far separated, which depends upon the form of the penis. The band has sometimes the appearance of a spirally cut delicate tube, sometimes that of a cylinder, like the snake-toys which are cut out of horn.

Next to this innermost layer the mass of the ductus deferens appears to be longitudinally striated to an irregular extent. Externally again it becomes circularly striated, and not unfrequently some layers appear to be more sharply distinguished from the rest. In the midst some portion will frequently be found wholly structureless, and quite external to the ductus deferens; a strongly marked layer has again all the characters of a so-called vitreous membrane.

In the penis the whole ductus deferens, without reference to its contained spiral band, sometimes forms spiral coils of much greater extent, in which the outer layers of the penis take but little part.

Many modifications of the ductus deferens occur which appear to indicate different stages of development. Instead of the usually tolerably solid enlargement at its commencement (Kölliker, pl. 2. fig. 11 *d*), there exists at times a somewhat large pyriform body which attains a few lines in length, and the larger it is so much the softer are its contents. In its axis, however, one can already distinguish the commencement of the inner denser tube, which further on in the ductus deferens incloses or forms the spiral band.

In one of the specimens without any externally visible penis there projected from the cleft in the back a transparent, pointed, ovate vesicle of a few lines in length, which contained merely a fluid, and at its fixed end was drawn out into a more delicate fine tube of about the same length. The latter appeared when the vesicle, in consequence of being frequently touched, detached itself, and was evidently formed analogous to the ductus deferens; it consisted of a longitudinally striated cord (*i.e.* perhaps a folded tube) and an external, distant, structureless, partially laminated sheath. The larger vesicle therefore may perhaps be considered as an earlier form of development of the bulb, with which the vas deferens generally begins. Other changes in the latter and in the penis appear to belong to a later period. In two *Hectocotyli* which were met with in copulation upon female *Tremoctopoda* (*vide infra*), the abdominal capsule was also open and empty, probably in consequence of long lying in water. The penis, however, with the external part of the ductus deferens plainly visible in it, was distinguished on both occasions by a length of an inch and a half. It passed out of the skin, not in the middle line, but nearer to the right-hand series of suckers, and close to the penultimate pair, which plainly arose from its being torn. Its outermost third appeared to be similar to the whole free part of the penis in other cases; the two upper thirds were thinner, as if pulled out longitudinally. After the skin was taken away from the place of exit of the penis as far as the abdominal capsule, the portion of the penis lying below it was seen to pass below the axis obliquely towards the last sucker of the left side, and there cease. This inner part of the penis formed a fusiform enlargement, which appeared to be hollow. The outermost layers of the penis passed into the surrounding fibrous tissue, but the connexion with the axis was no longer recognizable. In all probability these changes of form of the penis and ductus deferens are connected with the function of copulation, and a third *Hectocotylus*, in which the outermost portion of the penis was plainly torn off, but the inner end had the same relation as in the other two, had probably already performed this act. Its abdominal capsule also was open and empty. The eversion of the ductus deferens for the purpose of ejaculation, indicated by Von Siebold (*l. c.* p. 411), appears to take place, and indeed in a peculiar manner, which reminds one of the process of eversion of the spermatophora of other Cephalopoda described by Milne-Edwards (*Annales d. Sc. Naturelles*, 1842).

From the preceding facts I will merely draw the conclusion, that the sexual organs in *Hectocotylus Tremoctopodis* are not only more complicated than in *Hectocotylus Argonautæ*, but that different stages in their development occur, although the *Hectocotylus* possesses in general the same form as that with which we are already acquainted. Our knowledge of this *Hectocotylus* is too imperfect to enable us to give a general interpretation of the generative organs. But its structure and the analogy with the *Hectocotylus* of the Argonaut lead to the supposition that the vesicle which contains the seminal coil is not the testis, but a seminal receptacle, although the mode in which the semen makes its way, and the place of its origin are less demonstrable than in the *Hectocotylus* of the Argonaut.

Next to the generative apparatus, the most striking features in *Hectocotylus Tremoctopodis* are the numerous villi on each side of the back, which Kölliker has with great probability called gills *.

In the living *Hectocotylus* the single villi are contractile, apparently in consequence of the fibres which form a meshwork in their interior. Independently of this movement of their substance, a considerable rhythmical contraction may be observed in the efferent (venous) part of the very rich and frequently anastomosing vascular network which lies in each villus, and which passes from the finer to the coarser vessels, as was stated above to be the case in the *Hectocotylus Argonautæ* and in the Cephalopoda in general. In one instance there were twenty-two contractions in ten minutes.

Since these branchial villi might occur in different individuals in different degrees of contraction, the determination of their size in different individuals appeared to be a matter of some interest. For this purpose the largest group of villi in each of several specimens preserved in spirit was selected. When they were very much developed, their length was about 0·6–1·2 of a

* Do these in any way subserve nutrition within the mantle of the female? (see Von Siebold, *l. c.* p. 389).

line. The smallest were not much shorter, and some were longer. The breadth in the middle of the villi was generally 0·15, hardly under 0·12, but as much as 0·22 of a line. These were *Hectocotyli* with a freely projecting penis.

In two others, on the other hand, whose penis was hidden, the length of the villi was but rarely over 0·6–0·7 of a line, and the most were shorter. The breadth was at the base rarely more than 0·12 of a line, and diminished rapidly to 0·06 or 0·04 of a line. The villi namely, had here the form of a rapidly diminishing and pointed cone, whilst in specimens with well-developed gills the diameter of the gills in the outer half surpassed at times that of the base, and the end was more rounded than pointed.

Since it may be assumed that *Hectocotyli* with larger gills have in general progressed further in their development than those with smaller ones, we have here a further evidence that the penis rolled up under the skin of the latter is a younger stage of development than the common form of the free penis.

The *Hectocotylus* of the *Tremoctopus*, then, is very strongly distinguished from the two others by the want of a pigmented dorsal capsule; by the position of the seminal coil in the capsule at the end of the body, and the peculiar structure of the ductus deferens; lastly, by the presence of gills: and, indeed, from the great discrepancies which exist among the *Hectocotylus*-bearing males of Cephalopods among nearly allied species, we should be prepared for thorough differences among themselves.

Upon the other hand, the analogy of the *Hectocotylus* of the *Tremoctopus* with the others in all essential points is so great, that although there is a complete want of all direct observations, we must assume it to have a similar origin, and that one day an entire male *Tremoctopus* belonging to this *Hectocotylus* will be discovered, the exact investigation of which will doubtless be still more interesting than in the Argonaut. However that may be, all three *Hectocotyli* must be kept in mind in attempting to determine the nature of the *Hectocotyli* in general.

Nature of the Hectocotyli.

With regard to this problem, we must consider, first, their relation to the animal which lodges them in their free condition, and, secondly, to that as whose arm they are developed.

The main point as respects the former relation, which Kölliker first demonstrated for the *Hectocotyli*, may be safely assumed to be—that each of the three forms of *Hectocotylus*, considered as one with the animal upon which it is developed *, forms the male factor with respect to a particular kind of female Cephalopod; *Argonauta*, *Tremoctopus* and *Octopus granulosus*, Lamarck, *O. Carena* †, Verany. The evidence of this consists in the following facts :—

1. No other males of the Cephalopoda mentioned are known. All Argonauts ‡ of the ordinary form with velate arms, and all individuals of *Tremoctopus* which have been dissected, were females with ova. To the Argonauts enumerated by Kölliker I can add fifty others of every size, and to the thirteen individuals of *Tremoctopus*, thirty which I have examined with reference to this matter. As has been said, nothing is known respecting the *Octopus*.

2. Most of the free *Hectocotyli* carried semen demonstrably; and it is very probable that the others had done so. To the fifteen *Hectocotyli Tremoctopodis* fourteen others may be added in which this was certain, whilst in four the demonstration failed on account of the emptiness of the capsule. In Cuvier's *Hectocotylus Octopodis* Dujardin found spermatozoa. To the six *Hectocotyli Argonautæ* enumerated by Kölliker, I can add thirteen which all carried the white sac under the pigmented dorsal capsule, and as often as this was opened it was found to contain spermatozoa. To these free *Hectocotyli* are to be added the Argonauts which carried a *Hectocotylus*-arm inclosed in its sac. All the specimens, which were carefully examined, contained semen either in the sac of the *Hectocotylus*-arm or in the testis.

Respecting these animals, indeed, doubts might be raised as to the identity of the species with the common Argonaut, on

* *Hectocotylus Tremoctopodis* questionably.

† If these be different, there will be four species.

‡ Verany (p. 54) cites a solitary statement of Leach that he had found a male Argonaut.

account of the want of both the expanded arms and the shell. But, in the first place, the similarity of the *Hectocotylus*-arm with the free *Hectocotylus* speaks for that identity. Next, the mode in which they occur: during a few days only did I obtain the animals with the *Hectocotylus*-arm and Argonauts of the ordinary kind in any quantity together. The latter were partly larger ones with shells, partly also not more than 2–4 lines long, and these, like the males, had no shell, at least as I obtained them, while the expanded arms were already easily recognizable. The colour and remaining form of the body were, however, in such close agreement with those of the male animals *, that the presence of the expanded arms and afterwards of the shell must be considered not to be specific, but to be sexual differences. It is perhaps not without importance, that these vela with a kind of mesentery on the twisted axis of the arms occur in females of that species whose males carry an arm so excessively developed, which however belongs to a different pair from the vela of the female. The same probably holds good of *Tremoctopus*; for in this, as I shall elsewhere show, the two upper arms have not the shape which is commonly figured, but form, when, as rarely happens, they are well preserved, elongated lobes, which excite as much surprise by their enormous size as by the extraordinary magnificence of their coloration.

It may be expected that the male *Tremoctopus* may have such a structure, as to have been described as some other kind of *Octopus*. Since Cuvier says nothing of any difference in those Octopods which lodged the *Hectocotyli* from the other which carried the *Hectocotylus* as an arm, it seems that the male, as which the latter no less than Verany's specimen of *Octopus Carena* must be regarded, in this case is not strikingly different from the female.

3. The anatomical agreement of the suckers, &c. of each *Hectocotylus* with those of the Cephalopod female upon which it occurs, has been especially made out by Kölliker.

4. In like manner the exclusive association of each *Hectocotylus* with its kind of female only. Up to the present time free *Hectocotyli* have only been found in the society of female Cepha-

* Even the bundles of hairs described by Kölliker (*Entwickelungsgeschichte d. Cephalopoden*) were present as in the females of the size of a hazel-nut. In larger specimens I no longer found them.

lopoda, and indeed, as Kölliker observes, only upon females with ripe ova. I have myself found the free *Hectocotylus Argonautæ* only upon the inner surface of the shell, or upon the ova, or fixed or creeping upon the animal itself, and I can affirm that among the many Argonauts, less than a nut in size, which I have examined, I never found a *Hectocotylus*. The *Hectocotyli* of the *Tremoctopus* were almost all fixed in the mantle-cavity; a few crept about in its vicinity externally, or lay at the bottom of the vessel in which the *Tremoctopus* was contained; since, as Kölliker has stated, they usually leave the dead animal.

5. Direct testimony that the *Hectocotyli* play the part of males to their female Cephalopoda is afforded by two observations of a perfect copulation in *Tremoctopus*.

Upon the 2nd of August two large specimens of *Tremoctopus* were brought to me at the same time, each of which carried in its mantle-cavity a *Hectocotylus*, fixed as usual in the neighbourhood of the gills. Upon pouring water on them, it was seen that the penis of each was inserted far into the opening of the right oviduct. Both of the *Hectocotyli* moved vivaciously, and appeared to be very angry that their endeavours were disturbed. Since it was late in the evening I was obliged to defer further examination until the following morning, when I found both *in situ*, but dead. Both *Hectocotyli* were distinguished by the length of the penis; on endeavouring to draw it out of the oviduct it was held pretty fast, and if let go was retracted again for a certain distance; one might so allow half an inch of the penis to glide in and out. This resulted from a very elastic filament, which, from the point of the penis, projected in deeper; it could be drawn out for an inch from the opening of the oviduct with the penis, and then when it finally gave way it slipped back again. In both cases this thread did not exactly enter at the point of the penis, but somewhat behind; and then in its further course it could be clearly identified as the inner part of the formerly-described ductus deferens.

The right oviduct of the *Tremoctopus* possessed, besides the chambered gland, two dilatations whose walls were greatly softened. The external enlargement was little larger than upon the left side, and contained, together with mucus, merely a portion of the thread torn off from the penis, which has been mentioned. The second larger expansion contained the very singularly constructed continuation of this; I will only remark that there hung therein a solid white reniform body of some lines in diameter which consisted wholly of spermatozoa. These were quite similar to those which are usually found in *Hectocotylus Tremoctopodis*, and it is therefore unquestionable that these *Hectocotyli* also serve to fecundate the female *Tremoctopoda*.

The observation of peculiarly-formed masses of spermatozoa far back in the compartments of the oviducal gland itself, was repeated in many specimens of *Tremoctopus*, and it seems almost as though this gland had at least in part the function of a spermatheca; though indeed its relations in other Octopods do not well agree with this view. On the other side of the gland I found no semen, neither in the two copulating *Tremoctopoda* nor in others; but I will so much the less question the possibility of its penetration as far as the ovarian capsule, as the portion of the oviduct between the gland and the ovary is remarkable for its conspicuous ciliary epithelium. A similar epithelium invests also the folds of the ovarian capsule itself which converge towards the internal aperture of the oviduct; it is found there over a considerable space, and finally extends through the so-called water-canal described by Delle Chiaje and Krohn in *Tremoctopus* and *Eledone*, which reaches from the posterior side of the ovarian capsule towards the lateral compartment.

For *Argonauta* I can bring forward no such complete observation, yet the copulation and fecundation by the penetration of the appendage of *Hectocotylus Argonautæ* into the female sexual aperture become very probable from the following facts.

The ovarian capsule of an adult Argonaut contained a filiform body, which, from its form, from the lobe at the thicker end, and from its minuter structure, was certainly the torn-off appendage of a *Hectocotylus Argonautæ*. Attached to it were very diffuse masses of spermatozoa in lively motion. In another very large Argonaut I had sought in vain for *Hectocotyli*. After cutting up the intestines, and especially the generative organs in many directions, I found in the water used for washing the parts, three filaments, which were the appendages of so many *Hectocotyli*.

Functionally, then, the appendage of *Hectocotylus Argonautæ* is to be compared to the penis of *H. Tremoctopodis*, although perhaps the appendage is not always intended to reach the ovarian capsule, and may have been a result of some accident to the *Hectocotylus*.

The state of polygamy in which many females of these Cephalopods live is worthy of remark. Cuvier (Laurillard) found three *Hectocotyli* in the mantle of an *Octopus*; Kölliker, among twelve *Hectocotyli* of the *Tremoctopus*, once found three together, and twice, two; Von Siebold found among three, two together; I among eighteen found four together once, and three times, two upon one specimen. I also met with two *Hectocotyli* upon one Argonaut, twice.

Since it is improbable that the *Hectocotyli* can pass from one female to another, either the number of the males must be greater than that of the females, or many of the latter must altogether despair of the society of the former. On the other hand, it seems that the many *Hectocotyli* for one female are *οὐκ ἀποφώλιοι*, as Homer says of the *εὐναὶ ἀθανάτων*. In the oviduct of one *Tremoctopus* were found two distinct, but for the rest almost identical seminal masses, each with its appended tubular filament, and many such fragments appeared to indicate something more than bigamy.

This is perhaps connected with the manner in which at least a portion of the Cephalopoda here referred to lay their eggs. The ova of *Tremoctopus* and *Argonauta* are, it is well known, found in groups, each of which is attached to a delicate stalk. These stalks are in the Argonaut fastened to the convoluted portion of the shell; in *Tremoctopus* to a principal stem some lines thick. The ova of each such single group are as a rule at about the same stage of development; whilst the different groups vary so greatly, that in the larger bunches we frequently meet fresh-laid ova in company with perfect embryos. In this case a regular progression may frequently be detected, so that development gradually advances from one end to the other of the whole bunch. In one bunch of ova of *Tremoctopus* there was furthermore this distinction between the two ends of the principal stem: that the end which carried the most fully-developed embryos had a brownish, wrinkled, old appearance; while that in which the ova were undeveloped was clearer, smoother, softer, and fresh-looking. Between the two were transition-states. The size of each group which has a distinct thinner stalk answers pretty closely to the quantity of ova which we often find in *Tremoctopus* in a dilatation of the oviduct, which, on the outer side, immediately follows the gland. The ova which we find in the part of the oviduct before the gland, as well as in *Argonauta* in the beginning of the oviduct, are as yet only provided with their separate proper stalks, which are delicate, but already somewhat long; these become united in the outer part of the oviduct into a group with a common stalk, and thence they probably remain here for a considerable period. It may therefore well be, that the different groups of a large bunch of eggs are attached at different times, and although the duration of the intervals is wholly unknown, it may be imagined to be not very small, and perhaps too considerable to allow of the fecundation of all the ova by a single previous copulation. Such ova belonging to different periods might be fecundated by many *Hectocotyli* at different times.

Inasmuch as it has been said that the Argonaut is hermaphrodite, I beg expressly to observe that nothing which I have ever noticed favours this conclusion. In the male specimens the testis lay where otherwise the ovary would be found, and of the latter there was no trace; whilst in a female of 3 lines long it was already very perceptible, and characterized microscopically by ova of 0·02 of a line in diameter. Besides, the want of the velum upon the arms of the *Hectocotylus*-bearers shows that these are quite separate individuals from the females.

If now with regard to two kinds of *Hectocotylus* the anatomical fact is established, that they are developed as arms of perfect Cephalopods, and also that all three *Hectocotyli* very frequently occur isolated, there is a question which promises to be one of a more general interest, viz. What is the relation of the free *Hectocotylus* to the animal from which it has detached itself?

1. That the *Hectocotylus* stands still less in the relation of a parasite (Cuvier) to the animal as whose arm it is developed, than to that in whose mantle it resides, is clear. I will only call to mind, how from the very first all observers have brought forward the striking similarity to a Cephalopod-arm; they have not, however, come to the readiest conclusion, that it *is* such an arm, without many deviations.

2. That Madame Power also wrongly imagined the *Hectoco-*

tylus Argonautæ to be a vermiform embryo of the common *Argonauta* (*vide supra*) has been already shown by Kölliker.

3. Kölliker brought forward formerly the view that the *Hectocotyli* as male individuals are the independent equivalents of the female Cephalopods. According to the present state of knowledge, this view can be tenable only under two suppositions. Either, one must assume an alternation of generations in its wider sense between the *Hectocotylus* and its previous supporter; or, after the separation of the *Hectocotylus* from the rest of the body, it must be regarded as the representative of the individuality, having thrown off the remainder as so much no longer useful ballast.

Against the former view of a kind of alternation of generations however, too many objections at once arise; among others, the development in the place of one of the eight typical arms; the imperfect organization as regards the other generations; further, that the alternation would take place merely in the males; whilst the females of *Argonauta* and *Tremoctopus* are known to lay eggs from which individuals similar to them proceed. Lastly, the presence in *Argonauta* of a testis with perfect semen, which probably passes thence into the *Hectocotylus*, opposes altogether the hypothesis that the latter is a male generation proceeding from an asexual gemmiparous one.

For the other supposition, that the *Hectocotylus*, together with its producer, forms only one animal, but after its separation must be regarded as a continuation of the whole, because it is the means of propagation of the species, analogous cases might be adduced of certain animals in which the organs of individual life retrograde in relation to those of the propagation of the species.

It might be instanced that many Echinoderms, for example, are produced by budding from larvæ, which then waste away; and herewith might be compared the surprisingly great and rapid development of the *Hectocotylus*-arm, as contrasted with the small size of the other arms*. But before drawing such comparisons, further observations must be obtained upon the duration and mode of life of the two separated moieties of the

* In my specimens not more than six pairs of suckers are distinctly developed upon three arms.

original animal. For we know as little how long the isolated *Hectocotylus*, as how long the seven-armed Cephalopod, lives; whether the latter produces new *Hectocotyli**, or passes through yet other metamorphoses. In this respect it is remarkable that male individuals of only a very small size relatively to the females have been observed, and that, independently of sex, they exactly resemble the very young females. The circumstance also that many of the small animals had a tolerably advanced mass of semen in the testis, and that others already carried perfect semen in the seminal sac of the *Hectocotylus*-arm, rather indicates that these males do not grow large, for the ova of females of the same size are nowise developed to the same extent. If large male Argonauts occur, they have been without doubt overlooked in consequence of their wanting the expanded arms and the shell. The specimens of the *Octopus* described by Verany are indeed considerably larger; and Cuvier says nothing about the size of the animals which bore the *Hectocotyli* either in the mantle or as an arm. Yet the case of an *Octopus*, brought forward by Verany, which, in the usual place, had merely the pedicle without an arm or vesicle, is the only direct evidence for the continued existence of the Cephalopod which has cast off the *Hectocotylus*.

Until more light is thrown upon these relations, it seems unnatural to assume that all the most important organs of an animal, the central organs of the circulating and nervous systems, the apparatus of sense and digestion, and so forth, are thrown off *en bloc*, and that the remainder with the semen, which is not even produced in it, should continue to represent the individual.

4. If for the present then the *Hectocotylus* can hardly be considered to be an entire individual, it only remains to regard it as a separated portion of the whole.

Costa has expressed the view that the *Hectocotylus Argonautæ* is the spermatophore of the Argonaut (*Annales des Sciences Naturelles*, 1841, p. 184). The *Hectocotylus* might be rightly so

* In favour of a regeneration of the cast-off *Hectocotylus*-arm we have the fact, that not uncommonly this occurs with other arms. A small conical process covered with a number of small suckers sprouts forth from the torn place of the arm.

called, if the word is to be taken in its general sense; but it can certainly not be classed together with the well-known seminal cases of other Cephalopods which at present bear that name. These spermatophora are mere capsules composed of a no further organized mass, whose movements take place from purely mechanical causes. They are seminal machines, which might as well be called a secretion, if the semen is to be so denominated. The *Hectocotyli*, on the other hand, are composed of different organs and of almost all the elementary tissues which exist, in the same condition as they are found elsewhere in the living body. I will not neglect, however, to draw attention to the analogy which exists in many respects between the spermatophora and the structure above referred to in *Hectocotylus Tremoctopodis*, as the ductus deferens. In both the seminal mass is fixed to a spiral band contained in a sheath, and its uncoiling appears to be connected in the one case as in the other with the extrusion of the semen. The substance of the spermatophora, as of the ductus deferens, is a mass which exhibits transitions from a less to a more considerable consistence, and also from a complete absence of structure to a striation, which, however, is not produced by any peculiar elementary parts. The substance of which the capsules and pedicles of the ova are formed is similar, and in the oviduct of *Tremoctopus* we find masses, of which it is not easy to say how much proceeds from the *Hectocotylus* and how much from the female herself. Should this analogy, upon which I will not enter further here, be confirmed, the *Hectocotylus Tremoctopodis* might at most be called a spermatophore-bearer.

In any case, the *Hectocotylus* of the Argonaut (and probably also the two others) stands in the relation to the rest of the animal, of an arm, which is at the same time penis and ductus deferens. When separated it may be compared with any other part, which separated from a living individual, yet preserves for a certain time a given amount of vital properties. How far, as regards amount and duration, this may extend, cannot be determined *à priori*, and the *Hectocotyli* may perhaps surpass all hitherto known instances.

Nothing can better illustrate the character of their movements, than that Laurillard, Delle Chiaje and Kölliker were led thereby to hold them for decidedly independent animals, and every future observer will be unable to avoid the same impression*.

The circulation of the blood of the *Hectocotylus*, although its course is only imperfectly known, is very lively and rhythmical. It should be observed, that in detached arms of *Tremoctopus* a rhythmical movement of the veins from the periphery to the centre continued for half an hour after separation from the body, although the animal had been dead for an unknown time. The protracted contractility of separated portions of the Cephalopoda, for example of the skin with the chromatophora, is also already known. Yet in the whole male Argonaut the *Hectocotylus*-arm was the part in which the reflex movement ceased latest, since it continued to make apparently voluntary movements for many hours after these had ceased in the rest of the animal. How long the movement, and indeed the existence of the *Hectocotyli* endure after their natural separation is altogether unknown†, but probably for a considerable time, if copulation be not effected; if indeed they do not exist afterwards.

The presence of the appendages described as gills in *Hectocotylus Tremoctopodis* is very remarkable: since they do not occur in other Cephalopod-arms and *Hectocotyli*, and since, like the penis, they appear to become still larger in detached *Hectocotyli*, it is to be concluded that the *Hectocotylus* in question is originally intended to have a longer separate existence. But the other *Hectocotyli* also are evidently by no means torn off accidentally, but from the manner of their occurrence as well as

* Verany mentions in comparison the gill-processes of Eolidæ, which, when detached, continue to move for many hours.

† Since it is not easy to keep Cephalopoda with *Hectocotyli* in confinement long enough, it will be desirable to pay particular attention in future to their occurrence at particular seasons of the year. Verany obtained the *Octopus Carena* at different seasons; Kölliker obtained the *Hectocotylus Tremoctopodis* in August and September pretty frequently; that of the Argonaut again but rarely. I found most Argonauts without *Hectocotyli* before the end of September, but at that time and in the beginning of October the majority of the large specimens possessed them. In the end of July and the beginning of August I obtained *Tremoctopoda* pretty frequently, and usually with *Hectocotyli*; on one occasion there were eight of the latter in one day. Subsequently the *Tremoctopoda* occurred only singly, and no longer contained any *Hectocotyli*. Hence the deficiencies in my account of the *H. Tremoctopodis*, since I erroneously expected always to obtain the same supply as at first.

the structure of their place of attachment, they are intended to be detached*. In all probability, finally, the thin appendage of the *Hectocotylus* in *Argonauta* and *Tremoctopus* finds its way into the female sexual aperture only after the separation, for we find almost all *Hectocotyli* filled with semen, and the penis of *Hectocotylus Tremoctopodis* often is in an apparently virgin condition. This is easily possible, considering the lively twisting movements which the appendage in both *Hectocotyli* makes, even independently of the rest of the body, and in *Hectocotylus Tremoctopodis* it is rendered still more easy by the circumstance that in the other portions of the penis the epithelium forms a multitude of recurved hooks, the hinder edge of each cell riding on its neighbour. It is to be considered, however, whether preliminary acts of coition do not first determine the separation of the *Hectocotylus* from the rest of the animal.

It is remarkable enough, anatomically, that certain Cephalopod males should be distinguished from those of the immediately allied species by the presence of the *Hectocotylus*-arm; but the facts adverted to render the relations of the detached *Hectocotylus* so peculiar, that one is forced either to remain in doubt, or to come to the conclusion that the line of demarcation between independent animated beings, and such as are not so, is by no means so distinct as the schools draw it.

It is, however, hardly the time at present to draw any theoretical conclusions, when so many matters of fact remain to be inquired into with regard to the known species of *Hectocotylus* (and there may be others), by which perhaps all that has been done may be upset again; for what has been stated here can only indicate in what direction future investigations must be undertaken. I thus sum up the chief results :—

1. Perfect male Argonauts occur distinguished from the females, which only have hitherto been known, by the absence of the expanded "vela" upon the two upper arms.

2. These male Argonauts carry the *Hectocotylus Argonautæ*

* It is important to know whether changes in the size and form of all *Hectocotyli* occur after their separation; whether, for example, the coalescence of the everted edges of the skin in *Hectocotylus Argonautæ* happens before or after separation from the rest of the animal. In my free specimens the pigmented capsule was in all cases fully formed.

(D. Ch.) in a pedunculated sac in the place of the third arm of the left side.

3. The thick end of the *Hectocotylus* is fixed to the pedicle, while the thin coiled-up part is free.

4. By the bursting of the sac and the eversion of its edges, the pigmented capsule on the back of the *Hectocotylus* arises.

5. The testis lies in the abdomen of the whole animal, the external aperture of the ductus deferens being near the point of the *Hectocotylus*-arm, whose thin appendage has at the same time the function of a penis.

6. In the axis of the *Hectocotylus* there lies a chain of ganglia.

7. It is not to be supposed that the *Hectocotyli* are developed as vermiform embryos in especial bunches of ova.

8. The *Hectocotylus Octopodis* of Cuvier, which Verany has shown to be the arm of an *Octopus*, is mainly distinguished from the *Hectocotylus Argonautæ* by its size, by the presence of a capsule at the free end, and by its development as the third arm on the *right* side of the *Octopus*.

9. The *Hectocotylus Tremoctopodis* of Kölliker is distinguished by its gills, by a peculiar structure of the ductus deferens, and by the want of a pigmented dorsal capsule; but it possesses a ganglionic chain in its axis, its penis is a more delicate prolongation of this, like the appendage of the *Hectocotylus Argonautæ*, and its cleft abdominal capsule is to be compared to the lobe upon the appendage of the latter.

10. The *Hectocotylus Tremoctopodis* is thence to be considered analogous to the two other *Hectocotyli*, although the animal as whose arm it is developed is not at present known.

11. Each Cephalopod with a *Hectocotylus*-arm is to be regarded as the male of the corresponding female Cephalopod.

12. The *Hectocotyli* are intended to separate from the rest of the body, and are then received and lodged by the female.

13. In this condition they have apparently independent motion and circulation; they contain perfect semen; and in *Tremoctopus*, as also probably in *Argonauta*, a copulation with the female animals takes place.

14. The *Hectocotyli* are not comparable to the spermatophora

of other Cephalopoda; but perhaps the so-called ductus deferens in *Hectocotylus Tremoctopodis* is similar to these.

15. The free *Hectocotyli* can by no means be regarded as independent animals.

Note by Professor Kölliker.

I desire to take this opportunity of stating, that I have convinced myself of the truth of the most important of the discoveries made by M. Müller, by examining the Cephalopods which he has brought, and that I entirely agree with his view of the relation of the *Hectocotylus Argonautæ* to the male Argonaut. As it now appears, I was led formerly to put too great a value upon the statements of Maravigno and Madame Power, and I was thence induced to consider the *Hectocotyli* as male Cephalopoda which were developed as such in the ovum. It appears now that I was indeed right in the main, when I claimed the *Hectocotyli* as belonging to the Cephalopoda; but that they are not complete animals, but only parts of them, separated indeed in a very strange manner, and by the great independence of their organization and vital manifestations forcibly resembling independent animals.

Kölliker.

EXPLANATION OF FIGURES 1 AND 2 OF PLATE I.

(Both figures are magnified somewhat more than four times.)

* Represents the natural size.

Fig. 1. The perfect male Argonaut seen from the left side: the numbers indicate the pairs of arms; the second and fourth arms of the left side are thrown back, in order to show in what manner the sac containing the *Hectocotylus* is fixed by its pedicle in the place of the third arm. Over the exterior of the sac a ridge extends longitudinally.

Fig. 2. A male Argonaut in the same position, only the *Hectocotylus* has come out of its sac. The sucker-bearing portion is twisted once completely round upon its own axis, so that it is seen at first from one side, then from above, then from the other side, then in the ascending portion directly from below, and again upon the same side as at first. The fixed end of the *Hectocotylus* is still covered by the pigmented membrane of the sac; further on the latter is torn longitudinally upon the

sucker-side towards the mouth, and so inverted in consequence of the *Hectocotylus* being bent back, that one looks upon what was previously the inner surface of the sac: the chromatophora glimmer through only indistinctly. The margins of the cleft lie in the concavity of the first flexure; one margin passes before, the other behind the thick end of the *Hectocotylus*; both unite at * on the dorsal side. Between the edges and the white streak which indicate the seminal sac there is a pit, whose inner surface is formed by what was previously the outer surface of the sac. Where the sucker-bearing part of the *Hectocotylus* passes into the filiform appendage (penis), the lobe appears on the back, and from this on each side a fold passes on to the appendage.

[T H. H.]

Article III.

A few Remarks upon Hectocotylus. By C. Th. von Siebold, Professor at the University of Breslau.

[From Siebold and Kölliker's *Zeitschrift* for June 1852.]

I HAVE read with the greatest interest the recent discoveries of Verany and H. Müller as to the true nature of the *Hectocotyli.* I have now, with Kölliker, arrived at the persuasion that Madame Power, through the too great positiveness with which she described the development of the Argonauta in the egg, has partly been the cause of the hitherto erroneous views that have been entertained upon the subject. Since Maravigno, in fact, only reported upon the communications concerning Argonauta made by Madame Power to the Academy of Catania, it is difficult to say for how much share in the error he is responsible by additional careless observations of his own. From the first I was desirous to have a sight of the figures which Madame Power added to her treatise, and which neither Oken, Creplin, Erichson, nor Kölliker had as yet seen. I availed myself of my last visit to Vienna to examine Madame Power's treatise in the *Atti dell' Accademia Gioënia di Scienze Naturali di Catania* (tom. xii.), contained in the Imperial Library, and especially to convince myself of the resemblance of the figures of Argonauta embryos given by Power, with *Hectocotylus.* I found that the complaints made by Oken (*Isis,* 1845. p. 617) about the careless editing of these academical papers were fully justifiable, since even in this Viennese copy of the twelfth volume the illustrative plate of Madame Power's essay was wanting. In accidentally turning over the leaves of some of the succeeding volumes, however, I came in the fourteenth volume upon the missing plate. Figs. 1–4 represent, somewhat magnified, but very coarsely executed, a something which has a remote resemblance to a *Hectocotylus*; one distinguishes an elongated clavate body, one end of which runs out into an acute point, and whose thicker end is provided laterally with a double series of indistinct prominences. Figs. 1–3 exhibit five or six such elevations upon each side. Fig. 4, on the other hand, has ten upon each side. Fig. 4 then differs from the three preceding figures only by the increased number of the lateral elevations, and yet Madame Power says (see Wiegmann's *Archiv,* 1845, vol. i. p. 378, or Oken's *Isis,* 1845, p. 610) of this fourth form, which she supposes to be an embryo three days old, that from this stage elevations like buds gradually arise, provided with a double series of dark points, and that these are the commencement of the arms and their suckers; where, however, in fig. 4 these commencements of the arms are supposed to be, I can by no means comprehend; for this body, described and figured as an embryo three days old, reminds one only of the arm of a Cephalopod with its double row of suckers. Had Kölliker chanced to see these figures, he would certainly have still more strongly believed that the *Hectocotylus* actually leaves the egg in its proper form.

Now that Verany and H. Müller have drawn attention to the external sexual differences of the Cephalopoda, the different accounts given by Aristotle of the sexual distinctions and functions of the *Octopus* acquire an especial value, since Aristotle appears to have been acquainted with the natural history and internal structure of the Cephalopoda to an extent that we must even now consider astonishing. From the following passages, which I here extract *verbatim* from Schneider's translation (*Aristotelis de Animalibus Historiæ,* book x.), Verany and H. Müller, who have produced a new phase in the history of *Hectocotylus,* will learn with astonishment, that Aristotle may fairly contest with them the priority of their discovery of the relation of the male *Octopus* to the *Hectocotylus*-arm. In fact, in book iv. chap. 1, 6 (*loc. cit.*), it is thus written:—"Polypus (such is Aristotle's invariable designation for *Octopus*) brachia sua ad officium cum manuum tum pedum accordat: namque duobus, quæ supra os habet, admovet ori cibum. Postremo autem omnium, est hoc inter cetera acutissimum et solum aliqua parte candidum in dorso (vocatur autem dorsum pars brachii lævis a qua prorsum acetabula collocata sunt) et in extremo bifidum hoc igitur ad coïtum utitur."

In the fifth book, chap. v. 1, we find further:—"Aiunt nonnulli, marem habere non nihil simile genitali in uno ex brachiis, quod duo maxima acetabula continet; id protendi quasi nervosum usque in medium brachium atque totum in narem (*funnel*) fœminæ inseri."

In the same book, chap. x. 1, lastly, Aristotle returns once more to the sexual distinctions of the Cephalopoda in these words:—"Differt a fœmina mas capite (*abdomen*) oblongiore et id quod genitale vocant piscatores habet in brachio candidum."

The task now remains for those observers who have the opportunity of investigating that portion of the Mediterranean which lies between Greece and Asia, to decide what species of *Octopus* Aristotle understood by his "Polypus," and how far his acquaintance with the sexual relations of the male *Octopus* coincides with the history of the *Hectocotylus* as it has been recently made known.

[T. H. H.]

ARTICLE IV.

Investigation of the question: Does Cellulose form the basis of all Vegetable Membranes? By HUGO VON MOHL.

[From the *Botanische Zeitung*, vol. v. p. 497 *et seq.*]

IN a former paper* I laid down the anatomical and chemical reasons which led me to persist in maintaining the doctrine of the growth of the membrane of the elementary organs of plants propounded by myself and attacked by various writers, and induced me to reject the view, defended by the Utrecht professors, Mulder and Harting, that the outermost layers of those membranes are the youngest and the inmost the oldest. Since that paper was written I have carried through a long series of new observations for the further elucidation of the conditions here in question, the results of which, so far as relates to the chemical† characters of vegetable membranes, I believe may be published with advantage, because they may serve to throw light upon some points as yet unknown, and to refute the chemical evidence brought forward by Harting and Mulder in favour of their view.

In the Essay already referred to, I closely discussed the opposition presented by the deductions drawn by Mulder and Harting on one side, and by myself on the other, from the known reaction of cell-membranes when acted on by sulphuric acid and iodine. My opponents are of opinion that the circumstance of thin recently formed membrane being coloured blue by iodine and sulphuric acid, while in many full-grown cells only the inner layer manifests this reaction, while the outer are tinged yellow by these two substances, gives ground for the deduction that these outer layers have been formed subsequently to the others, and that the inmost layers of the full-grown cells are the same membranes which constituted alone the wall of the young cell. On the other hand, I asserted that this conclusion is too hasty,

* *Botanische Zeitung*, vol. iv. p. 337 *et seq.* Translated in the Annals of Natural History, vol. xviii. p. 145 *et seq.*

† I shall speak of the anatomical conditions on another occasion.

since a particular layer of an elementary organ may undergo a chemical metamorphosis in the course of time, without experiencing on that account any alteration in dimensions, or affording cause for it to be regarded as a new layer in an anatomical sense of the word: I stated that in respect to this metamorphosis we have to consider two possibilities, since it might arise either through the cellulose of which the layer was originally composed becoming dissolved and replaced by some other chemical compound, or through the persistent cellulose becoming saturated by another compound, and hence losing the capability of reacting with iodine and sulphuric acid. For various reasons I declared the latter view, which certainly offers the most glaring contradiction to the views of the chemists, to be the more probable, but I could not distinctly prove it, because I was unable at that time to extract the infiltrated matters from such membranes as offered an obstinate resistance to the action of sulphuric acid and iodine, and in which cellulose could not be demonstrated to exist by the application of those reagents; such a process of extraction being necessary to render the cellulose (which I assumed to form the basis of the membranes) accessible to the action of the iodine. Now, as the following pages will show, I have succeeded in this with all the elementary organs of vegetables, and I therefore assert most distinctly that the walls of all the elementary organs of plants are composed of cellulose; that it is quite inadmissible to draw conclusions as to the period of origin of any given layer of their walls from its chemical conditions, and that in regard to this question anatomical evidence alone is valid.

In order to establish this proposition, I am compelled to enter somewhat minutely into the details of my investigation: if I enter into more extended explanations of the methods I followed than seems to many altogether necessary, this is to be attributed to the circumstance that I only arrived at determinate conclusions after many unsuccessful experiments, and I wish others to be able to confirm the correctness of my views.

Cuticle stands first of all the structures, in which it is impossible to demonstrate a trace of cellulose by iodine and sulphuric acid. It either completely withstands the action of sulphuric acid, or, if it undergoes a certain degree of softening by this acid,