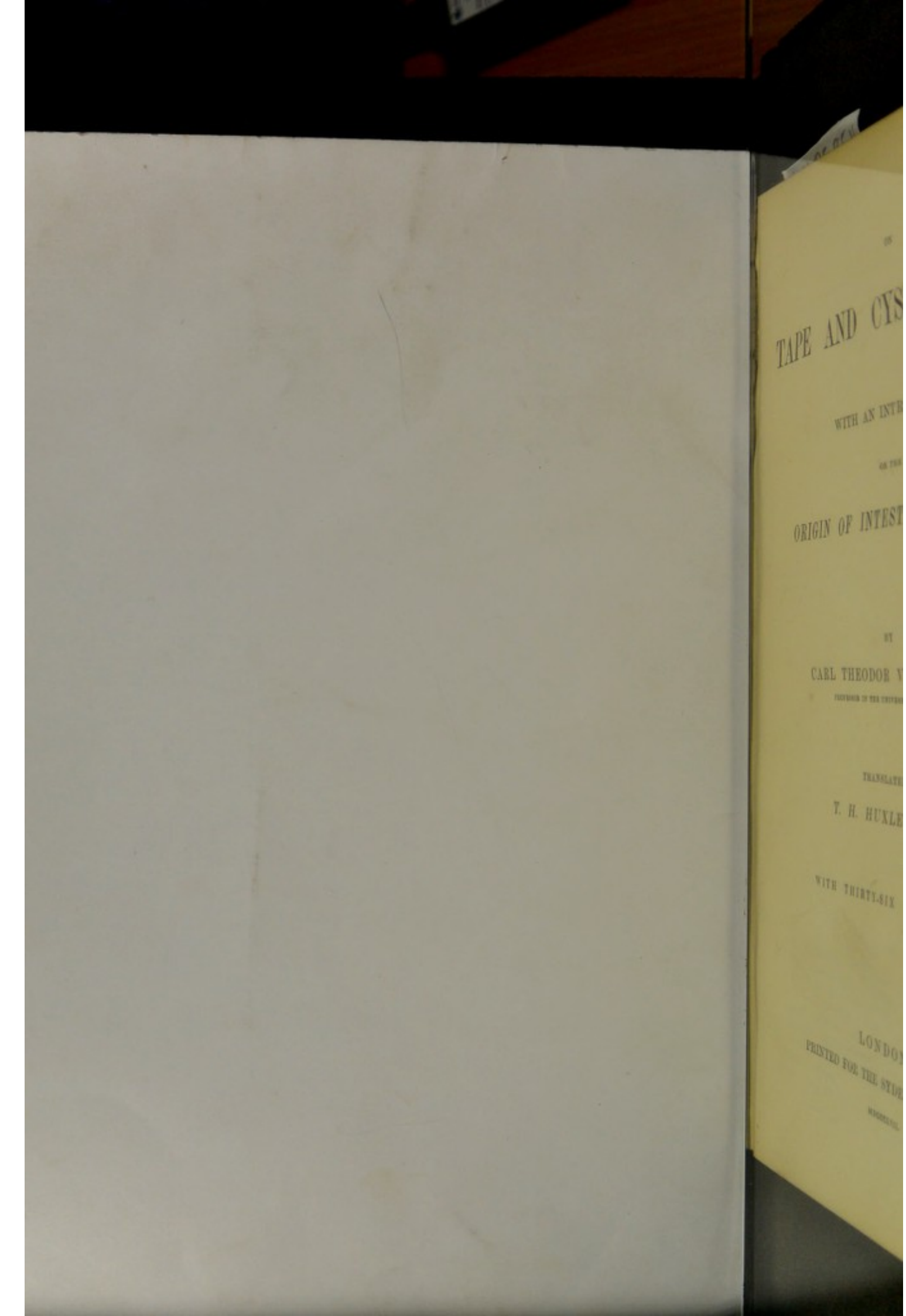
On tape and cystic worms : with an introduction on the origin of intestinal worms / by Carl Theodor von Siebold ; translated by T.H. Huxley.



ON

TAPE AND CYSTIC WORMS,

WITH AN INTRODUCTION

ON THE

ORIGIN OF INTESTINAL WORMS.

BY

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VON SIEBOLD

ON

TAPE AND CYSTIC WORMS.

CONTENTS.

AUTHOR'S PREFACE.

Investigations into the natural history of the entozoa, continued for many years, have taught me that it is impossible to obtain a complete view of the different stages of existence through which these parasites pass, if one's observations are restricted to but a few of the localities in which they are found. At an early period of my researches, it became evident that the same entozoon, in its young state, may have a very different habitation from that in which it is found in its adult condition; for these animals undergo the most remarkable metamorphoses, and their habits varying with their changes in form and age, they are necessitated repeatedly to change their residence.

These peculiarities in the natural history of the entozoa, often most difficult of investigation, have rendered the task of the helminthologist, in seeking to obtain a just conception of their genera and species, a very difficult one. It has only too frequently happened that the different stages of development of the same species of entozoa, have been described as so many distinct species or genera; and thus the systematic arrangement of the group has been built upon a faulty foundation. Hence, again, a difficulty has arisen in the way of attaining correct ideas with regard to the modes of propagation of the intestinal worms, and this obstacle could only be removed by determining, in defiance of the authority of the older helminthologists, to give up many genera and species established upon what they supposed to be independent forms.

The investigation of the natural history of the intestinal worms, at the same time, opened up a channel through which their mode of origin could be traced; and indicated a way in which the attacks of those parasites which are dangerous or troublesome to man and animals, could be prevented; an object, in certain cases, of the highest importance, since the morbid changes induced by many entozoa in the organs which they infest, are not always removable.

For a long period, I have been at much pains to inquire into the origin of the entozoa found in man and the domestic animals; and in the present essay I lay before physicians, veterinarians, and breeders, a summary of the results of the observations and experiments which I have made upon the production and development of these creatures. My chief attention has been directed to the destructive cystic-worms, and I believe that the conclusions at which I have arrived are not merely a gain for science, but promise to be of useful practical application.

MÜNICH; *March 30th*, 1854.

INTRODUCTION.

CHAPTER I.

UPON THE ORIGIN OF INTESTINAL WORMS.

HAVING been occupied for many years with inquiries into the natural history of the intestinal worms, a subject involved in much obscurity, I have gradually arrived at the decided conclusion that these parasites do not originate, as has been commonly believed, by "equivocal generation," from substances of a dissimilar nature. With the usual exaggeration and misuse of language, the doctrine of equivocal generation has been applied both to the infusoria and to the intestinal worms. It was difficult, at first sight, to account for the origin and reproduction of these animals, and, even upon closer investigation, they presented many phenomena which could not be recognised in the organization and vital manifestations of other, especially of the higher animals; but instead of seeking for the cause of these exceptional peculiarities, people, accommodating themselves to the usually accepted view as to the natural history of these lower creatures, set the matter straight in their minds, by supposing that the unusual phenomena occurred somehow or other in that way; thus allowing the imagination to indulge in fancies of the wildest description, and even in opposition to the most important laws of nature. It was in this manner that physicians and naturalists thought themselves justified in assuming, that the parasitic worms in the intestines of men and animals owed their origin to ill-digested nutriment, or that they were developed in the most widely different organs from corrupt juices. They took it for granted, that certain

morbid processes in any organ were competent to give rise to parasites, assuming that the elementary constituents of an organ affected by disease, mechanically separated themselves from their natural connection, and not perishing, but transforming themselves into independent organisms, became parasites. Clothed in fine phrases, this idea was everywhere received with favour, and took such deep hold of the public mind, that it is now a matter of no small trouble to eradicate what has, with many, become an article of faith, and to substitute the laws of nature, drawn from experience, for the creation of their fancy. It was certainly more convenient and enticing to give free scope to one's thoughts, and to fill up the frequent gaps left in our knowledge of the origin and multiplication of the lower animals, with pure hypotheses, than as now, renouncing this faulty method of inquiry into nature, to attain, by troublesome researches and careful experiments, a secure insight into her hidden workings.

It was by the latter method that a remarkable and hitherto unanticipated development of the sexual apparatus was discovered in many parasites, such as round-worms, thread-worms, tape-worms, and flukes,[1] in which such an immense mass of eggs and young can be generated, that it seems unnecessary to look further in order to account for their origin. But the precise mode in which the countless brood of these parasites make their way into the interior of the animals they are destined to inhabit, was long but dimly understood, until by degrees attention was directed to certain peculiarities in the mode of life of these creatures, which threw great light upon the subject.

It has been ascertained, in fact, that at particular periods of their existence, the intestinal worms undertake emigrations, and these often very extensive ones, in order to reach that animal whose organs are by nature fitted for their habitation. We now know that the young of the tape-worm, (which inhabits the intestine of the higher animals only,) leave the place where they were brought

[1] With respect to the tape-worms, it is well known that a single individual is often composed of many hundred joints. Each joint is capable of laying many hundred ova, so that the number of the progeny of a single tape-worm is enormous. Professor Eschricht of Copenhagen (see his work 'Das Physische Leben in populären Vorträgen, Berlin, 1852, p. 115) posesses a tape-worm, expelled by a patient of his, which consists of 1000 joints, and some of the joints contain more than 1000 ova. The same writer (ibid., p. 112) having carefully examined the reproductive organs of a female *Ascaris lumbricoides*, estimates the number of eggs in a single thread-worm at many millions.

forth, or laid as eggs (that is to say, they emerge from the intestine of their parent's host), and seek an opportunity to enter into the intestine of some other creature. It is easy to convince oneself of this emigration of the young of the tape-worm, by examining the excrement of animals infested by them, at those times of the year at which they attain their sexual maturity. We then observe, that sometimes single joints, or connected series of joints, full of ova; sometimes immense masses of the ova, are passed with the fæces. The same thing holds good with regard to the ova of the *Distomata* that infest the livers of our ruminating animals; their eggs, after they have been transferred from the liver to the gall-ducts, being washed out with the bile into the intestine, and evacuated with the dung.

These emigrations of the young of the intestinal worms benefit not only the creatures they infest, but themselves. There are many kinds of intestinal worms, in whose eggs the embryo is never hatched if they remain in the place where they have been laid. They must wander to some other place in order to develop their young, or to allow of the escape of the young already developed in them.[1] These young must then either wait for, or seek, an animal to lodge in, having entered into which, they are capable of attaining sexual maturity. By such emigrations the infested animals are at the same time freed from guests, whose increase would be both troublesome and prejudicial. For example, what would happen if the millions of eggs that a single round-worm or tape-worm can produce, were to develop and generate their young in the same intestine in which they were laid? Would not the intestine, after the young had attained their full growth, and brought forth others in their turn, become at last so choked up as to disable this part of the digestive apparatus, so that the whole organism of the unhappy animal must perish, together with his parasites? In any case, the emigration and immigration of the young of the intestinal worms, is a very important though long unregarded part of the history of their propagation; and since

[1] Hence a tape-worm which has found its way into the intestine of an appropriate animal will attain its sexual maturity, but will not, properly speaking, multiply its kind there. For this reason, the tape-worm (*Tænia solium*) infesting the human subject, which is common in Germany, France, [and England,] is commonly called the solitary worm, (Einsiedler-wurm, ver solitaire,) although the name is not a very fit one, as it depends entirely on accident whether only a single individual or a whole society of these worms shall enter the human intestine in the course of their wanderings.

physicians and naturalists have devoted the requisite attention to the subject of these wanderings (to which I directed attention some years back[1]), a number of facts have been discovered, showing more and more that the origin of the intestinal worms in the viscera of animals can be readily accounted for according to natural laws; whereas formerly, hardly anything being really known of the natural history of these parasites, their mode of origin and propagation, already difficult enough of comprehension, was rendered more and more mysterious by an hypothesis of "equivocal generation" entirely devoid of any direct support.

An important circumstance, very favorable to the progeny of the intestinal worms during their wanderings, is the solidity of the egg-shell in which they are commonly contained. By its hardness and resistance, the egg-shell of many kinds of intestinal worms efficiently protects the enclosed germ and yelk, or the already developed embryo, against injury from without, and maintains within the ovum the degree of moisture requisite for the further development of the young. In this way the ova preserve their vitality for months together, notwithstanding the many vicissitudes to which they are exposed after leaving the dwelling of their parents. They pass into dust-heaps, privies, drains, &c., where, surrounded sometimes by a greater, sometimes by a lesser degree of moisture, they are subjected to various degrees of temperature, until, deposited in the dung-heaps into which corrupt and mouldering organic substances are usually converted, they are, as manure, spread upon the fields and meadows, where, under favorable influences of the weather, particularly if supplied with adequate moisture, they become further developed. It will be obvious that the young of the intestinal worms have not far to seek for an opportunity of re-entering other animals, when we consider that they are scattered through the manured soil amongst the seeds that have been sown there; that these produce plants which generally serve for the support of men and animals, and that the young worms adhering to them may thus be easily swallowed. Again, it may well happen that showers of rain occasionally wash out the ova of the intestinal worms from the dung-heaps or manured soil, carrying them off into streams and brooks, and

[1] See my article "Parasiten" in R. Wagner's 'Handwörterbuch der Physiologie,' Bd. ii, 1844, p. 645.

so affording another mode of entrance into men and animals, by the water which the latter drink.

Many of the young intestinal worms, more or less developed, but still enclosed in the egg-shell, remain quite inactive in their wanderings, and for these passive emigrants it is, of course, a mere matter of chance whether they reach their goal or not. The young of others, having previously left their egg-shell, may take an active share in the process, creeping up out of their holes and corners in wet weather, or in the damp mornings, upon the slippery plants, and so entering the animals fitted for their habitation, when they come to seek for food.

According to an old-standing custom which careful shepherds strictly keep up, sheep are never allowed to be driven out in the morning till all the dew is off the grass, nor yet to graze in damp swampy pastures. By this precaution the shepherds unwittingly protect their charges from the attacks of *Strongyli* and *Distomata*. It is on like grounds that seasons of wet weather are so frequently fatal to flocks, it being then easier for the young intestinal worms to enter the sheep and give rise to entozoic pestilence; whilst in continuously dry and hot seasons a great number of these young worms must be dried up and destroyed, and thus the sheep are delivered from their attack and all its evil consequences.

But in thus expressing my opposition to the various hypotheses of the origin and multiplication of the parasitic worms, it might appear as if I had fallen into the very error I condemn, and the objection might be raised that the explanation I have just given of the singularities observed in the mode of occurrence of the intestinal worms is, like former hypotheses, merely imaginary, and that I am unable to support it by demonstrative experimental evidence.

This I must beg leave to deny. It is true that what I have said respecting the origin of the *Strongylus filaria* and of the fluke (*Distomum hepaticum*) in sheep, is as yet only an assumption, and not to be regarded as directly proven. Nevertheless, my assumption rests upon the analogy of reliable facts, which I have established by observation in other intestinal worms. The recognition of definite, though at first isolated truths, has often done much for science, since by careful application of the laws of analogy they have furnished the key to phenomena long hidden in obscurity.

In order to show that emigration and immigration are regular

phases in the life of many intestinal worms, I will here recall certain observations of my own on the natural history of the following parasites.

For a long time the origin of the thread-worm, known as *Filaria Insectorum*, that lives in the cavity of the bodies of adult and larval insects could not be accounted for. Shut up within the abdominal cavity of caterpillars, grasshoppers, beetles, and other insects, these parasites were supposed to originate by equivocal generation, under the influence of wet weather or from decayed food. Helminthologists were obliged to content themselves with this explanation, since they were unable to find a better. Those who dissected these thread-worms and submitted them to a careful inspection, could not deny the probability of the view that they arose by equivocal generation, since it was clear that they contained no trace of sexual organs. But on directing my attention to these entozoa, I became aware of the fact that they were not true *Filariæ* at all, but belonged to a peculiar family of thread-worms, embracing the genera *Gordius* and *Mermis*. Furthermore, I convinced myself that these parasites wander away when full grown, boring their way from within through any soft place in the body of their host, and creeping out through the opening. How many a butterfly-collector, keeping caterpillars for the breeding of fine specimens of butterflies, must have seen one or more yellowish white thread-worms winding their way out of them! These parasites do not emigrate because they are uneasy, or because the caterpillar is sickly, but from that same internal necessity which constrains the horse-fly to leave the stomach and intestine of the horse where he has been reared, or which moves the larva of the gad-fly to work its way out of the boils on the skin of oxen. The larvæ of both these insects creep forth in order to become chrysalises and thence to proceed to their higher and sexual condition. This desire to emigrate is implanted in very many parasitic insect larvæ, and has long been a well-known fact in entomology. Now I have demonstrated, that the perfect, full-grown, but sexless thread-worms of insects are, in like manner, moved by this desire to wander out of their previous homes in order to enter upon a new period in their lives which ends in the development of their sexual organs. It is true that in the boxes and other receptacles, in which one is generally accustomed to keep caterpillars, these creatures perish; they roll themselves together, and from the absence of

the necessary moisture, they in a short time dry up. But their fate is very different when the infested insects remain under natural conditions; the thread-worms, as they leave the bodies of their hosts, then fall to the ground, and crawl away into the deeper and moister parts of the soil. Thread-worms found in the damp earth, in digging up garden-beds and cutting ditches in the fields, have often been brought to me, which presented no external distinctions from the thread-worms of insects externally. This suggested to me that the wandering thread-worms of insects might be instinctively necessitated to bury themselves in damp ground, and I therefore instituted a series of experiments with such entozoa (which I procured in numbers from the caterpillars of a moth, *Yponomeuta evonymella*), by placing the newly emigrated worms in flower-pots filled with damp earth.[1] To my delight, I soon perceived that these worms[2] began to bore with their heads into the earth, and by degrees drew themselves entirely in. For many months (through the whole winter) I kept the earth in the flower-pots moderately moist, and on examining the worms from time to time I found, to my great astonishment, that the sexual apparatus became gradually developed in them, and that, after a time, eggs were formed and were eventually deposited by hundreds in the earth. Towards the conclusion of winter I could succeed in detecting the commencing development of the embryo in these eggs. By the end of spring they were fully formed, and many of them, having by this time left their shells, were to be seen creeping about the earth in the flower-pots, which I still carefully kept damp. I now conjectured that these young worms would be impelled by their instincts to pursue a parasitic existence and to seek out an animal to inhabit and grow to maturity in, and it seemed not improbable that the brood I had reared would, like their parents, thrive best in the caterpillar. In order, therefore, to induce my young brood to immigrate, I procured a number of very small caterpillars of *Yponomeuta*, of half a line in length, which the first spring sunshine had just called into life. For the purpose of my experiment I filled a watch-glass with damp earth, taking it from amongst the flower-pots where the thread-worms had wintered, and of course satisfying myself that it con-

[1] These experiments and their results have been already published in the 'Entomologische Zeitung,' 1848, p. 290.

[2] I have named this species of thread-worm *Mermis albicans*.

tained a number of lively young of the *Mermis albicans*. Upon this I placed several of the young caterpillars of the *Yponomeuta* in order that the worms might gratify their immigrative propensities. I must explicitly remark, that before experimenting with the caterpillars, I carefully examined each with the microscope, in order to ascertain whether it was not already inhabited by young thread-worms. From their softness and transparency, I could ascertain this point with certainty, without in the least injuring them. The event proved that this inspection was necessary, for out of twenty-five individuals which I at first selected, three contained a thread-worm embryo, which was excessively like those in the flower-pots. I published the results of these experiments a year or two back, in an essay upon the thread-worms of insects[1], from which I quote the following :

" From amongst those caterpillars which microscopic inspection clearly demonstrated to be free from thread-worms, thirteen were placed in a watch-glass filled with damp earth containing many lively *Mermis*-embryos. After eighteen hours I was able to discover *Mermis*-embryos in five of the caterpillars. On a second occasion, three-and-thirty of the caterpillars of *Yponomeuta cognatella*, likewise carefully examined and found free from parasites, were in the same way placed in a watch-glass filled with damp earth containing *Mermis*-embryos. After four-and-twenty hours, fourteen contained *Mermis*-embryos. Six of these little caterpillars each contained two small worms, whilst in two others there were as many as three worms. I also employed other caterpillars (of three lines in length) of *Pontia Crataegi*, *Liparis chrysorrhœa*, and *Gastropacha Neustria*, which I took out of coccoons where they had passed the winter. They were, in like manner, placed in a watch-glass upon moist earth containing *Mermis*-embryos. On the next day, among fourteen caterpillars thus treated, I found ten infested with *Mermis*-embryos ; five of these contained two worms each, and into one even three worms had wandered." It was clear that these young thread-worms had bored their way through the soft skin into the interior of the young caterpillars.

From the results of the experiments I have just recorded, one must conclude that it is not necessary to turn to the mystical doctrine of equivocal generation for an explanation

[1] See 'Entomologische Zeitung,' 1850, p. 239.

of the presence of worms in insects, since here the origin of the parasites is sufficiently obvious. Those who cannot make up their minds to renounce the easy and convenient doctrine of equivocal generation, may perhaps object, that the history I have given of the propagation of the *Mermis albicans* stands alone, and only makes an exception from the rule. To this I answer, in the words of Goethe: "Nature goes her way, and that which appears to us as the exception, is the rule." That this is really the case in the present instance, is proved by recent investigations into the natural history of the intestinal worms. Since attention has been directed to their wanderings, more and more facts have been daily brought to light, all tending to show that the emigration and immigration of these parasites is a much commoner and more widely extended occurrence than was at first imagined. Habits, very similar to those which I have just described in *Mermis albicans*, are also to be observed in another thread-worm, the well-known *Gordius aquaticus*, which has also been shown to live parasitically in the cavities of the bodies of various insects, viz.: grasshoppers, terrestrial and aquatic beetles, and in their larvæ; and to grow from a most diminutive worm to one of several inches in length, which then makes its way out, to attain to sexual maturity elsewhere, often in the water. These facts were formerly wholly unknown, though it must have long appeared surprising that this thread-worm, which, on account of its form and colour has been compared to a horse-hair, is, whenever met with in the water, of its full size. But now that we know that the *Gordius aquaticus*, like the *Mermis albicans*, enters in the embryo state into insects, growing with them, and only quitting them when it has done growing, the striking phenomenon I have mentioned is easily accounted for.

Just as, for the reasons already named, some kinds of parasites that have emigrated are never met with below a certain size; so, some kinds of parasites that have already made their way into the interior of animals are not to be found under a certain size, however often and carefully they may be sought for, a circumstance which must certainly have been noticed by many physicians and naturalists, without their having paid further attention to it. It is now known that many parasites do not enter into the animals in which they are to pass through their further stages of growth until they have attained a

certain degree of development elsewhere. This is particularly the case with such intestinal worms as remain parasitic in the last stage of their existence, viz.—that of sexual maturity, whilst the *Gordiacæi* (*Gordius* and *Mermis*), as soon as they are full-grown, quit their parasitical life, in order to become sexually mature, away from the animal they have infested. During these early wanderings, the worms in question commonly undergo a change of form—a sort of metamorphosis, often accompanied by other phenomena of so highly remarkable and abnormal a character, that naturalists could not at first understand the varied character and import of these phases of existence, nor comprehend their relation with hitherto known facts.[1] For a long time it was supposed that these discoveries were isolated facts, and they were regarded as a sort of curiosity; but here again the saying was verified, that that which at first appeared to be the exception, eventually proves to be the rule. By degrees, a mass of observations upon certain remarkable metamorphoses of the intestinal worms accumulated, and constituted a complete chaos of seemingly irregular phenomena, which broke down every barrier hitherto set by the acknowledged laws of animal existence and propagation, until the penetration of the Danish naturalist, Steenstrup,[2] succeeded in evolving a certain order out of this confusion, by the discovery therein of a hidden, underlying law of nature, by which all the phenomena that had seemed so devoid of plan could be reduced to order. Steenstrup named the newly discovered law, the "Alternation of Generations," a phrase which describes this phenomenon. "That an animal bears young which

[1] I may refer to the "king's-yellow" worms discovered by Bojanus in water-snails, and now become famous. (See Oken's 'Isis,' 1818, p. 729, plate 9, figs. A, F.) Of this discovery Oken says "Observations of this kind make one dizzy." No less attention was excited by Von Bär's description of the *Bucephalus polymorphus* of the fresh-water mussel. (See 'Verhandlungen der Kaiserl. Akad. d. Naturforscher,' B. xiii, 1826, p. 570, pl. 30); and by the *Leucochloridum paradoxum*, first discovered by Ahrens, and afterwards described anew by Carus. (See 'Magazin der Naturforschenden Freunde zu Berlin, 1810, p. 292, pl. 10, figs. 12—19, and the 'Verhandlungen der Kaiserlichen Akademie,' Bd. xvii, 1855, p. 87, pl. 7.)

[2] See his important essay on the 'Alternation of Generations,' Copenhagen, 1842. [This essay has been translated by Mr. Busk, and forms one of the publications of the Ray Society. It must not be forgotten that the first conception of the doctrine of the "Alternation of Generations," and the first use of the term, are due to Chamisso. See his 'De Animalibus quibusdam e classe vermium Linnæana,' 1819, and 'Reise um die Erde.'—Ed.]

are, and remain, dissimilar to their parent, but bring forth a new generation, whose members either themselves, or in their descendants, return to the original form of the parent animal."

Any one who has not familiarized himself with the fundamental idea of this doctrine of the alternation of generations, may easily imagine it to be nothing but a modification of the long well-known metamorphosis, exemplified by the tadpoles of frogs and toads, or by the larvæ and chrysalises of most insects. This is, however, by no means the case. Those reptiles and insects that are subject to metamorphosis, no doubt bring forth young that differ from the parent, but there are two respects in which the act of simple metamorphosis widely differs from the highly complex alternation of generations.

Although Steenstrup has already particularly noticed these two grounds of difference in his definition of the alternation of generations, I deem it not altogether superfluous on my part once more to draw especial attention to these important divergences, if only for the benefit of those who are unfamiliar with the phenomena. The first point of difference between the alternation of generations, and metamorphosis, is, that the young of those animals whose mode of development comes under the former head, are not only unlike their parent at first, but remain so: the second distinction rests on the important fact that this young generation, so dissimilar to the parent animal, brings forth new creatures, which either themselves, or in their descendants, revert to the original form of the first parent. Whereas, on the other hand, in simple metamorphosis, the dissimilar young pass by gradual changes into the likeness of the parent animal, and until this metamorphosis is complete, are incapable of generation. Steenstrup has given the name of "nurse" to those young, which, whilst departing from the parent type, remain, and propagate under their own form.

It thus happens that in the alternation of generations (to use the words of Steenstrup), the parent animal produces "nurses," whose descendants only, take her form. A most important circumstance which characterises these nurses or "Agamozooids"[1]

[1] I have rendered the word "keim-körper" by "sporula," meaning thereby a free germ which is capable of development without fecundation, just as is the spore of a cryptogamous plant. When the sporulæ are developed in a special organ I term this organ (the "keimstock" of Von Siebold) the "sporularium." Any independent form from which sporulæ or their equivalents alone are developed (the "ammen" or "nurses" of Von Siebold, Steenstrup, &c.) I term "agamozooids." See concluding note.—[Ed.]

physiologically, is, that they bring forth young, without themselves possessing any real sexual apparatus. These Agamozooids, in fact, multiply by division, by external or internal gemmation; they develop within their bodies germs which become fresh creatures. But these germs do not deserve the title of "eggs;" nor is the place where they are developed to be called an "ovarium," since the germs, which I shall for the future distinguish by the name of "sporulæ," are not only devoid of the ordinary constituents of an ovum, as vitelline membrane, yolk, germinal vesicle, and so called germinal spot, but the further development of the germ-body is not preceded by those conditions, (I mean that "impregnation" by means of a special seminal matter produced in a testis,) which is essential to the development of true ova developed within an ovarium. The organ in which, in certain Agamozooids the "gemmæ" are formed, cannot therefore be properly termed an "ovarium," and I shall distinguish it by the name of "sporularium." No "nurses" present any sexual distinctions, and hence their method of multiplication and propagation, which takes place by means of sporulæ formed within sporularia, or by ordinary budding, or by division, must be arranged amidst the modes of asexual reproduction.

Very many cases of the alternation of generations occur among the *Trematoda*. The relations that the various changing forms of these animals have to one another, remained long unsuspected, since it was not an easy matter to discover among the various successively alternating generations of a single fluke-worm, the clue to their origin from one and the same parent. The recognition of the connection of these forms, was rendered more difficult of discovery by the fact, that these alternating generations of animals not only changed their appearance, but also their dwellings, whereby their parentage was still further concealed. These multitudinous difficulties in the way of the observers of the alternation of generations, render it impossible for me to give a complete account of all the complex series of changes undergone by any single Trematode in the course of its development. Up to this time only longer or shorter fragments of the circle of vital phenomena, broken as they are into many phases by the alternation of generations, have been made out in a few *Trematoda*.

However, these fragments do not relate to one and the same period in the life of these parasites, nor to the same generations

of Agamozooids, but to the most widely various periods and stages of their development. We can, therefore, by careful selection and judicious arrangement of these observations, build up a general view of the complicated process of the alternation of generations in the *Trematoda* in general.

The so-called *Cercariæ* offer the best exemplification of the alternation of generations as it occurs in the *Trematoda*. These *Cercariæ*, which swim about with great activity by means of a cylindrical tail, have long been known; but until the discovery of their real origin and signification, were taken, on account of their diminutiveness, for *Infusoria*. When, at a recent period, their parasitic nature was recognised, it became a matter of much astonishment that the *Cercariæ* were not derived from parents resembling themselves, but that they originated in peculiar animated, worm-shaped sacs, which were found buried amidst the sexual and digestive organs, in various kinds of fresh-water snails and mussels. The form of the sacs that produce the *Cercariæ* is, notwithstanding the simplicity of their organization, very various; in accordance with the form and kind of *Cercaria* to be developed within them. Some kinds of *Cercaria*-sacs have an oral aperture, and a simple blind intestine, but in others this digestive apparatus is entirely wanting. One series of *Cercaria*-sacs possesses contractile walls, whilst others again are stiff and inflexible. In one particular group, the *Cercaria*-sacs are simple shut receptacles; in another, the sacs ramify and anastomose to a great extent. The whole of these multifariously-shaped *Cercaria*-sacs enclose within the walls of their bodies a cavity which, besides the intestinal

Fig. 1. Fig. 2. Fig. 3.

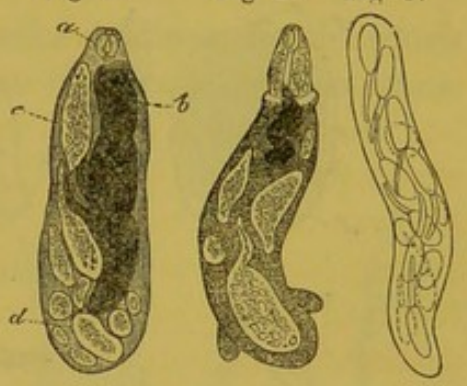
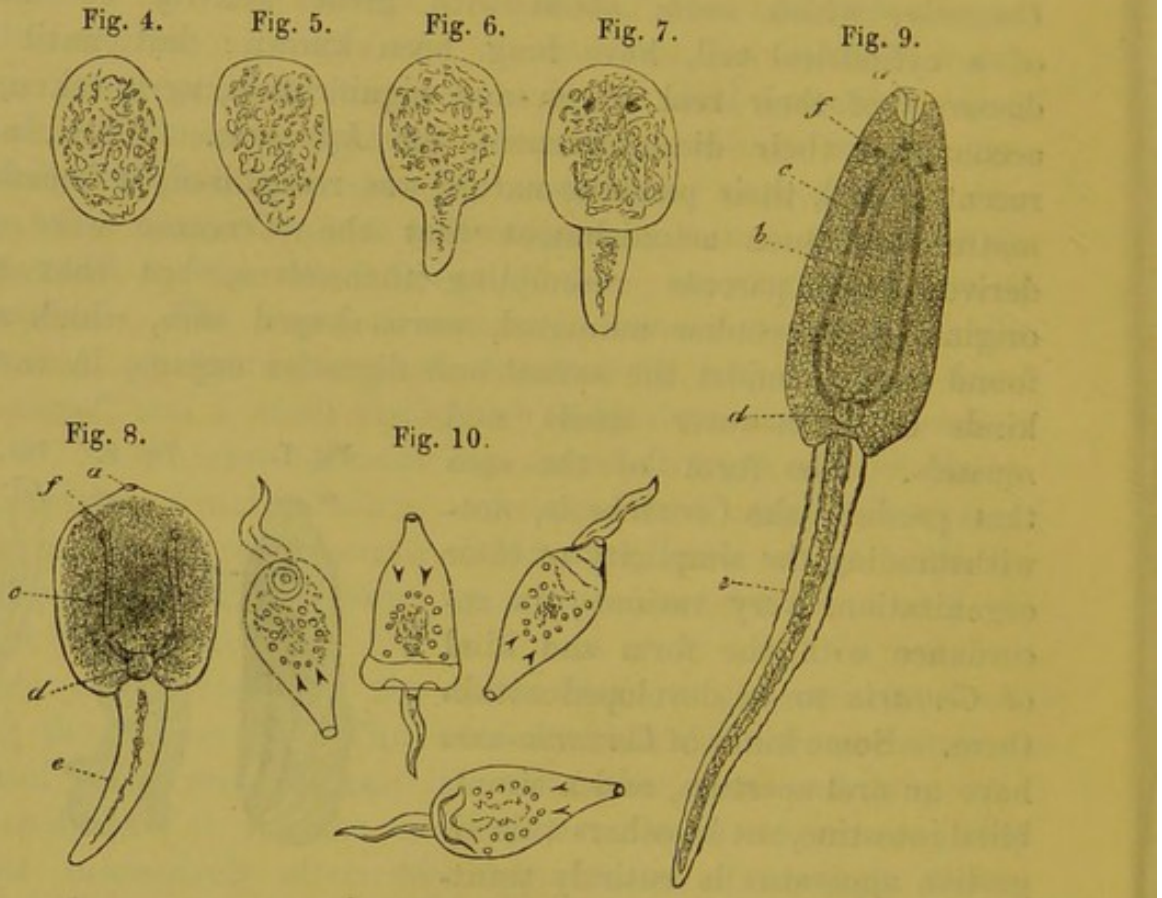


Fig. 1. A cercaria-sac (two lines long) provided with an elongated alimentary canal —the agamozoöid of *Cercaria ephemera*. *a*. Oral cavity. *b*. Alimentary canal. *c*. A developed *Cercaria ephemera*. *d*. Sporulæ not yet developed into *Cercariæ*. These sacs are found in *Planorbis corneus*. Fig. 2. A cercaria-sac—the agamozoöid of *Cercaria armata*— provided with a very short alimentary canal and remarkable for the two short lateral abdominal processes, found in *Lymnæus stagnalis*. Fig. 3. A perfectly simple cylindrical cercaria-sac, having no digestive canal. I found it as the agamozoöid of *Cercaria sagittifera* in *Helix pomatia*.

cæcum, (where such a structure exists,) contains nothing but young *Cercariæ*. These young are developed, not from ova, but from gemmæ, which differ essentially from ova. They are solid, round, and somewhat flattened discs, which, growing and developing, become little caudate worms, resembling in form and organization certain *Trematoda* (*Distomum, Monostomum, Diplodiscus, Gastrostomum*).[1]



Figs. 4—10. The various stages of development of *Cercaria ephemera*, from the agamozoöid, fig. 1. Fig. 4. Sporula. Fig. 5. Sporula thinned at the hinder end. Fig. 6. Sporula with this taper posterior extremity elongated into a tail. Fig. 7. The sporula in this stage has assumed the form of a *Cercaria*. The tail is already defined. Two black pigment-spots appear on the fore part of the dorsal surface. Fig. 8. A still further developed *Cercaria*. *a*. The oral aperture. *c*, *d*. The urinary organ. *e*. The Tail. *f*. Two pigment-spots. Fig. 9. A fully formed *C. ephemera* (one millimetre long). *a*. Oral cavity. *b*. Alimentary canal. *c*, *d*. Urinary organ filled with granular urine. *e*. Tail. *f*. Three black spots on the anterior part of the dorsal surface. The median pigment only begins to be developed in the last stage of development. The whole figure of the body of *Cercaria ephemera* corresponds with that of *Monostomum*. Fig. 10. Four cercariæ, after Filippi, from *Planorbis nitidus*, whose posterior sucking apparatus (composed of two suckers, one enclosed within the other) is seen in different stages of contraction and expansion. When the tail is cast off these *Cercariæ* are altogether similar to *Diplodiscus*.

[1] The *Cercariæ* and the sacs have been so often referred to of late that I may leave

It was a long while after the origin of the *Cercariæ* was known, before any explanation offered itself as to how the parasitic *Cercaria*-sacs in water-snails and mussels arose, and as to what became of the *Cercariæ*, which, when fully formed, always seemed to desire to leave the bodies of the dissimilar parents in which they had been developed; penetrating the walls of their sacs, and boring through the substance of the bodies of the snails and mussels into the water, where they at first creep, and at length paddle swiftly about by the help of their tails.

With regard to the origin of the *Cercaria*-sacs, it cannot be supposed that they proceed from *Cercariæ*, since, in these last, no organs of propagation are perceptible. In this perplexity the doctrine of equivocal generation was again invoked, and it was assumed that certain glandular cæca of the digestive or sexual apparatus, in the snails and mussels in which *Cercaria*-sacs are found, were converted into such sacs, and produced *Cercariæ* by equivocal generation. This was, of course, a mere assumption based upon no direct observation.

Now I was so fortunate as to make a discovery by which much light has been thrown upon the obscure history of these *Cercariæ* and *Cercaria*-sacs.

It was in the year 1833, whilst fulfilling my duties as district medical officer (kreisphysicus) at Heilsberg, in East Prussia, that I had occasion to examine a large number of specimens of those *Trematoda* known to Helmintho-logists by the name of *Monostomum mutabile*, which were very commonly found in the geese of that locality, in the cavities which lie underneath the eyeballs. I convinced myself that these para-

Fig. 11. Fig. 12.

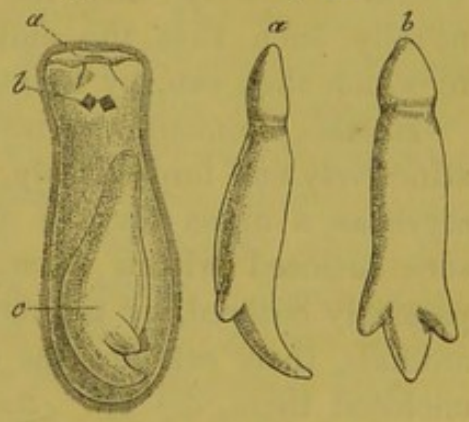


Fig. 11. An infusoroid embryo of *Monostomum mutabile* which has just left the egg. (See my essay on this subject in Wiegmann's 'Archiv.,' 1835, i, p. 69.) *a*. Sucker. *b*. Double pigment-spot. *c*. Sporule-cyst.—Fig. 12. *a*. The sporule cyst left free by the death of the infusoroid embryo. *b*. The same viewed laterally. This body closely resembles the sporule cysts of *Cercaria armata*.

their manifold forms undescribed in this place, merely referring to the descriptions and figures which Von Bär, in his masterly 'Beiträge zur Keuntniss der niederen Thiere' ('Nova Acta,' vol. xiii, pars 2a, 1826,) and Steenstrup, in his 'Alternation of Generations,' have given.

sites, belonging to the order *Trematoda*, bring forth living young, which assume the form of *Infusoria*, and swim about in the water by means of the cilia which cover the whole surface of their bodies. After some time, I observed that these embryos apparently died, their bodies seeming to break up and gradually disappearing, but always leaving behind a sharply defined, mobile, cylindrical body, provided with two short, lateral processes. In all the embryos, without exception, this body was visible through their parietes while they still lived. To my great astonishment, upon further observation of these contractile remains of the *Monostomum* embryos, I discovered that they agreed precisely in form, structure, and movement with certain young *Cercaria*-sacs. Hence I ventured to conclude that the *Cercaria*-sacs proceed from *Trematoda*. At the same time, these observations seemed to indicate how it was possible for the inert, helpless *Cercaria*-sacs to make their way into snails and mussels. The *Monostomum mutabile* is known to reside in such cavities of the body of wading and swimming birds, as possess natural external apertures; when, therefore, the embryos of a *Monostomum mutabile* are born, they will issue without much difficulty from the animal infested by their parents, each carrying its *Cercaria*-sac within its body: and the habits of the infested animals are usually such that the embryos will at once pass into water, in which they can, by means of their cilia, swim swiftly about.

In this element, the infusory *Monostomum* embryos will, instinctively and immediately, seek out those animals that are fit to serve as a nidus for the further development of the *Cercaria*-sacs enclosed within them. After the *Cercaria*-sacs have thus passively entered, by the natural apertures, into their appropriate animals, their carriers, the ciliated embryos which have hitherto enclosed them, die off. As a sort of animated covering to the *Cercaria*-sacs, they have performed their office; and it is now left to the young that have just been released, to work themselves deeper into their new habitation by their own efforts, and to seek out those places which will afford them the necessary nourishment for further growth, and for the development of their brood of *Cercariæ*.

I have not yet been able absolutely to witness this process of immigration of *Monostomum* embryos containing *Cercaria*-sacs, and as I have filled up the gaps in observation with my own ideas on the subject, what really occurs may be somewhat

different; still, the immigration of the *Monostomum* embryo, which is the principal point, must take place, since the singular relations of the infusorial *Monostomum* embryos and the young *Cercaria*-sacs they contain, point distinctly to this conclusion.

Every one will understand, that the knowledge of even such a small fragment of the history of the development of the *Monostomum mutabile* as this, was of the utmost value, since it afforded the key to the long inexplicable mode of origin of the *Cercaria*-sacs. There now only remained the question as to what became of the *Cercariæ*, and in what relation they stood to the *Trematoda*. It was an old idea that there was great similarity between the bodies of the *Cercariæ* and certain *Trematoda*, viz., *Monostomata* and *Distomata*, and the force of the comparison was strengthened by the fact that the *Cercariæ* cast off their tails after leaving the sacs, and thus become still less different from these *Trematoda*. Many *Distomata* whose bodies are encircled with spines at their anterior extremity, for example, *Distomum trigonocephalum, echinatum, uncinatum,* and *militare,* are so like certain *Cercariæ,* that when the latter have thrown off their tails, any unprejudiced person would take them for the young of these *Distomata*. In fact, in their whole organization, the *Cercariæ* are really no other than young *Trematoda*. The circumstance that one never finds sexual organs in the *Cercariæ* is strongly corroborative of the notion that they are young *Trematoda* not yet sexually developed. Here again we have to do with parasites destined to emigrate and immigrate, that in some other situation they may arrive at sexual maturity. The course which the *Cercariæ* take in their wanderings is, however, a much longer and more complicated one, than that followed by the sexless *Gordiacei*. These need only leave the insects they have hitherto infested and withdraw into damp ground, where fully grown as they are, and provided with the necessary store of fat in their bodies, they can quietly await the development of their sexual organs. On the other hand, the emigrating *Cercariæ* are destined to enter vertebrate animals, since it is only in the intestinal canal of certain mammals, birds, reptiles, or fishes, that they can grow and mature their sexual organs.

Many of my readers may be unable to conceive how it is possible for *Cercariæ* living in water, to enter into the intestines of such mammals and birds as live far away from water, or, at any rate, never come into proximity with the

waters in which the *Cercariæ* live. I can, however, offer a solution of this apparent mystery, having surprised many *Cercariæ* in the act of migrating. Before I say anything more about this, I must mention a peculiarity which is to be noticed in most of the *Cercariæ* after they have left their sacs. This is their habit of encysting themselves, a process which is effected in the following manner. After a *Cercaria* has been for some time in the water, first creeping and then swimming about with manifest restlessness, it gathers itself up into a ball, and emits from its whole surface a mucous secretion which soon hardens, and since inside of this mucous mass the worm, coiled up into a little ball, turns round without stopping, invests it as it were in an egg-shell. During this process of encysting the *Cercaria* invariably casts off its tail, so that the capsule eventually encloses the body merely. (fig. 13). For a long time I vainly wondered what could be the object of this process, and, never understood what its signification in Cercarian life was, until, in dissecting some insects, I met with a fact which suggested how I might gain the knowledge I sought for. In the larvæ of a great number of various kinds of aquatic insects, of *Libellulidæ, Ephemeridæ, Perlidæ, Phryganidæ*, I found encysted *Cercariæ*, which I again discovered in the same animals, after they had left the water, and had been transformed into winged insects. Not one of these encysted *Cercariæ* lodged in an insect, was either full-grown or possessed sexual organs. I only observed one other slight step towards their further development; the sexual apparatus, viz., the testis, the germarium, and the copulatory organs, were already faintly indicated. As, however, perfectly full-grown and sexually developed *Trematoda* are never met with in insects, I decided, after the discovery of the encysted *Cercariæ* in them, that they merely sought out the insects as a temporary resting place.

Fig. 13. Fig. 14.

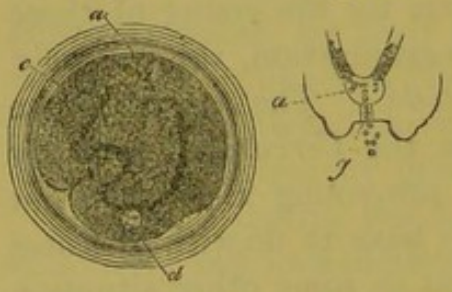


Fig. 13. Encysted *Cercaria ephemera*. *a*. Sucker. *c, d*. Urinary organ.—Fig. 14. Abdominal extremity of a *Cercaria ephemera*, in which, by the casting of the tail the urinary organ has been opened externally. *a*. Inferior expanded end of the urinary organ. *g*. Aperture out of which the granular urine is excreted. Before I pointed out the true import of this urinary organ these granules were regarded as eggs, and when the urine was excreted they were thought to be laid.

Most of the sexually developed *Trematoda* are parasitic upon the higher *Vertebrata*, the *Cercariæ* being, in fact, nothing else than young sexless *Trematoda*, whose instinct it is, to pass out from the inferior animals where they are produced, into the higher forms in which they attain the power of sexual reproduction. Should those *Cercariæ* which are generated in aquatic molluscs, be able to attain their sexual maturity in the intestines of insectivorous birds or mammals alone, they can only reach the latter locality by entering the larvæ of aquatic insects, and then becoming encysted in the manner already described. In this condition they remain, until the new animal in which they have established themselves, having undergone its metamorphosis, leaves the water and is swallowed by some insectivorous vertebrate.

In the act of digestion the body of the insect is destroyed, together with the capsule of the imprisoned *Cercaria*, which in this manner finds itself transplanted into those new circumstances which are alone fitted to permit of its further change into a sexual Trematode.

That this instinctive impulse of the *Cercariæ* to encyst themselves after emigration, is accompanied by a desire to pass into insect larvæ, I assured myself by ocular demonstration. I had procured a large number of specimens of *Cercaria armata* which had emigrated from the common *Lymnæus stagnalis*, and put them into a watch-glass filled with water, in company with several live Neuropterous larvæ (of the families of the *Ephemeridæ* and *Perlidæ*). I soon observed, with the microscope, that the *Cercariæ*, which at first, flapping their tails, moved freely about in the water, at last betook themselves to the insect larvæ, and crept restlessly about them. It was easy to see from their movements that the little worms had some object in view. The *Cercaria armata*, as is well known, is provided with a spine-like weapon, pointing

Fig. 15.

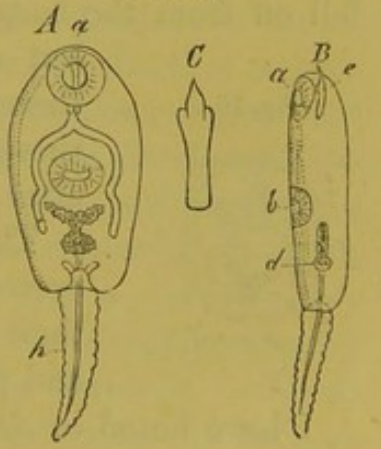


Fig. 15. *A.* A *Cercaria armata* viewed from the abdominal surface. *a.* Oral sucker with the frontal spine showing through it. *b.* Ventral sucker. *c.* Digestive apparatus. *d.* Urinary organ. *h.* Tail whose root plugs up a pit in the hinder end of the body, in which the urinary organ opens.—*B.* The same *Cercaria* viewed laterally *a*, *b*, *d*, have the same signification.—*e.* The frontal spine. The alimentary canal is left out in this view.—*C.* The frontal spine of this *Cercaria* very much magnified, and viewed from above.

forward from the centre of the animal's head. (Fig. 15 *B.*) I could readily perceive, that these *Cercariæ* which I was observing, frequently paused in their inspection of the insects, and inserted this weapon into their bodies as they crept over them. This probing experiment, for it was clearly nothing else, was repeated again and again, until the larva had discovered one of the soft places between the segments of the insect's body; this being reached, it never moved from the spot, but worked incessantly with its spine, until a way was bored through the soft place it had fastened on. Scarcely was the point of the spine fairly through, ere the supple worm inserted his thin anterior extremity into the wound, widened the opening a little, and by degrees drew in his whole body, which became wonderfully slender under the operation. The tail of the *Cercaria* was not drawn inside the insect, but remained hanging outside the puncture, being doubtlessly seized and nipped off, by the sudden closing of the wound when the body of the *Cercaria* had slipped through. Having selected very young and delicate Neuropterous larvæ for my inquiry, the transparency of their bodies enabled me to continue to observe the tail-less *Cercariæ* after their entrance; they forthwith lay still, drew themselves up into balls, and surrounded themselves with a cyst. During the process of encysting, the frontal spine fell off from the body of the *Cercaria*, and lay apart by its side, but enclosed within the cyst.[1] This weapon, therefore, undergoes the same fate as the tail of these animals, each apparatus being cast aside after fulfilling its intended end.

Fig. 16.

The impulse to immigrate and become encysted is so strong in all the *Cercariæ*, that their efforts appear to be occasionally over hasty, and perhaps lead them altogether astray.

I have found in *Aselli* and *Gammari*, encysted *Cercariæ*, which in every way resembled those which had passed into insects.

Fig. 16. An encysted *Cercaria armata*. *a*. Oral sucker. *b*. Ventral sucker. *c*. Digestive canal which is connected with the oral sucker. *d*. Urinary organ filled with granular urine. *e*. Cast off frontal spine which now lies free in the cavity of the cyst. *f*. Aperture of the urinary organ, which becomes visible after the tail is cast off. *g*. Cyst in which the tailless *Cercaria* remains encysted as an asexual *Distomum*.

1 The observation above detailed (which I have already published in Wagner's 'Handwörterbuch,' Bd. ii, p. 669,) can be easily repeated, since the sacs of *Cercaria armata* are excessively common in our fresh-water snails.

Now, if these *Cercariæ* can only attain their sexual maturity in the warm-blooded vertebrate animals, which devour insects, and therefore seek their food in the air or on land alone, the *Cercariæ*, that had established themselves in the *Aselli* and *Gammari*, would wait in vain for the time to arrive when they should be transported into the air, since the animals in which they were domiciled would never quit the water. Again, many *Cercariæ*, in their haste, become encysted incautiously at so early a period, that the purpose of the process is defeated.

I have already shown that the emigrated *Cercaria ephemera* attaches itself to water-plants, or any other objects in the water, by means of the cyst which it elaborates; other *Cercariæ* even become encysted before they quit the body of the aquatic snail in which they were generated; whilst some, again, have even been found encysted within the *Cercaria*-sacs.[1] Steenstrup takes this to be a normal phenomenon; I should only consider it such, provided that the encysted *Cercariæ* in the snails are intended to attain their sexual maturity, in the intestines of fishes or of water-birds feeding on snails.

Although the various facts I have communicated can only be regarded as fragments of the natural history of certain *Trematoda*, they are yet capable of being connected into a whole, if the theory of the Alternation of Generations be extended to them. For instance, from the foregoing statements, we perceive that certain sexually matured Trematoda (*Monostomum*, *Distomum*) generate young within their sexual organs, which are not developed into sexual individuals similar to their parents in form and structure; but that, on the contrary, each embryo is converted into an animal of remarkably different form, viz., into a *Cercaria*-sac, which has the import of a sexless nurse, since without possessing sexual organs, it nevertheless generates young *Cercariæ*. These *Cercariæ* again differ from their parents, but gradually become sexually perfect, and in form and structure take the likeness of their grandparents. The several embryos of these *Trematoda*, therefore, do not pass into an equal number of new and separate sexual *Trematoda*, but each embryo produces a nurse, which, by asexual generation, brings forth a greater or less number of sexual *Trematoda*.

[1] Steenstrup (l. c., p. 85, pl. iii [English translation]), has more particularly described and figured such *Cercaria*-sacs containing encysted *Cercariæ*.

If we follow those *Trematoda* which are subject to the Alternation of Generations, in their wanderings, we shall see that they are likely to meet with many obstacles to the completion of their developmental course, which is the entering into the viscera of an animal in which they can become sexually developed. It may happen that the various emigrations and immigrations of the infusorial embryo, or of the tailed *Cercariæ*, may miscarry ; or it may be, that the exact time for the *Cercaria* to become encysted may be missed ; or that after the due occurrence of the encysting process, the insect selected for its penultimate habitation may die at an inappropriate time or place, and so prevent the encysted *Cercaria* from reaching the last animal, or that one fitted for its final residence. This destruction of the various forms of *Trematoda* by untoward circumstances is compensated by the fact, that they are furnished by the Alternation of Generations with the means of greatly multiplying the various developmental stages of their descendants. By these means the propagation of these animals is secured, since, notwithstanding the mishaps by which many are arrested or destroyed, a sufficient number of individuals always remains out of the numerous young of the nurses and larvæ, who, in spite of all obstacles, achieve the end in view—the propagation of their species.

The history of the *Cercariæ* enables us to comprehend many phenomena which were necessarily quite erroneously interpreted by the older helminthologists, who were ignorant of these wanderings and unacquainted with the occurrence of the Alternation of Generations. It is a common thing to find capsules or cysts, in the midst of the tissues of the most widely different organs of men and animals, containing asexual and only partially developed intestinal worms. It was difficult to understand how such living Entozoa could have originated in the viscera of animals (sometimes in those which are deeply seated and cut off from all external communication) and could here propagate their kind. Hence it was taken for granted that they had been produced by equivocal generation from the surrounding parts, and the mode of origin thus assumed, conversely furnished the reason why these *Entozoa* were unprovided with sexual organs. Frequently too, free, young, or imperfectly developed intestinal worms were met with in the substance of organs, and their occurrence was in the same way attributed to equivocal generation, though in reality these *Entozoa* were either in the act of emigrating or of immigrating,

or else, having found a resting place in some organ, were tarrying till the creature they infested should be swallowed by some other animal, when the passive immigration for which they waited would take place.

Many wandering parasites are unresistingly suffered to bore their way into and remain in, the organs of animals, whilst on the other hand, certain kinds are arrested and finally stopped, by becoming enclosed in a coagulable lymph thrown out by the organs which they traverse. Hereafter we shall have to distinguish two kinds of encysted intestinal worms. In the one kind the cyst is thrown out by the parasite itself, as I have already explained in the case of the *Cercariæ ;* in the other, the organ in which the encysted parasite lies imbedded, furnishes the walls of the cyst. These last "extrinsic" cysts are easily recognised in the passively encysted parasites of vertebrate animals, being immediately and intimately connected with the neighbouring tissues and traversed by blood-vessels.

In such capsules or cysts are found the most diverse kinds of intestinal worms, whose further course may be very various.

Many of the encysted young of the intestinal worms experience no further change, but only remain for a longer or a shorter period until such time as they may, together with their host, pass into the intestine of some animal of prey suitable for their future development. To this kind belong the *Cercariæ* I have already mentioned (page 20). There is also a small, imperfectly developed, round worm, hitherto always erroneously described as a perfect intestinal worm, under the name of *Trichina spiralis,* which remains a long time in its cyst without either growing or developing sexual organs. This minute *Trichina spiralis* is not only met with in the substance of the muscles of man, but also in the pleura and peritoneum of the most widely different kinds of vertebrate animals, enclosed in oval capsules about a quarter of a line in length. Most probably a certain time of imprisonment is allotted to the little worm, and after this period has elapsed, should its deliverance not be effected by passive emigration, it dies, and its body, which has not in the least increased in size, is, without changing its outward form, transformed into a brittle glassy mass composed of carbonate of lime. This process of calcareous degeneration also takes place in other encysted and dead intestinal worms, in which, however, the form does not always remain

perfect, but is either more or less altered, or else entirely destroyed.

Other encysted intestinal worms succeed in obtaining nourishment through the walls of their prison, and thus go on growing. Those, however, amongst the encysted entozoa, which are intended by nature to attain their sexual maturity only in the digestive organs of certain animals, cannot arrive at this condition in their cysts, and must, in spite of their further growth, fail in the attainment of the power of sexual propagation, until the animal they inhabit is devoured by the predacious creature, whose intestine is alone fitted to allow of the passage of these asexual intestinal worms into the last stage of their development. I may cite here, as examples, various *Nematoidea* and *Cestoidea*. In many marine fishes the liver is covered with capsules, which often contain a well-grown nematoid worm more than an inch long. Naturalists have arranged this parasite among the intestinal worms as *Ascaris capsularis*, *Filaria piscium*, *Filaria cystica*. I have never met with one of these round worms containing developed sexual organs. As in their further organization no less than in their whole form, these ascarids most strikingly resemble certain sexually-mature nematoid worms, namely, *Ascaris osculata*, *spiculigera*, *angulata*, *aucta*, and others, which infest the alimentary canal of seals, cormorants, divers, gulls, and predacious fishes, the idea presents itself that these encysted, not yet fully developed *Nematoidea* belong to either one species or another of the last-named *Ascaridæ*. More particular inquiries into the subject will instruct us what species of these round worms, which are now considered to be distinct species, will hereafter have to be united into a single group, as younger or older individuals of one and the same species. The sexless *Ascaris incisa*, represented in fig. 17,

Fig. 17.

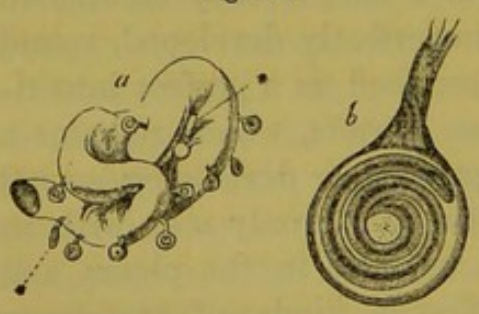


Fig. 17. A convoluted piece of the intestine of the mole (nat. size), with many flattened, pedunculated cysts, each enclosing a little thread-worm, attached to its peritoneal investment. * * Such cysts viewed edgewise. *b*. A single capsule much magnified, so as to render the enclosed thread-worm more clearly visible. This parasite belongs to that group of the *Ascaridæ* whose intestine is provided anteriorly with a cæcum directed upwards.

which occurs encysted in the peritoneum of the Mole, must also be awaiting its transference to the intestine of some other anial, where it attains its sexual maturity.

From what has been stated we gather, that those young intestinal worms which are developed at a distance from the nidus of their parents, succeed, in the end, in reaching those situations where they may repeat the part of their progenitors, and reproduce their kind. Impelled by instinct, the embryo parasites, that have only just left the egg, disperse in all directions, so that they may immigrate into other animals, whenever an opportunity offers. Many thousands of these embryos of necessity never attain their object, on account of the numerous casualties that beset them in their wanderings. The point of most importance is, that these embryos should select, as their temporary residence, such creatures as will be consumed by those animals, whose intestine served their parents, as a habitation and birth-place for their young. But many of these young, immigrated, intestinal worms will have undertaken their journey in vain, and will die without reaching the last stage of their development, in consequence of their host and involuntary carrier, escaping from his natural enemies. Again, many embryos will be led astray by the migratory impulse, and pass into animals which never become the prey of those whose digestive canal is their goal. This I conclude from the frequent occurrence of one and the same kind of encysted parasite amongst the most various kinds of animals. And I shall regard those embryos which have failed in their object, in the way I have mentioned, as parasites which have *strayed* in their wanderings.

I know that there may be some difficulty in accepting this theory of *strayed* parasites; it will be urged that these, like all animals, have a sort of instinct implanted in them which never allows them to enter upon any fruitless undertaking, and which, without their knowing it, impels them to strike out the right path in their wanderings. If this were really the case, every tænioid embryo must some day become a tape-worm, and we should be so overrun with nematoid worms that, judging from the enormous quantity of their eggs, the animals they infest would perish by wholesale from their countless numbers. Those who have occupied themselves with the collection of intestinal worms, must only too frequently have remarked, however, that these parasites are by no means so numerous as the immense numbers

of their eggs would lead one to suppose. This inclines one more readily to the belief that nature, seeing how full of difficulties is the way of these parasites to sexual development, has endowed them with the power of generating millions and billions of eggs, when once they have overcome these obstacles and developed the necessary sexual organs. Through the unceasing spread of cultivation, the decrease and extirpation of certain animals, on the one hand, and the taming and increase of domestic animals on the other, the conditions of life of many of the intestinal worms have become so changed, and so widely different from their original state, that, with their inherent tendency to wander, many of these parasites must often go astray.

The *Trichina spiralis*, which is found in human beings, and which, as I have already shown, must be regarded as an encysted sexless nematoid worm, can hardly have found its way into the muscular substance of man, except by having gone astray; so also the *Cysticercus cellulosæ*, which not unfrequently appears in the muscles and other organs of man, and which, as I shall hereafter show, is an asexual tænioid agamozooid. The *Cysticercus cellulosæ* changes to a sexual tape-worm in the intestinal canal of certain mammals; the *Trichina spiralis*, after transportation to another and more favorable situation, will also become sexually developed. That these two parasites should have been originally intended to pass into and establish themselves in, human beings, waiting for the opportunity to emigrate, which could only occur when the person who harboured the sexless parasite should be devoured by some appointed beast of prey, is an idea insufferable to the dignity of man,[1] which every reader of these lines must of necessity reject; and admit, instead, that the appearance of these parasites in the interior of man can only be accounted for by the fact of their having gone astray.

Many of the young of the intestinal worms which only attain the last stage of their development in the digestive canal of the *Vertebrata*, chance, in the course of their wanderings, to pass into the wrong organs; for instance, into the muscular substance, the liver, or the peritoneum; here they remain undeveloped,

[1] To appeal to the "dignity of man" in a zoological argument appears a little out of place. Nature seems to have had small respect for our "dignity" when she created the fleas, lice, and bugs which annoy us; the *Ascaris*, which reduces us below the level of the beast; the *Strongylus*, and the *Echinococcus*, which destroy us outright.—[Ed.]

whilst other individuals of the same brood, which have found their way into the intestine of the same animals, arrive at maturity. *Triænophorus nodulosus,* infesting fishes, offers an example of this, developing into a long, sexually-mature tape-worm, in the intestines of pikes and perch, whilst at the same time these fishes often harbour other tape-worms, which are, however, always sexless, in cysts in their liver. These last must certainly be also regarded as strayed parasites.

In these wanderings through the bodies of vertebrate animals, the very small embryos of the intestinal worms, boring their way through the walls of the blood-vessels, not unfrequently fall into the current of the circulation, and so become distributed with the blood. In fact, embryos of intestinal worms, to which the name of *Hæmatozoa* has been given, have often been discovered in the blood of birds, reptiles, and fishes.[1] These *Hæmatozoa* neither become further developed in the blood, nor increase in size; but many of them, whilst circulating in the vascular system, stick in the narrow blood-vessels of certain organs which afford a more congenial soil for their further growth; such at least is the most natural way of accounting for the appearance of intestinal worms in the brain, in the spinal marrow, and in the eyeball of man and animals. These organs are so completely enclosed, partly by bones, and partly by dense fibrous membranes, that before the existence of animals in the blood was known, it was supposed quite impossible for parasites to penetrate into such well protected organs; but that they must have originated then and there through equivocal generation. The *Cysticercus cellulosæ,* the *Cœnurus cerebralis,* and the *Echinococcus hominis* and *Veterinorum,* have long been known as occasional denizens of the brain and of the spinal marrow in men and animals, and have, up to the very latest times, served as a stronghold for the supporters of the doctrine of equivocal generation. Having subjected these very cystic worms to particularly close investigation, in order to confute this fabulous hypothesis as to

[1] I have collected together the different observations on hæmatozoa in the article "Parasiten" in Wagner's 'Hand-wörterbuch' already referred to (p. 648); subsequently, new facts of the same kind have been published by Ecker (Müller's 'Archiv.,' 1845, p. 501), Wedl (in his 'Beiträge zu Lehre von den Hämatozoen,' Wien, 1849), and Leydig (in Müller's 'Archiv.,' 1851, p. 227).

[See also the remarkable observations of Bilharz, 'Ueber das Distoma hœmatobium,' 'Zeitschrift für Wiss. Zoloogie,' 1852. This diœcious hæmatode is found in the portal blood of man.]—[Ed.]

their mode of origin, I will give an account of the results below.

With the migrations and alternation of generations amongst the intestinal worms, two other phenomena are connected, which were formerly quite unnoticed, but which now, since attention has been directed to them, have been very generally observed. In the neighbourhood of those sexually perfect intestinal worms which, in their wanderings, are subject to the alternation of generations, only eggs, or recently hatched embryos are met with; but the further stages of development are always wanting, since they first make their appearance after the emigration of the young to other places. Further, many of these intestinal worms, taken whilst in the act of migrating, are never found below a certain size, since they do not commence their wanderings, either as nurses or larvæ, until they have already reached a certain stage of their development.

In this chapter I have expressed myself somewhat at large upon the wanderings and alternation of generations of the intestinal worms, in order that I may be fully understood in the ensuing ones, when I have occasion to refer to this generation by agamozooids. The history of the propagation of certain parasites, in the foregoing pages, may seem new and astonishing to many readers, and yet the alternation of generations is not more wonderful than metamorphosis. We have been so long acquainted with the way in which metamorphosis takes place in the higher and lower members of the animal kingdom, that we no longer wonder at the various transformations of the frog, nor gaze with surprise when a caterpillar becomes a chrysalis, and after a certain time flies off in the shape of a butterfly. The many to whom the metamorphosis of frogs and insects is a common appearance, forget that there was once a time when it was unknown, and when the multiplication of grubs and larvæ was ascribed to equivocal generation, their true origin being unsuspected. It is to be hoped that a time will also arrive when the complicated alternation of generations will not be known to naturalists alone.

CHAPTER II.

ON THE TAPE-WORM.

The tape-worms (*Cestoidea*) constitute a peculiar group of entozoa which only attain their perfect development and sexual maturity in the intestinal canal of vertebrate animals. Those that are often met with in other internal organs than the intestinal canal, in fishes, reptiles, birds, or mammals, or in the interior of inferior animals, are always sexually undeveloped. In this sexless state the tape-worms wait for an opportunity to pass out, which occurs when the creature they lodge in is swallowed by some vertebrate carnivore. It is only when such sexless tape-worms have thus passively effected their entrance into the intestinal canal of the appropriate *Vertebrata*, that their sexual maturity takes place, and they become capable of laying eggs for further propagation. In this wandering the remarkable circumstance occurs, that whilst these undeveloped tape-worms pass into the stomach of the predacious animal in a more or less uninjured condition, and establish themselves in its intestine, the soft parts of their former host yield to the digestive juices. Numerous examples attest the truth of this assertion, but of these I will only select the following.

In certain neighbourhoods the sticklebacks are infested by a kind of tænioid parasite which lies free in the cavity of the abdomen, and often distends the body to an unusual size. This parasite has been before described under the name of *Bothriocephalus solidus*. In the stickleback its joints and sexual apparatus are undeveloped and always remain so.

In the intestine of many of the water fowl which prey upon these sticklebacks, a sexually matured tape-worm, known to naturalists by the name of *Bothriocephalus nodosus*, has been found. This is no other than the *Bothriocephalus solidus* in a further stage of development; after its former host, the stickleback, has been digested in the bird's stomach, it is released,

and entering uninjured into the intestine of its new owner, arrives at sexual maturity. The extent of development in each individual will be found to be in proportion to the time it has passed in the bird's alimentary canal after its passive emigration. Since the connection between *Bothriocephalus solidus* and *nodosus* has been known, helminthologists have ceased to regard these two tænioid worms as different species, but in accordance with the suggestion of Dr. Creplin, who first drew attention to the relationship between them, they have been considered to be different stages of the same species, *Schistocephalus dimorphus*. A similar instance occurs in the case of the *Ligula simplicissima*, infesting the abdominal cavity of various species of carp, whose sexual organs are, and remain, undeveloped, as long as the worm remains within the fish, whilst when the latter is eaten by, and the entozoon thereby conveyed into the intestines of, ducks, divers, waders, and other water-fowl, it attains perfect sexual development. In the older helminthological systems the sexually matured *Ligula simplicissima* is described under various specific names, sometimes as *Ligula sparsa, uniserialis*, sometimes as *Ligula alternans*, or *interrupta*.

Many *Cestoidea*, during their youth, lodge in the liver and peritoneum of fishes. In these organs they excite a morbid exudation whereby a membranous substance is produced, which forms a kind of capsule round the worm, and thus, as it were, excludes it from the organism. This act, by which the organs seek to free themselves from such unwelcome guests, I shall designate by the name of "extrinsic"[1] encysting process already given in page 25.

The encysted *Cestoidea* increase in size, but do not become sexually mature, from the absence of the conditions necessary to the attainment of this state; and should their hosts perish without having been devoured by an animal of prey, the sexless *Cestoidea* will die with them, without leaving any progeny. Various examples illustrate the truth of this statement.

Mention has already been made (at page 29) of the *Triaenophorus nodulosus* which infests the intestine of the pike and the perch, where alone it is to be met with sexually mature. Helminthologists, however, give other localities of this worm, as

[1] I have added the word "extrinsic" here to distinguish this from the self-encysting process by exudation from the entozoon itself.—[Ed.]

certain species of salmon, for instance; but in these it is met with encysted in the liver and peritoneum, and is invariably sexless. The examination of the livers of a great number of the *Salmo salvelinus* caught in the Königs-see, near Berchtesgaden, recently convinced me that this worm can only attain to sexual maturity in the alimentary canal of perch and pike. These livers were covered with various sized cysts containing larger or smaller individuals of *Triænophorus nodulosus*, which were every one sexless. The *Cestoidea* were obviously awaiting their sexual development, which could only take place when they should have passed into the intestine of a pike or perch, a migration which may easily occur, since the lake is full of such predacious fish, who are always ready to seize upon the salmon. When the *Triænophorus nodulosus* has come to sexual maturity and has deposited its eggs in the intestine of the pike and perch, these eggs will be passively extruded, since the cestoid embryos are never hatched in the spot where they have been laid; that is to say, they will be expelled with the fæces through the anus of the fish. With regard to the ultimate fate of the young of the *Triænophorus nodulosus*, I can state nothing from actual knowledge, but from what has been observed in regard to other intestinal parasites, I think one may infer that the young of the former will be impelled by the same instinct, to wander, and to seek that situation which can alone develop their powers of reproduction. Although I am unacquainted with the form in which the embryos of the *Triænophorus nodulosus* commence their wanderings, yet, having found tolerably large individuals of this species encysted in the livers of various fishes (of salmon, sticklebacks, millers' thumbs, burbot, blennies, and others), I conclude that the young *Triænophori* have merely made these a temporary resting-place, and are waiting till their host becomes the prey of the above-named fishes. Whether the young of the *Triænophorus* always avail themselves of an intermediate host by whom they may be conveyed into the intestine of their final entertainer, the pike or perch—I cannot say. It is possible that they may pass, at once, into the pike or perch whenever an opportunity offers; but under these circumstances it would be by no means immaterial into which organ of the fish they first entered. Since the intestinal canal is the only proper place for their sexual development, they will, by passing into the liver or

peritoneum, most assuredly meet with the same fate as if they had entered the other fishes; they will become encysted, and may grow within the cysts, but will not become sexually mature unless their owner be swallowed by a larger creature of his own kind.

Similar migrations and strayings from the right path are exhibited by the *Tænia longicollis* and *ocellata*, which are met with, not only in the intestine, but also encysted in the livers, of salmonoid and percoid fishes, in a jointed but sexless state. I must call attention to the fact that the *Triænophorus nodulosus*, in its sexless condition, is not uncommonly found in the liver and peritoneum of the sticklebacks; and as this fish, on account of its spines, is generally avoided by the pike and perch, the immigrated young of the *Triænophorus* in the stickleback must be certainly regarded as having gone astray.

The various species of the cestoid genus, *Tetrarhynchus*, enumerated by systematic helminthologists, are nothing more than imperfectly developed, sexless forms of *Cestoidea*, which, in their fully developed and sexually mature condition, have been regarded as belonging to an entirely distinct genus. Following Rudolphi, later helminthologists termed this latter genus, *Rhynchobothrium*. The genus *Tetrarhynchus* must now, however, be set aside, since the forms of animals hitherto included in it must be considered as younger stages of development of true *Rhynchobothria*. The head end of many kinds of *Tetrarhynchus*, with its four protractile proboscides, armed with numerous sharp grappling hooks and provided with four moveable suckers, in form and organization resembles so exactly the fore part of the *Rhynchobothria*, that there is no doubt as to the origin of the former.

The *Rhynchobothria* in their full grown and sexually matured state, are only found in the digestive canal of plagiostome fishes. In order to secure their migration into other individuals of this order, the young of the *Rhynchobothria* make use of such marine creatures as serve the former for prey. As the ravenous shark or ray is not over nice in the choice of its food, it is not necessary for the young *Rhynchobothria* to select any particular marine animal as its temporary host, in order to introduce itself into their intestine. Indeed one meets with *Tetrarhynchi*, (that is to say young *Rhynchobothria*), in soles, flounders, mullets,

in cod-fish, gurnards, congers, and even in cuttlefishes. From the encysted condition in which the parasites are found in these animals, it is easy to see that they have only made them their temporary abode. That they are by no means at home in these intermediate hosts seems evinced by their lively and restless proceedings; their four protractile feelers, with their countless hooks, being employed most cleverly, to bore through the flesh, the walls of the stomach, and the tunics of the various organs.

The head end of the young *Cestoidea* takes, at a very early period, the form of that of their sexually matured parents, whence it is easy to distinguish to which species of cestoid worm they belong. According to Van Beneden's suggestion, helminthologists have designated such undeveloped sexless *Cestoidea* whose heads have already assumed the parental form, as "scolices." From their physiological signification these cestoid scolices have been compared with the larvæ of insects; the comparison, however, is not tenable, since every insect larva leaves the egg in its larva-form, and is gradually changed into an individual insect capable of propagation, whilst the scolices of the *Cestoidea* do not come forth from the egg in the condition of scolices, nor are converted into a reproductive tape-worm individual, but by sexless generation give birth to a great number of sexual individuals. Here, therefore, we have to do, not with metamorphosis, but with an alternation of generations in which the scolex-forms play the part of agamozooids.

In studying the history of the *Cestoidea*, it must be strictly borne in mind that all scolices, whatever be their form, are only different stages of cestoid worms; and, on the other hand, that the cestoid embryos leave the egg in a form widely different from a scolex. The embryos of the genera *Tænia* and *Bothriocephalus* are precisely similar, widely different as are the forms of the so-called "heads" of these worms subsequently. The whole organization of these embryos seems specially adapted for the purpose of digging and boring, a circumstance most favorable to them in their wanderings. They possess, in fact, a very small rounded body, (fig. 18 *a*), at one end of which six little hooks or claws project, two in the middle and two on each side. Each pair of these hooks is differently shaped from the others (fig. 18 *b*, *c*, *d*), and they are so arranged, that one of each form is placed on each side of the embryo, so that the two innermost, the two middle,

and the two outermost hooks are alike.[1] If one of these embryos is set free (which can be effected by carefully crushing the eggshell between two plates of glass), without destroying the living tape-worm embryo, its various movements may be examined under the microscope. It draws its round body together, and enlarges and contracts its transverse diameter, and by this operation protrudes, first in front and then at the sides, the six little hooks from that end of its body which, from these hooks being situated there, I shall call the fore part. The observer can readily understand how, by such movements, the excessively minute cestoid embryo succeeds in boring its way into the moist and tender soft parts of other animals and in traversing their interior in all directions.

Fig. 18.

When the cestoid embryos have, by immigration and subsequent encysting, lodged themselves in an animal by whose means they will eventually become introduced into the alimentary canal of one of the *Vertebrata*, and so reach the last stage of their development, a remarkable metamorphosis takes place by which they pass from the condition of embryos into that of scolices. In the interior of the embryo an organ is developed which gradually assumes the characters of the head of a cestoid worm, and always resembles that of the particular species from which the embryo has been produced. When once the head of the cestoid is fully formed it may become extruded from the interior of the body, and the entire worm then constitutes a scolex.

The whole of this process of scolex-development may be justly compared to an internal budding.

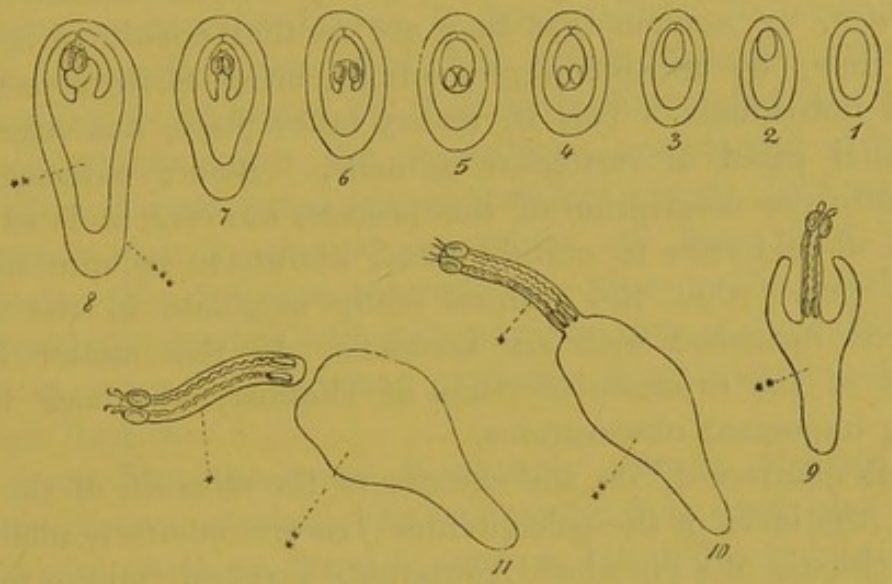
According to the view of the earlier helminthologists, the scolices consist of the head end of a cestoid worm, out of whose posterior extremity the proper body is subsequently developed. In regard to the organization of the scolices, it must be particularly noted that they possess no oral aperture, and are only nourished by the absorption of fluids through the surface of their

Fig. 18. The embryo of *Tænia crateriformis*. The six hooklets are formed upon three different types; *b*, *c*, *d*, represent the three kinds more highly magnified. *b*. One of the two uppermost, *c*, one of the two median, and *d*, one of the two outermost hooklets.

[1] See my description of these hooks in Burdach's 'Physiologie,' Bd. ii, 1837, p. 204.

integument. In the substance of their bodies, spherical or discoidal bodies of a glassy appearance are often seen: these

Fig. 19.



have frequently been mistaken for eggs, whereby the nature of these creatures has been wholly misconceived. The particles are, in fact, nothing more than organized deposits of carbonate of lime. Integumentary concretions of the same kind are found in many other of the lower animals. The scolices have also been described as young cestoid worms: we shall, however, more readily comprehend the various stages through which the *Ces-*

Fig. 19. Series of developmental stages of a *Tetrarhynchus*, or rather of a scolex of *Rhynchobothrium*, represented diagrammatically, and partly after Van Beneden. The cestoid embryo becomes a *receptaculum scolicis* by the development of a scolex in its interior. With the progressive development of the scolex the body of the embryo (*receptaculum scolicis*) and the cyst containing it, increase in dimensions. 1. The encysted embryo. 2. The encysted embryo developes a bud internally, and so becomes the receptacle of a scolex. 3. The internal bud out of which a scolex is being developed has increased in size. 4. In the interior of the bud the head of the future *Tetrarhynchus* appears, and the suckers become perceptible. 5. The head of the *Tetrarhynchus* becomes more clearly defined; and, 6, acquires a neck. 7. The neck elongates, the four hooked proboscides make their appearance. 8. The more elongated neck is forced to become curved in order to accommodate itself to the narrow space in which the scolex is undergoing its development. 9. The adult scolex out of its cyst, and beginning to be extruded from its receptacle. 10. The extruded scolex; which, in 11, has separated itself from its receptaculum. In this condition, the scolices of the *Rhynchobothria* have hitherto been described as species of *Tetrarhynchus*. * Scolex. ** Receptaculum scolicis. *** Cyst. For the further development of the *Tetrarhynchus* into a *Rhynchobothrium*, see fig. 23.

toidea pass, and be better able to bring them into unison with the phenomena presented by the other entozoa, if, as has been suggested above, we regard the scolices as agamozooids.

In taking this view of the nature of the scolices of the *Cestoidea*, we assume that they are in that condition in which they may, by asexual reproduction, bring forth a series of sexual individuals. This in reality takes place, but only in the intestinal canal of vertebrate animals. Before entering more fully into the description of this process, however, it is advisable that I should refer to certain facts, known to helminthologists, which prove that the scolices really originate in the cestoid embryos furnished with six hooklets. In this matter I avail myself of the evidence of Stein of Tharand, who made the following important observations.

Stein discovered,[1] on the exterior of the stomach of the meal-worm (the larva of the coleopterous *Tenebrio molitor*), small cysts about the size of a pin's head, containing a cestoid embryo in whose body a more or less fully developed scolex was included. In those that were fully developed Stein recognised a perfect *Tænia* head. Stein distinctly convinced himself that the *Tænia* embryo did not become a scolex by simple growth, but that the latter was produced by budding in the body of the embryo, having, amongst the numerous cysts that he examined, the most various transitional forms, from the simple unaltered embryos to those containing a fully developed scolex. During this development of a scoliciform agamozooid the embryo changes its form, growing rather longer on the one side than the other, in consequence of which its six hooks become irregularly scattered over the upper surface of the body and lose their import (fig. 26); a clear proof that they do not enter into the formation of the circlet of hooks of the tænioid scolex. It is clear that these tænioid embryos arrive by immigration into the abdominal cavity of the meal-worms, and in fact, as Stein suspected, through the walls of the stomach; for this observer more than once found tænioid embryos in the stomach of meal-worms, which, judging from their form, could only just have been hatched. Most likely these minute embryos had been taken in with their food by the meal-

[1] See his 'Beiträge zur Entwickelungsgeschichte der Eingeweidewürmer,' in the 'Zeitschrift für Wissenschaftliche Zoologie,' edited by Kolliker and myself. Bd. iv, 1853, p. 207.

worms, and so conveyed into the stomach. By the help of their six hooklets they pierce its walls and pass into the perivisceral cavity. Having got thus far, the immigrated tænioid embryos find in the meal-worms a fitting intermediate residence, and the scoliciform agamozooid begins to be developed in them. The embryos having thus completed their wanderings, and arrived at their appointed end, throw off their boring apparatus, and play a more subordinate part, the scoliciform agamozooid developed within them, henceforward taking the chief place. The scolex is itself sexless, but by asexual generation will bring forth sexual individuals; this, however, can only take place in the intestine of some vertebrate animal, and it is now the turn of the scolices to wander, in order that they may pass from their intermediate host into their final one.

In doing this the nurse is entirely passive, waiting until its intermediate host shall be devoured by that particular vertebrate animal which is fitted to serve as the nidus for its sexual stage. What vertebrate animal this is, is at present unknown, so that I can only speak conjecturally, and indicate that these meal-worms are the favorite food of various small mammals, such as rats and mice, and of numerous birds, the red-start, for instance; and that the *Tenebrio molitor*, which flies about, and is produced from the chrysalis of the meal-worm, is often caught and eaten by bats, swallows and other insectivorous animals. A minute comparison of the scolices of the meal-worms with the heads of tape-worms from the intestines of the animals I have named, may perhaps assist in filling up the gaps in these observations.

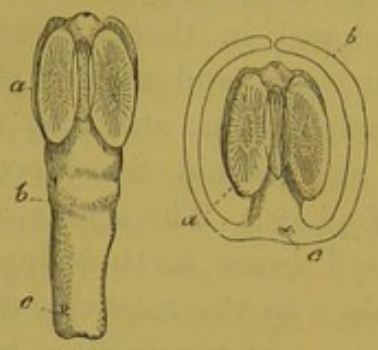
Another observation made long ago by myself, and which has since been more fully worked out by Dr. Meissner, serves to confirm the observations of Stein. In the substance of the pulmonary sac of *Arion empiricorum*, (a slug), I discovered many encysted scolices,[1] from the shape of whose heads I judged that they formed part of the developmental series of a *Tænia*. The form of these scolices, is, however, very different from that of those which are found in the meal-worms. Their head end is always involuted in the short, and only partially developed, hinder part of the body (fig. 20, 21).

One sees in the whole arrangement of the various parts of the

[1] See my essay 'Ueber den Generationswechsel der Cestoden,' in the 'Zeitschrift für Wissenschaftliche Zoologie,' 1850, p. 202.

encysted scolex with the retracted head, that the latter is produced in exactly the same manner as that of the meal-worm scolex described by Stein, viz., by internal budding, although I have never chanced to meet with such earlier stages of development of the scolex in the slug. However, that they do directly emanate from *Tænia* embryos, is evidenced by the three pair of hooks or claws, which are firmly fixed in the substance of the surface of the posterior extremity of the body of these retracted scolices. We are indebted to Dr. Meissner for the discovery that these six claws are the remains of the embryonic condition of these cestoid agamozooids.[1] The encysted scolices in the slug, therefore, are perfectly analogous in form and signification to the cestoid agamozooids in the meal-worm, with this difference, that the first are not elongated into a tail at the posterior extremity. The encysted cestoid agamozooids in the slug are evidently the result of the immigration of cestoid embryos, and yet in spite of the fact that these parasites are very frequently met with in slugs,[2] I have not been able to determine which species of *Tænia*-embryo passes into this form of scolex, nor into the intestine of what particular vertebrate animal the scolex of the slug must emigrate, to give rise to sexual individuals.

Fig. 20. Fig. 21.



The sexually matured individuals of the *Cestoidea* are no other than their full-grown joints; in which are developed the male and female genitalia, by whose co-operation eggs capable of reproduction are generated, and the continuation of the species is secured. Such a sexually-mature, hermaphrodite joint of a cestoid worm, which, in certain genera of *Cestoidea*, when fully formed, separates from the body of the scolex with great readiness, is denominated a *Proglottis*. The formation of these

Fig. 20. A scolex of *Tænia* from *Arion empiricorum* included within its receptacle. Fig. 21. The same extruded. *a*. Head of the scolex. *b*. Receptaculum scolicis. *c*. The remains of the six embryonic hooklets.

[1] See the 'Zeitschrift fur Wiss. Zool.,' B. v, 1854, p. 383.

[2] I have found, not only in Breisgau, but also in Schleswig, and here in Bavaria, the lung of the red slug (*Arion empiricorum*) very frequently infested by the encysted scolices referred to above; and I learn from Dr. Meissner that the same is the case with the slugs found in the neighbourhood of Hanover.

Proglottides takes place at the posterior end of the scolex by asexual reproduction; viz., by a simple process of growth and division. If we compare this process with the phenomena of the Alternation of Generations, we shall discover in it all the essential characters of the latter. The matured joints, or the sexual individuals, of the *Cestoidea* in their proglottis form, produce a brood of embryos armed with six hooklets, which are quite dissimilar in shape from their parents, the *Proglottides*, and remain so, since at a later period they assume the scolex form, and take on the functions of an agamozooid. From the posterior end of the body of such a scoliciform agamozooid a series of joints are developed; that is to say, a generation of sexual individuals, which again present the original proglottis form. In their organization, the *Proglottides*, apart from their sexual apparatus, so far resemble the scolices, from which they have been produced, that they possess no oral aperture, and moreover are subject to a deposit under their integument, of those glassy calcareous particles which I have already mentioned.

It seems, at first, paradoxical to say that the joints of a tape-worm, which have hitherto been believed to be mere parts of one animal, should be considered as individuals; but whoever will observe, with an unprejudiced eye, a fully developed *Tænia* with its sexually matured joints, must be convinced that it is no simple animal, but one composed of many individuals. The joints of a *Tænia*, when quite mature, become detached from one another with the greatest ease; the separated joints for a long while preserve their form and remain quite fresh and lively, being even capable of locomotion, and always seeking to disburden themselves of their eggs before dying. Even the older naturalists had regarded the single, separate joints of a *Tænia* as separate individuals, whilst others again, described the joints of the common tape-worm of Man, (*Tænia solium*), as "*Vermes cucurbitini.*" Later helminthologists, however, rejected the idea that a *Tænia* was composed of "*Vermes cucurbitini,*" and especially objected[1] to the view of Vallisnieri and Coulet,[2] who maintained that the *Tæniæ* were produced by the mutual adherence of a number of the cucurbitine worms into a complex, jointed whole.

[1] See his 'Considerazioni ed Esperienze intorno alla Generazione de' Vermi del Corpo umano.' Padoa, 1710, p. 63.

[2] 'Tractatus de Ascaridibus et Lumbrico lato.' Lugduni Batavorum, 1729, pp. 37, 56, &c.

Blumenbach stood almost alone among the later naturalists, when, to the astonishment of his contemporaries, he defended the incorrect views of Vallisnieri.[1] The older inquirers were quite right in regarding the various isolated *Tænia*-joints as separate individuals, though they certainly fell into a gross error in imagining that the long, many-jointed *Tænia* was composed of coalesced *Vermes cucurbitini*; in point of fact it is exactly the reverse, the *Vermes cucurbitini* owing their origin, to the breaking up of the *Tænia* into separate joints. That the first impression of these old naturalists was a just one is evident, from the circumstance that even modern helminthologists, meeting now and then with solitary *Tænia*-joints, with whose origin they were unacquainted, have regarded them as peculiar individual worms, and described them accordingly. A remarkable intestinal worm described many years ago by Diesing, under the name of *Thysanosoma actinoides*, which was found in the intestine of a species of deer from Brazil, created much sensation amongst helminthologists, until Diesing himself, not long ago, acknowledged it to be an isolated joint or *Proglottis* of *Tænia fimbriata*.[2] Dujardin described the isolated joints of various *Cestoidea* as forms of a peculiar genus of worms, to which he gave the name of *Proglottis*.[3] Although he believed them to be originally derived from *Tæniæ*, he was, notwithstanding, so firmly convinced of their independent existence, that he made them into a separate genus in his systematic arrangement of the *Cestoidea*.[4] However, since more has been known of the alternation of generations, whereby the origin of one animal from another of quite dissimilar form, and their mutual relations to each other have been explained and familiarized, helminthologists generally admit that a cestoid worm is really a colony of animals. How difficult naturalists formerly found it, to accede to a view that since the time of Blumenbach had been a subject of ridicule,

[1] 'Gottingischen Anzeigen von gelehrten Sachen,' 1774, No. 154. Blumenbach regards the anterior, smallest, joints of a tape-worm as the oldest, and he accounts for their being smaller than the posterior joints by supposing that they have to give up the nutriment which they take in, to their successors which have fastened on to them behind. He compares these worms to the mass of authors, the more modern of whom merely suck out of their immediate predecessors, that which these had extracted in the same way from still older writers.

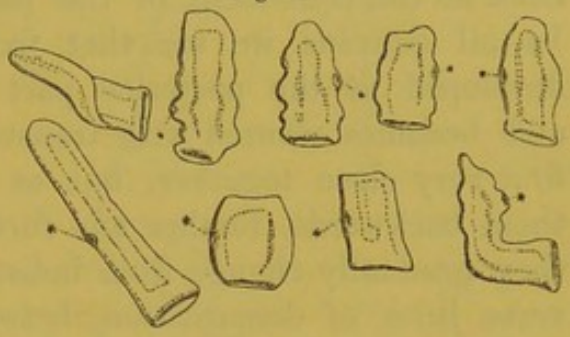
[2] See his 'Systema Helminthum,' i, 1850, p. 501.

[3] 'Annales des Sciences Naturelles,' t. xx, 1843, p. 341.

[4] 'Histoire Naturelle des Helminthes,' 1845, p. 630, pl. 10, figs. A, B, C.

is shown by F. S. Leuckart, who, rightly appreciating the true meaning of these jointed *Cestodea*, and yet apparently not liking to oppose his contemporaries too strongly, merely expressed himself thus upon the matter.[1] "I was almost inclined to consider the jointed tape-worms as organisms, in which each joint is a separate animal, and the whole a compound animal, as has been before supposed by many distinguished zoologists." Steenstrup returned to the idea (loc. cit., p. 103) that the tape-worms are compound animals, and subsequently, Van Beneden[2] in his admirable monograph, has pointed out and illustrated with excellent figures many striking and conclusive examples of the truth of the same view. In looking at Coulet's (l. c., figs. 2—16,) illustrations of the separate joints (*Proglottides*) of a *Tænia solium* in their various states of contraction and expansion, (fig. 22,) it is impossible not to admit the conception that these animal bodies are independent existences. The separate joints (that is, the *Proglottides*,) of the other species of *Tænia* are perfectly similar to these; and the *Proglottides* described by Van Beneden in the cestoid genera *Echeneibothrium*, *Phyllobothrium*, *Anthobothrium*, *Acanthobothrium*, *Onchobothrium*, *Calliobothrium*, and *Tetrarhynchus*, (all characterised by clearly marked articulations), closely resemble them.

Fig. 22.



Since we must henceforward regard these *Cestoidea* as compound animals, we may compare the many-jointed tape-worm with a polypidom, although we must not forget that there are some points of difference between the two. In the compound polypes, the individuals bud out in various directions and relative positions from their parent stock, whereby the polypidom, accord-

Fig. 22. Single and separated sexually mature joints of *Tænia solium* (of the natural size) with lateral sexual apertures, (*) and in different states of expansion and contraction (after Coulet). Each of these separate joints must be regarded as a sexual individual of the *Tænia solium*, and is the proglottis of this *Cestoid* worm.

[1] 'Versuch einer naturgemässen Eintheilung der Helminthen,' 1827, p. 21.

[2] 'Les Vers Cestoides,' 1850. It is to be regretted that Van Beneden has confined his investigations to the scolices and proglottides, and has not examined the development of the embryos.

ing to its genus and species, receives a specific, ramified, foliaceous, or encrusting form, whilst in the compound tape-worms, the individuals only grow out of the common stock in one direction, and in a single series.

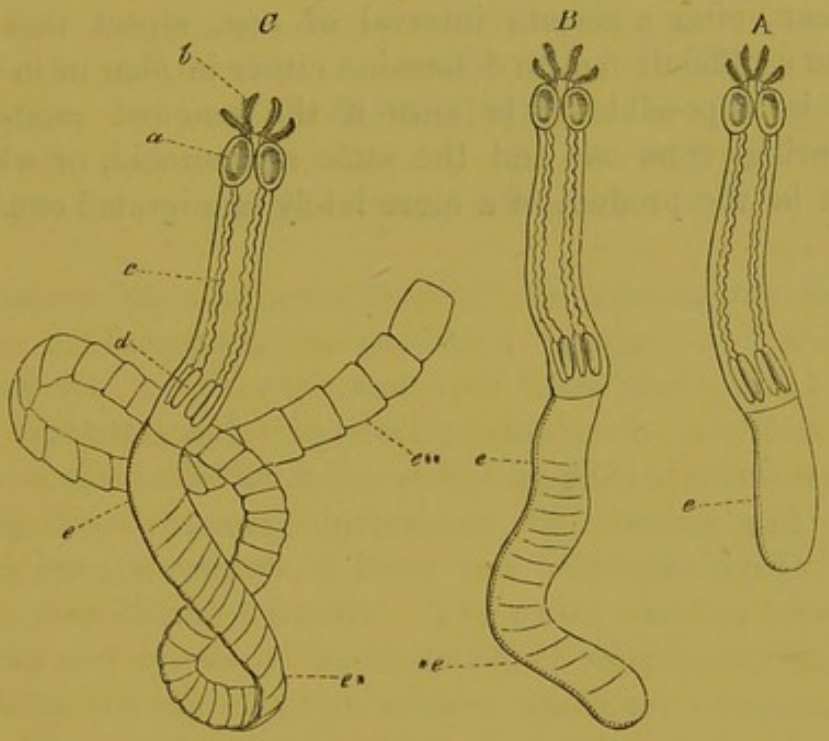
In the *Cestoidea* the stock is the posterior end of the scoliciform agamozooid. In the alternation of generations amongst the *Cestoidea*, there is this peculiarity, that the agamozooid preserves its efficacy and independence, whilst the agamozooids of other animals which undergo alternation either die after producing their brood or pass into it.[1]

We must consider the head of every cestoid worm as the agamozooid still remaining and capable of reproduction, and its neck as the equivalent of the posterior extremity of the scolex. In all cestoids we see that fresh joints are continually being developed at the posterior part of the neck, which lengthens and becomes covered with transverse folds. These folds are at first very close together, but as the process of growth throws them backwards, further and further from their place of origin, they gradually change from indistinct wrinkles into sharp transverse lines of demarcation, between which the substance of the body dilates into a joint (individual), and assumes its specific shape. At a later period, the rudiments of the hermaphrodite sexual apparatus make their appearance in the interior of the joints: and in proportion as the latter move backwards from their parent stock (the neck), so much the nearer do they approach to maturity, through progressive development of their sexual apparatus; and finally they separate themselves from their younger fellows as independent individuals. I must not leave the fact unmentioned that the formation of marked proglottidiform joints does not take place in all *Cestoidea*. In the genera *Tænia*, *Tetrarhynchus* and several others furnished with cephalic hooks and suckers, the development and individualising of the proglottides occurs in perfection. In the genus *Bothriocephalus*, although the joints exhibit a distinct demarcation, they show little inclination to become separate. In *Triænophorus* the articulation is still less marked; whilst in *Ligula* it is obso-

[1] The correctness of this statement appears to be doubtful. The stock of the "*Hydra tuba*" remains after giving rise to a brood of *Medusæ*, and neither dies nor can be said to pass into the brood. The like is true of those *Sertularidæ*, *Diphydæ*, and *Physophoridæ* which give rise to medusiform Zoöids; nor does it seem to be otherwise in the remarkable Trematode *Gyrodactylus* described by Von Siebold himself.—[Ed.]

lescent, being only denoted by imperfect transverse folds on the sides of the body. Here, in fact, many groups of hermaphrodite

Fig. 23.



sexual apparatus become developed close together, in the ribbon-like body of the full-grown agamozooid, but the parts which surround them do not break up into joints. In this respect we may compare a *Ligula*, as a compound animal, with certain polypidoms in which the individuals become, in a similar manner, less distinctly separate from the parent stock.

For how long a time the head end of the cestoid worm can play the part of an agamozooid, and how many sexual individuals such a tape-worm can produce, has not yet been certainly proved. The number of proglottides which a single scolex can bring forth,

Fig. 23. Represents, diagrammatically the metamorphosis of a *Tetrarhynchus* into a *Rhynchobothrium* (after Van Beneden, see also suprà, fig. 19). A. A *Tetrarhynchus* scolex, whose posterior extremity is growing and elongating. B. The elongated hinder extremity exhibits transverse wrinkles which indicate the boundaries of the future joints. C. The posterior end of the same scolex appears clearly jointed, *i. e.* provided with proglottides. The *Tetrarhynchus* has thus become a *Rhynchobothrium*. *a*. One of the four sucking disks. *b*. Protruded part of the four proboscides provided with recurved hooks. *c*. Middle portion of the four proboscidean tubes. *e*. Unarticulated portion of the body. *e** Transversely wrinkled portion of the body. *e*** Articulated part of the body giving rise to proglottides.

must, in many species, be enormous, since many hundred articulations may still be counted, in cestoid worms which have, for months, been giving off numerous joints every day. Whether a cestoid worm, after giving off a series of sexless individuals as joints, can, after a certain interval of rest, repeat this process, would be a difficult fact to determine either in man or in animals, since it is impossible to be sure if the renewed production of joints springs from one and the same agamozooid, or whether it may not be the product of a more lately immigrated one.

CHAPTER III.

ON THE CYSTIC ENTOZOA.

Zoologists have hitherto founded the genera and species of *Cestoidea* on the characters presented by the head and by the fully developed joints only; and even these characters have been but superficially and imperfectly employed, so that a close revision of this order of *Entozoa* has long been necessary. This task has been recently undertaken by Diesing and by Van Beneden, but the labours of these two helminthologists have led them to very different results. The great point in revising the old genera and species of the *Cestoidea* is, to discover what forms of proglottis belong to certain scolices which are commonly found without proglottides (and which, therefore, have long been regarded as distinct genera of *Cestoidea*), and to unite these together. Diesing has not attempted to do this, having apparently no conception of the bearing of the alternation of generations upon the systematic arrangement of the lower animals.

On the other hand, Van Beneden, guided by the light of the alternation theory, has justly recognised and given due prominence to, the affinities of certain *Cestoidea*. To this end the different kinds of scolex require to be more carefully defined than they have hitherto been, and the use of the microscope becomes indispensable. The forms of the apparatus of attachment must be determined and compared with the utmost care, and those hooks and protractile proboscides, armed with more or less moveable hooklets, which are attached to the head of the scolices, are especially adapted, from their varying and well marked figure and disposition, to afford good generic and specific characters. If the form and arrangement of that apparatus of attachment of the *Tæniadæ* which is known as the circlet of hooks, of the proboscis which carries it, and of the sac which conceals it, had been carefully observed, the identity of many so-called species of *Tæniadæ* would long since have been recognised, and the close

relation of the *Cystica* with the *Cestoidea* would not have been a recent discovery. It must not be forgotten, however, that in very many *Tæniadæ*, the scolices lose their circlet of hooks with advancing age, and that in many *Cestoidea*, the suckers of the scolices undergo great changes of form when the development of proglottides commences; in consequence of which it is often very difficult to demonstrate the connection of the older and younger individuals of one and the same species of cestoid. The proglottides of the *Cestoidea*, again, considered as individuals wholly separate from the parental organism, present distinct specific characters, though they are not, perhaps, very obvious at first sight. In these it is the sexual apparatus more particularly which, forming as it does the principal mass of the proglottis, presents excellent specific characters, in the form, dimensions, number, and arrangement of its parts. Van Beneden has the merit of having paid particular attention to these particulars in distinguishing the different species of proglottis.

As I have already hinted, the cystic worms, which were made by Rudolphi into a distinct order of *Entozoa*, are so closely allied to the *Cestoidea* that they have no claim whatever to be regarded as an independent group. Since, in addition, various kinds of scolices have been regarded as distinct genera of *Cestoidea*, it is high time that zoologists should resolve to erase from their systematic arrangements all these groups, which are in reality, based only on our ignorance of the natural history of the *Entozoa*. How great a number of these improper genera have been introduced may be judged by the fact that out of the order *Entozoa cephalocotylea*, alone, established by Diesing,[1] and containing thirty-two genera, ten genera must be eliminated, namely, *Echinococcus, Cœnurus, Cysticercus, Piestocystis, Anthocephalus, Acanthorhynchus, Pterobothrium, Tetrabothriorhynchus, Stenobothrium, Scolex*. Many of the *Entozoa* arranged under these genera are merely the scoliciform agamozooids of other *Cestoidea;* a fact which is demonstrated not merely by their undeveloped and sexless body, but by their habitation, since they are almost all found, not in the alimentary canal of a vertebrate animal, but in its other viscera. Another portion of these genera consists of the cystic worms, which are also nothing but the scolices of certain *Cestoidea*, with this difference, however, that a portion of their body is enlarged into a vesicle.

[1] Diesing, 'Systema Helminthum,' i, p. 478.

To prove that the cystic Entozoa are the sexless and variously degenerated nurses of the *Cestoidea,* I must once again return to the already mentioned (page 36) development of the cestoid agamozooids. When the cestoid embryo has immigrated and established itself in any organ of an animal, it begins to develop a scolex by internal budding, which takes the form of a *Tænia*-head or of a *Tetrarhynchus*-head, &c., according to the origin of the embryo. The embryo then increases and becomes enlarged by the growth of the scolex, which it holds enclosed within the distended walls of its body. These walls pass internally into the neck of the scolex, directly over the spot whence the scolex sprung. On the external surface a funnel-shaped but narrow depression is developed opposite the scolex, from which a canal stretches through the neck of the scolex to its head. This canal, after the full development of the scolex, permits its evolution, by which means the hinder end of the scolex passes immediately into the body of the embryo. The fully developed scolex in the interior of the embryo appears as if it had drawn itself inwards by a process of involution; but observation teaches us that the scolex is originally developed in this involuted condition, instead of becoming retracted when it has attained its full development. The material required for the development of the scolex and of the embryo which invests it, is taken up by the latter by absorption through its integument. This absorptive power of the integument may vary in amount, and produce different results, which are, of course, dependent upon the quantity and quality of the fluids, and upon the special peculiarities of the organs of the animal in which the embryo has taken up its residence. Under particular circumstauces it may easily happen that an embryo should absorb, through the surface of its integuments, more nutritive fluid than is necessary for the growth and development of the scolex. The surplus nourishment then gives rise to exuberance of growth and to degeneration of the body of the embryo. The immediate consequence of the accumulation of absorbed and unemployed nourishing juices will be a vesicular enlargement of the embryonic body; and the cestoid embryo in this condition has received the name of a cystic worm. The development of the scolices in such cystic entozoa is sometimes more, sometimes less, advanced.

I have already shown that the cestoid embryos, after leaving their eggs, must wander, in order to establish themselves in

fitting animals and become developed into agamozooids. If anything is to come of these wanderings, however—that is to say, if the cestoid embryos are to propagate, two main conditions must be fulfilled. In the first place, the localities chosen for lodgement must afford suitable nourishment; in the second place, the animal selected by the embryo as its home must afford an opportunity to the scolex developed within it, to reach the appointed intestinal canal of a vertebrate animal, either by active or passive emigration, in order to accomplish its sexual development and propagation. That the cestoid embryos should often go far astray in their wanderings, whereby these conditions are left unfulfilled, is easily conceivable; however, these strayed cestoid embryos do not perish, but notwithstanding the degeneration which they undergo retain sufficient tenacity of life to be capable of further development and propagation. Objections have been raised by some to the opinion I have just expressed, that strayed cestoid agamozooids may undergo dropsical degeneration; and it is urged, on the contrary, that the vesicles of these hydropic scolices are a necessary organ, a sort of reservoir of nutriment. In answer to this, I can only repeat what I have already said in another place,[1] in vindication of my views, viz., that I cannot see why one should deny the possibility of a degeneration in form among worms, since it is observed in the higher animals, where the modifications produced by climatic influences and change of food are at once admitted as "Races." If, in many of these races, an extraordinarily luxuriant growth of hair shoots out over the whole body, or on various parts of it; if the horns of certain races of ruminants have the property of lengthening, or even of doubling; if the ears of certain kinds of our domesticated animals become disproportionately long and drooping; if, in some races, local fatty degeneration takes place in the shape of a fatty tail or hump, why should not an accumulation of serous fluid in certain parts of the body, giving rise to a local dropsy, take place amongst the lower orders of animals, when these are exposed to the influences of an unusual mode of life?

The processes of degeneration to which the cestoid embryos are liable in their wanderings are of two different kinds; either the body of an embryo lengthens posteriorly into a solid caudal appendage, or else it becomes distended into a watery vesicle by

[1] 'Zeitschrift für Wiss. Zoologie,' Bd. iv, 1853, p. 407.

the accumulation of serous fluid. It may even happen that both these forms of degeneration attack the same embryo. For the better comprehension of these occurrences of excessive growth and of degeneration in the course of the development of the cestoid embryo, I will distinguish the part of the body of the embryo which becomes distended by the formation of the scolex, by the name of the *receptaculum scolicis*. Strictly speaking, this receptacle is no other than the embryo itself (see page 37, fig. 19**).

Whilst the scolex is becoming developed within the receptacle of a cestoid embryo, many and various changes of form may be going on in the embryo itself, *pari passu* with the vesicular change, and these have given occasion to the erection of the various genera of cystic *Entozoa*.

Those Tænioid embryos whose receptacle has become distended to sometimes a larger, sometimes a smaller vesicle, have been hitherto included in the cystic genus *Cysticercus*. If such a *Tænia* scolex extrudes itself from its vesicular receptacle, it is obvious that the posterior part of the scolex passes immediately into the vesicle, and the presence of such a caudal vesicle in the scolex of a *Tænia* has been raised into the generic character of the *Cysticerci* (figs. 24, 25). Exposed to certain external influences, the receptacle of a *Tænia* scolex becomes distended into a very large and spacious vesicle, from the inner surface of which, a number of *Tænia* scolices develop by budding; this form of cystic worm has been elevated into a genus, *Cœnurus*. Another kind of Tænioid embryo becomes metamorphosed into a vesicle of larger or smaller dimensions, from whose inner surface countless scolices pullulate; these, however, become detached, and lie freely within the cavity of the closed parental vesicle. Upon this form the genus *Echinococcus* has been founded.

Fig. 24. Fig. 25.

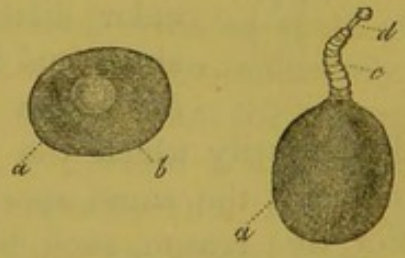


Fig. 24. *Cysticercus cellulosæ* from the human brain, of its natural size, and with a retracted anterior extremity. Fig. 25. The same *Cysticercus* extruded. *a*. The caudal vesicle of the Cysticercus, which is nothing but the *receptaculum scolicis* (or hinder end of a Tænioid embryo), distended into a vesicle by the accumulation of water. *b*. The retracted anterior end of the body of the Cysticercus contains the tænioid scolex developed by budding within the embryo. *c*. The transversely wrinkled anterior extremity of the Cysticercus. *d*. Its head and neck, which conjointly form the Tænioid scolex.

The changes of those cestoid embryos in which the receptacle grows out behind into a long, solid, caudal appendage, are very remarkable. The receptacle of the *Tænia* scolex which Stein observed in the meal-worms, developes such an appendage (page 38). I must remark here, that Stein considers the scolex receptacle as a cyst, and the caudal appendage as a part of it, which is certainly not correct, for if the tail does not appertain to the embryo, how could the six hooks have come to lie upon the upper surface of the tail, where, according to Stein's express assertion, he invariably saw them?

Fig. 26.

The *Piestocystis crispa*, which attains a length of from one to three inches, is nothing more than a *Tænia* scolex evolved from its receptacle, with a very long, ribbon-like, solid, caudal appendage.[1] In certain *Tetrarhynchi* the receptacle also becomes distended into a vesicle, and such forms of *Tetrarhynchi* were united by the older helminthologists into the genus *Anthocephalus*. From this genus Diesing separated, under the names of *Acanthorhynchus* and *Pterobothium*, those *Tetrarhynchus* scolices, the posterior end of whose receptacle is produced into a very long, unjointed, caudal appendage. As in these degenerations, the form and size of the vesicular dilatations of the receptacle, as well as the shape and length of its caudal appendage, are often dependent upon accidental external influences, the dissimilarity which the parts present in different individuals of one and the same species of scolex become readily intelligible. For this reason, such diagnostic characters of genera and species as are derived from the conformation of the vesicular enlargements and of the caudal appendages of the receptacle must be discarded on account of their uncertainty. Only on the form of the scolex (the so-called head of the sexually matured cestoids) is it possible to base constant generic and specific characters. A

Fig. 26. A *Tænia* scolex from the meal-worm retracted within its receptacle; partly after Stein. *a*. Head of the scolex. *b*. Receptaculum scolicis. *c*. Caudal appendage of this receptacle, on which lie scattered the six embryonic hooks.

[1] This animal was formerly described by Rudolphi as *Cysticercus crispus*. I have demonstrated, however, in the 'Zeitschrift für Wissenchaftliche Zoologie,' (Bd. ii, 1850, p 223), that this worm possesses no caudal vesicle.

striking proof of this is offered by the *Cysticercus cellulosæ*, of which the diagnosis invariably states, that it possesses a "vesica caudalis, elliptica, transversa." This form of caudal vesicle is, however, only found in such *Cysticerci* as are imbedded in the muscles of men and pigs; in individuals of the same species residing within the human brain, the caudal vesicle assumes the most various and irregular forms (figs. 24, 27, 28). Even in the *Tænia*-scolex observed by Stein,[1] the caudal appendage of the receptacle assumed the greatest variety of shapes.

Fig. 27. Fig. 28.

If attention had been earlier directed to these circumstances, the cystic *Entozoa* would not have been made into a separate order from the *Cestoidea*. The older naturalists and helminthologists took a far more just and unprejudiced view of the matter, when, from the similarity of the degenerated cystic scolices with the heads of certain *Cestoidea*, they divined the close connection of the two orders, and described the *Cystica* as *Tænia vesicularis*, *Tænia hydatigena*, *Tænia cellulosæ*. Even the dropsical condition of these cystic worms did not escape the eyes of the older naturalists, since already, in 1691, Tyson[2] described the *Cysticercus tenuicollis* as *Lumbricus hydropicus*.

But after Linnæus had animated naturalists with his spirit of arrangement, they worked with such good will and so exclusively, at the perfection and completion of his system, that for a long time it seemed to be thought enough if generic and specific names were given to newly discovered animals, and their due systematic place assigned. The inquiry into the natural history of these animals hence became quite a secondary consideration, and with such a one-sided study of animal forms, it could hardly fail to happen that not merely varieties, but also young states, larvæ, and even fragments of animals already known, should be described and systematically arranged as peculiar animals.[3]

Figs. 27, 28. Two *Cysticerci* rendered quite irregular by constriction of their vesicles; from the human brain, natural size. *b*. The retracted anterior edge of the scolex. In fig. 28 the constricted parts are produced into tubes.

[1] See 'Zeitschrift für Wiss. Zoologie,' Bd. iv, 1853, p. 207, and pl. x, figs. 12—14.

[2] 'Philosophical Transactions,' 1691, No. 193, p. 506, figs. 1—4.

[3] Ehrenberg's and Diesing's systematic works on *Infusoria* and *Entozoa*, testify that this faulty and one-sided method finds followers even now.

It is to the peculiarity in the form of the *Cysticercus fasciolaris* that we owe the recent recognition of the connection between the cystic and the cestoid worms. The similarity of the head of this *Cysticercus* with that of the *Tænia crassicollis* is so great and striking, that I can scarcely claim much merit for having been the first to entertain the idea which I thus expressed:[1] the *Cysticercus fasciolaris* is nothing more than a strayed or degenerated *Tænia*, which may, however, attain the normal form of a tape-worm if transported to the intestinal canal of a suitable animal. Both forms are so intimately related to each other in form and organization, that I am not surprised at Allen Thomson, of Glasgow, having recognised the agreement of the *Cysticercus fasciolaris* with the *Tænia crassicollis* without, as it seems, being aware of my researches and publications upon the subject.[2] The mutual affinities and relations of these two *Entozoa* are the more perceptible, because during the growth of the *Cysticercus fasciolaris* the joints of the future tape-worm are developed between the caudal vesicle and the head. These joints certainly remain narrow, and develop no sexual apparatus, but they give to the scolex, which in this stage of development always has the head extruded, such a characteristic appearance, that its identity with the *Tænia crassicollis* can only be denied by those who regard the caudal vesicle as the sole test of systematic position. If we examine the *Cysticercus fasciolaris* or altered *Tænia crassicollis*, more narrowly, we shall perceive in this tape-worm the same peculiarity which occurs in the various other cestoids, for instance, in *Triænophorus nodulosus*, *Tænia longicollis* and *ocellata*, viz., that the body of the tape-worm grows from the back part of the head and neck of the scolex, even before this has reached the intestine of the vertebrate animal adapted to its sexual development (see page 32). There is, however, an additional departure from the ordinary course in the *Tænia crassicollis*, that during the development of its scolex its receptacle undergoes a dropsical degeneration.

As the *Cysticercus fasciolaris*, which is found always encysted, in the livers of various rodents—most commonly those of rats and mice—is often met with several inches long, the caudal vesicle terminating the elongated body of such individuals, which

[1] Compare my article "Parasiten," l. c., pp. 650, 676.

[2] 'Zeitschrift für Wiss. Zoologie,' Bd. iii, 1851, p. 97.

never grows in the same proportion, is very minute, which seems to render probable the notion that the caudal vesicle of these cestoids has not originally been a scolex receptacle, but is rather the hinder end of the tape-worm in a diseased and dropsical state. Such dropsical enlargements are undoubtedly found occasionally in single joints of the *Cestoidea;* but if attention is paid to the gradual development of the tænioid *Cysticercus fasciolaris* it will be seen that its caudal vesicle is at an early period a true *receptaculum scolicis.* I have before me many examples of the *Cysticercus fasciolaris* which present the most various stages of development, the oldest being from five to seven inches long, whilst the youngest were no more than from one to four lines. Amongst the older individuals the long body is distinctly jointed; in the younger the short body merely presents very close transverse wrinkles as indications of the future joints. At all these different ages, the caudal vesicle appears to have about the same size, and indeed in the older individuals is even somewhat smaller. The youngest individuals, of one and one and a half lines long, have no body at all; in these the head and neck of the scolex only project, in the slightest degree, from the vesicular receptacle, whilst these parts, in the smallest individuals, which possess a perfectly rounded vesicle, are still, as I have most distinctly convinced myself, concealed in the receptacle. If one were carefully to inspect the livers of many different species of murine rodents, one would certainly come upon still younger forms of development of the scolex of *Tænia crassicollis;* one might even be so fortunate as to discover the embryo hooks on the external surface of the receptacle of the developing scolex, although the discovery of these six hooks of the cestoid embryo, on account of their excessively small size, is a very difficult task. In the *Cysticercus pisiformis,* which, always encysted, infests the livers of hares and rabbits, I have succeeded in meeting with the scolex receptacle, in a very early period of development, with a diameter of half a line. The internal gemmation had just begun, the four suckers of the future scolex were scarcely sketched out, and the still soft apices of the circlet of hooks were only just in process of formation (see fig. 33, *d, e*), but I sought in vain for the six embryo-hooks on the external surface of the receptacle. In pursuing these inquiries, however, a very interesting phenomenon was presented by the livers of some wild rabbits of this neighbour-

hood. Besides containing many very small scolices of *Cysticercus pisiformis* just developing, there were a number of short, pale-yellow lines crossing each other in all directions, which, upon microscopical inspection, did not seem to be sharply defined, and appeared to consist of a granular substance. I suspect that this substance was the product of an exudative process, occasioned by the creeping about of the immigrated *Tænia*-embryos in the substance of the liver; probably it would be gradually reabsorbed when, in course of their development and metamorphosis, these embryos had become converted into the dropsical receptacles of *Cysticercus pisiformis*.

CHAPTER IV.

ON THE ORIGIN OF THE CESTOID AND CYSTIC ENTOZOA.

The extraordinary likeness of the *Cysticercus fasciolaris* of rats and mice with the *Tænia crassicollis* of cats, and the fact that the above rodents are the principal food of cats, and that, moreover, the joints of the *Cysticercus fasciolaris* enclosed in the cysts in the livers of rats and mice are never sexually developed, inclined me to believe that this sexless *Cysticercus fasciolaris* would be changed into a sexually matured *Tænia crassicollis*, as soon as the animal it lodged in should be devoured by a cat. For, under these circumstances, the liver of the devoured rodent would be digested in the cat's stomach, and the cystic worm, freed from its cyst, would be transplanted to a place where, after casting off its caudal vesicle, it might, as a *Tænia crassicollis*, attain to sexual maturity in the intestine of the cat. Fully as I was persuaded of the possibility of such a transformation of the *Cysticercus fasciolaris* into *Tænia crassicollis*, yet I could hardly conceive that the other species of *Cysticercus*, in which no jointed body was developed between the head and caudal vesicle of the scolex, could become *Tæniæ;* and this appeared the more unlikely, as I had often found cysts that had perished, in which the *Cysticerci* they contained were dead, and lay shrunk and buried amidst inorganic calcareous deposits. Such a calcareous degeneration of the cysts[1] must assuredly render the cestoid scolices incapable of propagation; still all do not meet with this fate, for under favorable circumstances they can, even in spite of their dropsical receptacle, subserve the multiplication of sexual cestoids; that is to say, when they are transported into the intestinal canal of animals fitted for the development of *Proglottides*.

That the cystic *Entozoa* can thus become changed into sexual

[1] I have more particularly described this process in the 'Zeitschrift für Wissenschaftliche Zoologie,' Bd. ii, 1850, p. 225.

cestoids, has been proved by Küchenmeister, of Zittau, by experiments first made by him, and published in various medical and natural history periodicals.[1] It was a very happy thought of his to institute experiments of feeding animals with *Cysticerci*. I have repeated and extended these feeding experiments, and can substantiate what Küchenmeister was the first to make known, viz., *that certain cystic Entozoa become Tæniæ in the intestinal canal of dogs*.

The chief condition for the success of these experiments is, that the cystic worms should be lively, or at least capable of being revived when administered; to which end they must be made use of directly, or at the most a few hours after, the death of those animals which yield them. As long as the organs of the mammals in which these parasites abound remain warm, one may be sure that the worms are still living; with the cooling of the infested organism, they become gradually languid, and at last seem quite dead, but from this state they can be restored to life, even after the lapse of several hours, by the application of warmth. When I was not certain whether the cystic worms I was using for my feeding experiments were still living or not, I threw them into luke-warm water, and then only made use of those individuals which had by this means been re-animated.

To produce tænioid worms out of cystic worms, I caused the latter to migrate passively into the intestinal canal of puppies by feeding these with them. Puppies of about a week or two old were most suitable. They lapped up the milk in which the cystic worms were mixed very readily; those which exhibited no particular appetite at the moment had their jaws held open and the milk poured down their throats, so that the swallowing of the worms was secured. At first I made use of cats, rabbits, and Guinea-pigs, also, for these experiments; but they afforded me no satisfactory results.[2] But the dog, as I shall presently show, is by his mode of life naturally obnoxious to those cystic worms with which I experimented, and hence the experiments with puppies necessarily succeeded.

[1] The first notice is given in Günsburg's 'Zeitschrift für Klinische Vorträge,' 1851, p. 240.

[2] All the feeding experiments cited in the following pages were carried on in the year 1852.

1. EXPERIMENTS OF FEEDING WITH CYSTICERCUS PISIFORMIS.

The cystic entozoon, known by the name of *Cysticercus pisiformis,* is a very common inhabitant of the liver and peritoneum of hares and rabbits. Cysts as large as a hazel-nut are frequently disseminated completely through the substance of the liver of hares, and these cysts are not unfrequently found hanging down like bunches of grapes from the external surface of the liver; in rabbits the great omentum and the mesentery are generally full of these cysts. Commonly such a cyst only contains a single *Cysticercus pisiformis;* but two are also sometimes enclosed in a common cyst. In Breslau, the rabbits which were sold in the markets in the spring months of 1852 were almost invariably infested by this *Cysticercus,* whence I made use of them at the Physiological Institution in that place for my feeding experiments. The results of these experiments were published in the inaugural dissertation[1] of my pupil, Dr. Lewald, who took a very active share in them; subsequently I gave some account of them myself in the 'Zeitschift für Wissenschaftliche Zoologie,' Bd. iv, 1853. The number of *Cysticerci* which I administered at once in these experiments was various, seven, twenty, forty, and sixty. In all cases, the *Cysticerci* were left enclosed within their cysts, and in these experiments, as in all subsequent ones, I wrote down in my journal, the precise time of feeding, the number of the cystic worms made use of, and the dogs fed with them, subjecting these last, after feeding, to strict watching and careful attention.

Of experiments tried with *Cysticercus pisiformis* upon ten dogs, the following are the results, which I repeat from the report I made in my essay in the Zeitschift cited above. When the encysted *Cysticerci* are devoured, it is the cysts which are first attacked by the gastric juice in the dog's stomach, and then the caudal vesicle is consumed; but not, however, the remaining part of the *Cysticercus,* so that of the whole *Cysticercus pisiformis* nothing more is left than the whitish round body which was enclosed in the caudal vesicle, and which consists of the head and neck of the animal involuted within its body, or, in other words,

[1] This dissertation appeared at Berlin in 1852, under the title 'De Cysticercorum in Tænias metamorphosi pascendi experimentis in instituto physiologico Vratislavensi administratis illustrata.'

is the scolex. Even before the caudal vesicle is digested, it frequently shrinks and collapses, its thin contents being discharged, probably by exosmosis, into the thicker fluid of the stomach. Accompanying the latter, the remaining portions of the *Cysticerci*, viz., the tailless bodies with their involuted neck and head, pass into the duodenum through the pylorus. Having reached the duodenum, the heads and necks of the *Cysticerci* are extruded, in order that they may find places of attachment by means of their suckers and hooks, between the villi of the intestine, where they may await the growth and further development of the other parts of their body.

During the first hours of their sojourn in the small intestine, these outstretched tailless *Cysticerci* (scolices) often present a bloated œdematous appearance ; but by degrees the body becomes thinner, probably parting by exosmosis with its superabundance of fluid, and in this manner establishing an equilibrium with the more or less viscous chyle. In all these *Cysticerci* the posterior end is clearly the place where, at an earlier period, the caudal vesicle was attached, as is evinced by a sort of scar, like a notch or incision, from which at first very delicate flakes of membrane depend, the remains of the digested caudal vesicle. Already, after a day or two, the worms begin to exhibit a growth, in which only the body takes part, the neck and head being already fully developed, whilst the worms were still within the peritoneum of the rabbits. Whilst the bodies of the worms, as yet unjointed, and only provided with very close transverse wrinkles, increase in length, the transverse wrinkles also multiply ; and if the growth of the body goes on uninterruptedly, the transverse wrinkles, after a day or two, change by degrees into distinctly marked articulations ; the joints, which are at first very short, lengthen, and there appears either on the one lateral border or on the other a kind of papillose elevation, which afterwards becomes the aperture of the sexual organs. In this condition the ingested worms have exactly the appearance of a *Tænia*, and only betray their origin by that scar on the terminal joint of their body, of which I have already spoken. After remaining twenty-five days in the dog's intestine they have become *Tæniæ*, of from ten to twelve inches long. The growth of these *Tæniæ* goes on without intermission, the posterior joints increasing in size, and the reproductive organs in the interior developing more and more, whilst at the hinder limit of the neck fresh joints are continually

produced from the transversely wrinkled anterior part of the body. In three months these *Tæniæ* attain the length of from twenty to thirty inches and more.[1] In such *Tæniæ* the posterior joints seem to have reached their full sexual development. In some of these tape-worms the last joints become cast off, a proof of their having attained their sexual maturity. The eggs contained in the fully formed joints are perfectly developed, and contain an embryo, furnished, in the usual manner, with six moveable hooks.

After having thus obtained sexually developed *Tæniæ*, that is to say scolices with sexually matured *proglottides*, from the *Cysticercus pisiformis*, I was enabled to decide to which species of tape-worm these scolices, as the head end, and the *proglottides*, as joints, belonged, and I recognised in them the *Tænia serrata*, which had long been known to infest the intestine of dogs. The form of the head, the number, shape, and arrangement of the hooks encircling the head, the construction of the joints, and of the sexual organs within them, the form of the developed eggs, all persuaded me that I had educed the *Tænia serrata* out of the *Cysticercus pisiformis*.

Perhaps some of my readers may doubt the conclusion I drew from the above-mentioned experiments, and may object—How could I be sure that the dogs which I fed with the *Cysticerci* might not have come by the tape-worms known as *Tænia serrata* in some other manner? This objection occurred to myself, and all the more strongly since in searching the intestinal canal of dogs fed with *Cysticercus pisiformis* I often met with thread-worms and tape-worms of another kind (*Tænia cucumerina*), among individuals of *Tænia serrata*. So that the question naturally arose whether, in the same way as individuals of the dog's thread-worm (*Ascaris marginata*), and the ordinary dog's tape-worm (*Tænia cucumerina*), had found their way into the intestine of the dogs experimented upon, so these individuals of the other rarer tape-worm (*Tænia serrata*) might not also have arrived there without any assistance of mine. I can, however, bring forward the following demonstrative evidence to substantiate my assertion, that the individuals of *Tænia serrata* which I discovered in the course of these experiments were really produced from *Cysticercus pisiformis*. I have repeatedly searched the

[1] With regard to these different stages of development, see the figures in Lewald's 'Dissertation,' cited above.

intestines of puppies of the same litter as those I had used in my other experiments, and have never found *Tænia serrata* in them; but, on the other hand, I have very commonly met with *Ascaris marginata* and *Tænia cucumerina*. I must here remark that I only made use of parlour and house dogs for my purpose, and it is in these that both the above-named parasites ordinarily appear, the *Tænia serrata* more commonly infesting hunting dogs. Still further confirmation of my view is afforded by the important circumstance that after feeding the dogs with *Cysticercus pisiformis*, the number of tape-worms of the species *Tænia serrata*, which were found more or less developed in their digestive canal, agreed exactly with the number of *Cysticerci* I had given. Another circumstance worthy of observation, and strongly confirmatory of my view, is, that the size and the condition of development of the *Tænia serrata* in the intestine of the dogs that had been fed with *Cysticerci*, exactly corresponded with the time that had elapsed since the period of feeding.

2. EXPERIMENTS OF FEEDING WITH CYSTICERCUS TENUICOLLIS.

The slender-necked *Cysticercus* is very commonly met with in the viscera of our fat cattle; as regards its caudal vesicle it is the largest of all the *Cysticerci*, for this often attains to the size of a fist, whilst its head never exceeds that of an ordinary *Cysticercus* in circumference. As these *Cysticerci* were generally brought to me enclosed in their cysts, and as the walls of the cysts were penetrated by a great deal of fat, I always disengaged the tape-worms from their investments before I fed the dogs with them.

First experiment.—In the beginning of May, 1852, I made my first preliminary experiment of feeding with the *Cysticercus tenuicollis* upon a young hound ten weeks old, to whom I gave six *Cysticerci* within four days. A few days afterwards I found, in this dog's intestine, only the head ends of the ingested worms. They were from one to one and a quarter line in length, and consisted of the head and solid neck of the former cystic worm, of which the scolex had alone escaped digestion. In order to ensure the greater success of my experiments, I each time cut off beforehand the voluminous caudal vesicle of the selected tape-worms, and only fed the dog with those which had the neck and head involuted in the cylindrical and hollow body.

Second experiment.—On the 11th May, a second young hound

was fed with twenty-one cystic worms. On the 12th May, he had five, and on the 14th, three more, so that this dog altogether swallowed twenty-nine Cysticerci without their caudal vesicles. On examining the dog on the 17th May, seventeen scolices were found in his small intestine, of which the smallest was from three quarters to one line in length, and the largest two lines.

Third experiment.—A young poodle swallowed, on the 18th June, twelve *Cysticerci*, of which, on the 23d of June, eleven were found as scolices, from one to two and a half lines in length, in the small intestine of the dead animal.

It was then the body of the *Cysticercus* that had perished by digestion, for the short thick body of these scolices was no other than the neck of the *Cysticercus*. It showed no trace of transverse wrinkles, and at its posterior end appeared to be cut off transversely or obliquely, with a sort of hollow scar in the middle, denoting the place where the hollow cylindrical body of the *Cysticercus* had been detached in the dog's stomach.

In uninjured individuals of *Cysticercus tenuicollis* one can easily recognise that portion of the body which, in the small intestine of the dog, becomes the scolex, by putting the uninjured worms into lukewarm water. The worms seem to like the warmth, which corresponds with that of the mammals they infest, moving about in the most lively manner, and stretching out their tubular body (previously contracted into a short, transversely wrinkled, milk-white knot), with the head seated at its extremity on a short, slender, and solid neck, for a long distance. This thin neck appears to be sharply separated from the body of the worm, and easily permits the line of demarcation to be seen, where, at a later period, the head and neck become detached as the scolex.[1]

Fourth experiment.—A young mongrel pug-dog received, at various intervals, two-and-twenty cystic worms; namely, on the 11th July, six; on the 14th July, fourteen; and on the 17th, two. The examination of this dog when killed, on the 5th August, proved that out of these two-and-twenty worms nineteen individuals had passed as scolices out of the stomach into the small intestine, and that their seventeen to three-and-twenty days' sojourn had caused a remarkable growth in their abdominal

[1] Amongst the various figures of the *Cysticercus tenuicollis*, that given by Pallas, (see his 'Miscellanea Zoologica,' 1766, p. 167, Tab. xii, fig. 10; or 'Stralsundisches Magazin,' Bd. i, 1767, p. 69, Taf. ii, fig. 10), exhibits the head and neck marked off from the body of the worm as the future scolex, very distinctly.

end which gave them the appearance of tape-worms. The length of these tape-worms varied with the difference of age from four lines to an inch and three quarters. The shortest individuals evidently proceeded from those scolices which had been only seventeen days in the small intestine of the dog.

In the individuals of four lines long one could trace very close transverse wrinkles gradually appearing behind the neck, always more closely defined towards the posterior part, and denoting, where they became wider apart, the future joints of this portion of the body. The individuals of eight lines long, already possessed a clearly jointed hinder end, the joints increasing in number with the length of the individual. In all the individuals the scar I have mentioned was to be seen on the hinder extremity of the body, or on its last joint. This last joint with the scar, moreover, always appeared smaller and more slender than the preceding ones, from which it follows that it is in that part of the scolex which is situated between the posterior end and the neck that the growth and articulation of the tape-worm takes place. The sexual apparatus was not perceptible either in the interior or on the exterior of the joints of these tape-worms of from seventeen to twenty-three days old.

Fifth experiment.—On the 19th July, eight *Cysticerci* were given to a sporting dog, and on the following day six-and-twenty, to which were added four more on the 22d; so that within four days this dog had devoured altogether eight-and-thirty *Cysticerci tenuicolles*. The small intestine of this dog, which was inspected on the 20th August, afforded thirty-two *Tæniæ* in very different stages of development. In regard to their length, a great difference already prevailed; in the smallest individuals the diameter varied from four lines and a half to one inch and a half, whilst the longest extended from five to ten and a half inches. The consequence of this was that although from nine-and-twenty to two-and-thirty days had elapsed since the *Cysticerci* had been administered, their scolices had most unequally developed, some of them being greatly behindhand in point of growth. I observed the same thing in several other experiments. The reason of this unequal development of the tape-worms may lie partly in the different individuality of the *Cysticerci*, partly in that of the dogs fed with them. In the longest individuals that I obtained from this experiment the development of the joints was, moreover, most advanced; although these joints were always

wider than they were long, still the development of the sexual apparatus, manifested externally by the presence of irregularly alternating sexual apertures on one side or the other, had already commenced within them. In a few of the most developed posterior joints of one individual, I could perceive roundish hard-shelled eggs, which contained the characteristic embryo with six hooks, and in regard to shape, size, number, and arrangement of the investments of the egg, exactly resembled the eggs of the *Tænia serrata*. I must also remark, that in the larger individuals the developed joints were marked, on the upper surface, with transverse wrinkles, which gave their lateral edges a wavy appearance, and that the slightly prominent posterior edge of many of these joints seemed to be faintly and irregularly puckered. Some of the largest individuals had already cast off their hindermost joints; in others, the last "scarred" joint was peculiarly altered; it was much enlarged, but had at the same time taken quite an irregular shape, with blunt projecting angles at the sides; the sexual aperture at the side, and the small scar on the posterior edge, alone betokening its true nature.

Sixth experiment.—A mongrel of poodle and spaniel, which had devoured five *Cysticerci* on the 7th June, and twelve on the 29th June, was killed on the 25th July, that is eight-and-forty days after the first meal, and six-and-twenty after the second. Out of the seventeen *Cysticerci* administered, fifteen were again discovered as sexually matured tape-worms; the smallest were from four to nine inches long, the largest from fourteen to twenty-six inches. In these last the posterior joints appeared already to be longer than they were broad. In other individuals the less elongated posterior joints had a squarish or transversely elongated shape, and upon their exterior surface showed the above-mentioned transverse wrinkles. The hindmost joints were cast off in some of the larger individuals, whilst the rest still possessed the original posterior joint, which was remarkably grown, not being in the least degree inferior in size to the other posterior joints, from which, however, it was essentially distinguished by the small scar on its posterior rounded edge.

Seventh experiment.—From the 21st May to the 5th June, an interval of sixteen days, thirty-one thin-necked *Cysticerci* were administered to a young fox. On the 13th June he was killed and examined; but there was not a trace in his intestines of the *Cysticerci* he had eaten, either in the shape of scolices or of tape-

worms, from which we may venture to conclude that the stomach of the fox had perfectly digested the *Cysticerci* with which he was fed.

I now took much pains to determine the species of these tape-worms obtained from *Cysticercus tenuicollis,* and was astonished to discover that they had all the characteristic features of *Tænia serrata.* The form of the eggs of the tape-worms obtained from *Cysticercus tenuicollis* had first drawn my attention to the *Tænia serrata,* whose eggs, in form and in the number of their investments, completely coincided with the eggs of the tape-worms I had obtained. Comparing the head end of the latter with that of the *Tænia serrata,* I could neither in the outline, nor in the suckers, nor in the hooks of the double circlet, perceive any difference between these *Tæniæ ;* even the fully developed, as well as the less developed joints of these tape-worms, with their transverse wrinkles, reminding one of *Tænia serrata.*

In respect to the negative result of the seventh experiment, I must leave the question open, whether it is not possible that the intestine of the fox is unfit to afford a favorable nidus for the development of the scolex of the *Cysticercus tenuicollis.*

3. EXPERIMENTS OF FEEDING WITH CYSTICERCUS CELLULOSÆ.

The *Cysticercus cellulosæ* occurs, as is well known, in such numbers in the flesh of our domestic pigs, that from a single muscle of one of these animals hundreds of these cystic worms may sometimes be collected ; and even in the flesh and intestines of man, its occurrence is not an unusual phenomenon. For the last reason I was exceedingly anxious to try the result of feeding with *Cysticercus cellulosæ,* in order that I might discover from which kind of tape-worm these *Cysticerci* are produced.

First experiment.—A young dog was fed, on the 22d May, with forty-four *Cysticerci ;* on the 24th May, fourteen more were given him, and on the following day, five-and-thirty. Before the worms were given, they were taken out of their cysts. The dog was killed on the 3d July, which was thirty-nine days after the last feeding, and forty-two days after the first. Only four tape-worms of two inches in length were found in this dog's small intestine. From their appearance, they were evidently the product of the *Cysticerci* which the dog had swallowed.

Second experiment.—Having procured two *Cysticerci* from a

human brain, which, when put into luke-warm water thirty-six hours after the death of the subject, still moved, I would not, few as they were, allow the opportunity to pass of making an experiment of feeding with them; nevertheless the young dog to whom I administered them on the 22d May, and who was killed on the 14th June, that is twenty-three days after receiving them, showed not the slightest trace of a tape-worm or scolex.

Third experiment.—On the 18th June, a young poodle swallowed two-and-forty *Cysticerci* from the pig, deprived of their cysts. The examination of this dog, on the 4th August, fifty-one days after feeding, showed eight tape-worms of different lengths. The smallest individual measured one inch and a quarter, a few others measured five and a half to seventeen and a quarter inches, a larger individual was twenty-five and a quarter inches long, whilst the three largest individuals had attained the length of fifty-one inches. Notwithstanding the length which the worms had attained, and the great number of their joints, I could discover no perfectly developed eggs in any of the latter.

Fourth experiment.—To a young pug-dog two and thirty *Cysterci*, without cysts, were administered on the 11th July, and five-and-forty on the 17th. On the 21st July the dog was killed. On inspecting the small intestine forty-six scolices were found, of which the shortest measured one line, the longest six. All bore the characteristic scar on their posterior extremities. The smallest individuals consisted of nothing else than the head and neck of the *Cysticercus cellulosæ*. The remaining and somewhat longer individuals had a transversely wrinkled body, which as yet bore no traces of joints.

Fifth experiment.—On the 8th August, a young setter was fed with five-and-forty *Cysticerci*, which were still in their cysts and enclosed in flesh. On the 21st August, this dog was likewise killed. In his small intestine only a few tape-worms in course of development, of three fourths of an inch in length, were found.

I must here remark that the dogs I made use of for the second, fourth, and fifth experiments were troubled with the distemper, a thing of common occurrence amongst young dogs, and that the disease had probably had an injurious effect upon the development of the tape-worms. Notwithstanding that these experiments of feeding the dogs with *Cysticercus cellulosæ* afforded no such completely favorable results as the foregoing series, they nevertheless

went far enough to prove that the *Cysticercus cellulosæ* may also, in the intestine of the dog, become developed into a *Tænia*.

The few *Tæniæ* which were obtained from these *Cysticerci* were, moreover, a source of great perplexity to me, for when I attempted to define the species to which they belonged, I was doubtful whether to consider them as appertaining to the *Tænia serrata* or to the *Tænia solium*. The head and perfectly developed joints accorded with either species, only the neck was longer and more slender than that of *Tænia serrata*, so that I was inclined to regard them as *Tænia solium*. Owing to the resemblance of these tape-worms, *Tænia serrata* and *solium*, to one another, I was induced to submit the specimens of *Tænia solium* in my collection to a more searching examination, and to compare them with the examples of the *Tænia serrata* taken out of the dogs. To my no small astonishment I found individuals amongst *Tæniæ* which had been taken from the human subject that were not to be distinguished from *Tænia serrata*. They had the short broad joints with transversely wrinkled integument and undulating posterior edge, just like *Tænia serrata;* the head, too, was formed exactly like that of the latter, though the neck was more elongated. Besides these, there were a few feeble individuals amongst them, which fully corresponded with some of the tape-worms produced from *Cysticercus pisiformis;* and the eggs of the *Tænia solium* were not distinguishable from those of the *Tænia serrata*, so that I was forced to conclude that *Tænia solium* and *Tænia serrata* were identical. In order to obtain a still clearer insight into the matter, I further compared the heads with their apparatus of hooks of *Cysticercus pisiformis, longicollis,* and *cellulosæ* with one another, and in these also I could find no difference.

With regard to the length of the neck, and the circumference and contour of the joints, though there are, as I have already partly shown, discoverable differences, they are not sufficiently marked to rank as distinctive characters of two species of tape-worms, and I must therefore maintain that *Tænia solium* and *Tænia serrata* belong to one and the same species; that they are the extreme forms of a single species, connected by a series of transitional forms.

4. EXPERIMENTS ON FEEDING WITH CŒNURUS CEREBRALIS.

In order to make as sure as possible with these experiments, I took dogs, which I had selected for feeding, into the country with me, to the very place where there were sheep affected by the staggers, and let them swallow the cystic worms fresh from the sheep affected with the disease, that had just been killed. If the parental vesicle were small, and only covered by a few clusters of scolices, they were left in connection with it; but if the parental vesicle had attained a considerable size, it was divided and given in portions to several dogs. (Fig. 29.)

Fig. 29. Fig. 30.

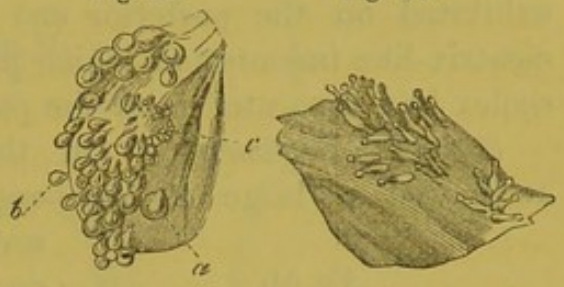


Fig. 31. Fig. 32. Fig. 33.

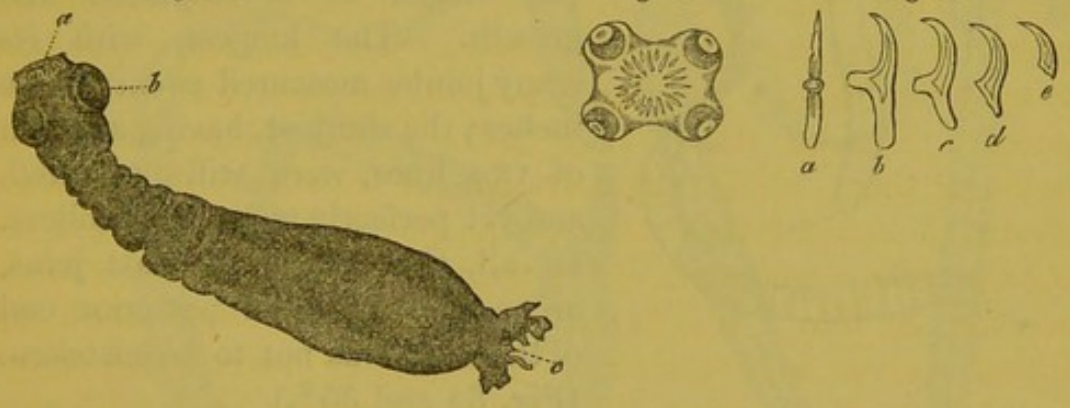


Fig. 29. A portion of the parental vesicle with an attached colony of involuted scolices of *Cœnurus cerebralis* from the brain of a calf, seen from the external surface, of the natural size. Each of the separate rounded corpuscles corresponds with a scolex developing or developed by internal budding: *a*, a complete involuted scolex; *b*, a still imperfect involuted scolex; *c*, many scolices commencing their development.

Fig. 30. A bit of the parental vesicle with a colony of everted scolices of *Cœnurus cerebralis* from the brain of a calf, seen from the external surface, and of the natural size.

Fig. 31. An everted scolex detached from its parental vesicle (fig. 30), and magnified to the same extent as the succeeding figures. *a*. The protruded double circlet of hooks on the cephalic extremity. *b*. One of the four cephalic suckers. *c*. Fragment of the detached parental vesicle.

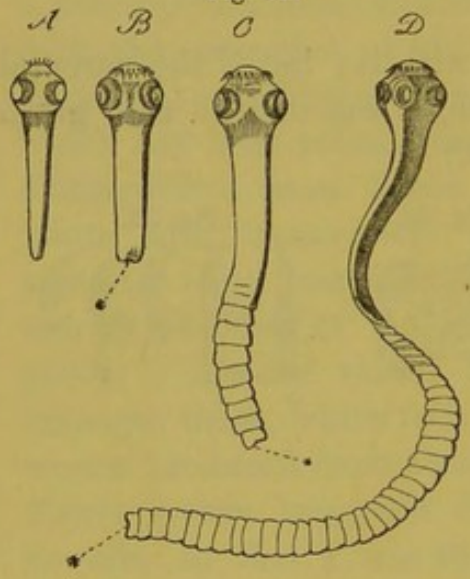
Fig. 32. The head of a similar scolex seen from above; the double circlet of hooks surrounded by the four suckers is seen in the middle.

Fig. 33. Various hooks from the double circlet of the scolices of *Cœnurus cerebralis*. *a*. A long hook of the inferior circlet seen from below. *b*. The same from the side. *c*. A short hook of the lower circlet also viewed laterally. *d*, *e*. Two not yet fully developed and soft hooks from the young buds, fig. 29 *c*.

First experiment.—On the 29th of May, a young dog was made to swallow a cyst with nearly a hundred scolices. He was killed on the 3d of June, that is, five days afterwards, and sixty-five free and everted scolices were found in the small intestines. Their length was from half a line to one and three quarters; they showed no trace of joints or transverse folds, and each exhibited on the posterior end of the body a small kind of cicatrix-like indentation, which plainly denoted the spot where the scolex had separated from the parental vesicle. (Fig. 34, *A*, *B*.)

Second experiment. — On the 6th of June, a young dog swallowed a large *Cœnurus*-vesicle, which was covered with several clusters of scolices. When, on the 26th July, the dog's small intestine was examined, it afforded an enormous number of tape-worms; I counted six hundred and forty individuals in the most various stages of development and growth. The longest, with its many joints, measured twenty-three inches; the shortest, having a length of two lines, were still unjointed, and yet perfectly resembled scolices. In all, the scar on the last joint, or on the unjointed posterior end of the body was not to be mistaken. (Fig. 34 and 35*.)

Fig. 34.

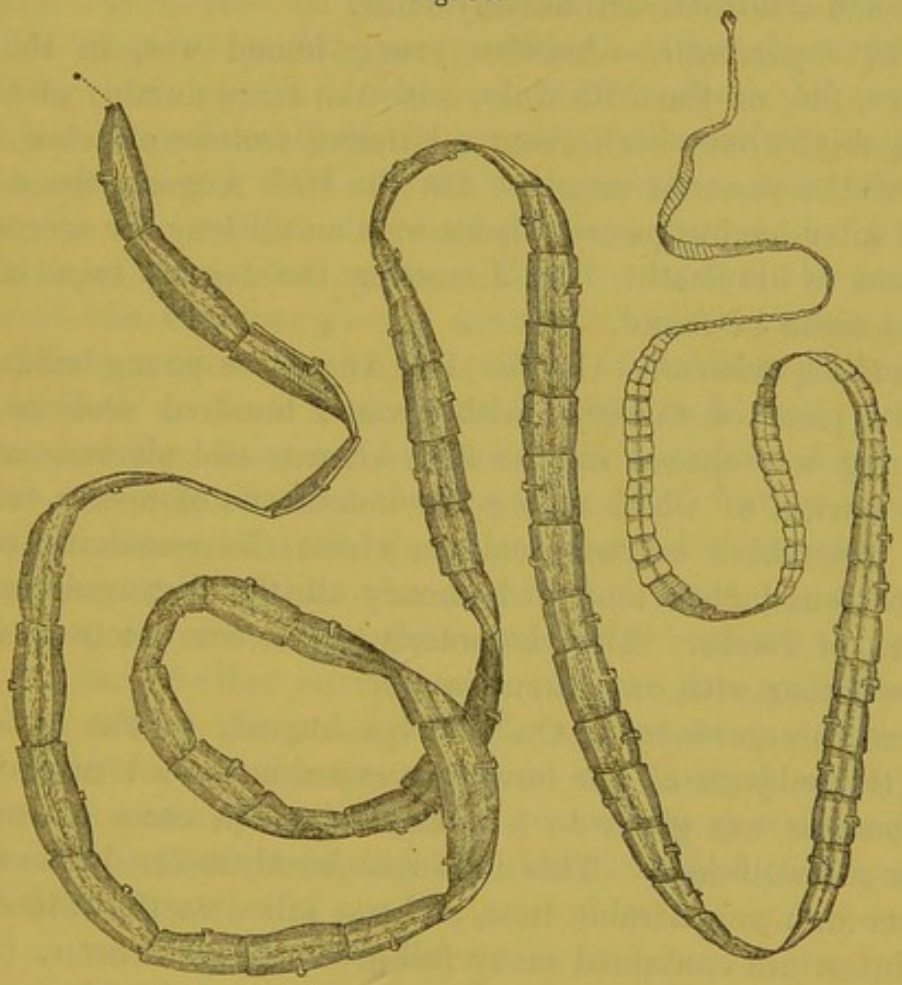


Third experiment.—On the 28th July a young terrier was fed with part of a large *Cœnurus,* and was killed on the 5th August, after a lapse of thirty-eight days. In his intestine there were seventy-one tape-worms variously developed. Three of the least developed individuals were from one and a half to two lines long, and appeared to resemble a scolex most completely, their smooth posterior end being devoid of joints;

Fig. 34. Different tæniæ developed in the intestine of the dog, from the scolices of *Cœnurus cerebralis*. *A*. A scolex one inch and three quarters long, with smooth and protruded body, viewed from the edge. *B*. The same scolex seen from the surface. *C*. A scolex three lines long; the articulation is beginning at the lower extremity. *D*. A still longer and more developed scolex, at whose hinder extremity the formation of proglottides has taken place to a great extent. * Scar, or place by which these *tæniæ* were fixed as scolices to the parental vesicle.

seven others were from four to six lines long, and showed a commencing articulation. A few worms of six lines in length appeared already distinctly jointed. Amongst the remaining specimens that had become fully developed into *Tæniæ,* several had attained the length of from sixteen to twenty-six inches. (Fig. 35). In the longest individuals the development of the

Fig. 35.



eggs was completed, in several shorter ones the characteristic scar on the last joint was wanting, and from the posterior edge of the last transversely truncated joint one could plainly perceive that these *Tæniæ* had already cast off matured joints (*proglottides*), and indeed it so happened that the dog had passed tape-worm joints with his fæces several days before his death.

Fourth experiment.—On the same day with the last mentioned

Fig. 35. A *Tænia serrata,* produced from a scolex of *Cœnurus cerebralis* in a dog's intestine, in thirty-eight days; natural size. The hindermost joints are fully formed proglottides. At the posterior extremity of the last joint the scar (*) clearly indicates that no proglottis has yet detached itself from this tape-worm.

dog, a young hound devoured a similar allowance of *Cœnurus*. He was killed on the 6th August, a day later than the other one. On searching his small intestines eighty-six worms were discovered, of which the majority had grown into jointed *Tæniæ* of three to ten inches in length, whilst several individuals of from four to five lines long only showed faint signs of the transverse wrinkling, and a few of from one to two lines long were still in the scolex condition without any folds.

Fifth experiment.—Another young hound was, in the same manner, fed, on the 28th July, with the same number of *Cœnuri*. There might have been about a hundred scolices attached to the coat of the parental vesicle. On the 10th August, the dog was killed after having passed tape-worms an ell long for several days previous to his death. On dissecting the dog no trace of tape-worms could be found.

Sixth experiment.—On the 1st August, a young setter swallowed a piece of *Cœnurus* with about a hundred scolices on it. The dog was opened on the 23d August, and showed seventy-three worms, of which only a few individuals of one to two lines long, resembled everted scolices, whilst the remaining ones of one to four inches long had already all the distinguishing characters of *Tæniæ*. The characteristic scar was not to be seen in any, whether with or without joints.

Seventh experiment.—On the 1st August, at the same time with the subjects of the foregoing experiments, a similar portion of *Cœnurus* was given to a mongrel-dog, (a cross between the setter and wolf-dog). This dog subsequently suffered from the distemper for a considerable time, and was killed on the 25th August. His intestines contained many full-grown thread-worms, (*Ascaris marginata*), and a few scolices of *Tænia cucumerina*, but no trace of worms that should have resulted from the feeding with *Cœnurus cerebralis*. The distemper had probably occasioned the failure of this experiment.

For the rest, the determination of the *Tæniæ* which I had obtained from these experiments of feeding with *Cœnurus cerebralis* was not difficult, the characters of the *Tænia serrata* being, in all of them, clearly and sharply marked.

It must have been remarked that in the third and fourth experiments (in which the scolices were retained in the dogs' intestines an exactly similar period of time), the *Tæniæ* in the one dog were twenty-two inches long, whilst those in the other

dog were only ten inches. This unequal development of the *Tæniæ* within the same period of time is probably to be accounted for by some special peculiarities of the circumstances into which, in these cases, the scolices of the *Cœnurus cerebralis* had been conveyed.

There is yet another remarkable phenomenon which was brought to light by the experiments on feeding with *Cœnurus cerebralis*. It is that in each separate case, worms, of a very dissimilar stage of growth were produced, although every individual dog had been fed only once with scolices of *Cœnurus cerebralis*. This diversity in the growth of the scolices conveyed at the same period of time into the same intestine, may, perhaps, originate in the various stages of development of the scolices at the time of their introduction. It is known that the parental vesicles of the *Cœnurus* go on growing without intermission, and that fresh scolices are, by the process of budding, continually springing forth on their inner surface. Through these peculiar conditions of the *Cœnurus cerebralis*, older scolices long since perfected, and only awaiting the opportunity of further development, were conveyed into the dogs' stomachs, together with younger ones, some of them only just formed, some, again, not yet fully developed. From this point the older scolices proceeded rapidly to their further development, and to the generation of *proglottides*, whilst the younger scolices grew more slowly, and the youngest forms, whose gemmation was not yet quite completed, were, probably, incompetent to pass from the stomach into the small intestines of the dog, but yielded to the digestive powers of the former.

Experiments on feeding with Echinococcus veterinorum.

The *Echinococcus veterinorum*, which is of such common occurrence in the liver and lungs of our domestic cattle, does not, probably, differ specifically from the *Echinococcus hominis*, whose parent vesicle often attains such an enormous size in the most widely different viscera of man, and by its growth so obliterates the substance of the organs round about it, as to bring about the death of its host. The experiments of feeding with these worms which I made on twelve young dogs and a young fox, I have already fully described.[1] For each experiment

[1] See the 'Zeitschrift für Wiss. Zoologie,' Bd. iv, 1853, p. 409, Taf. xvi, A, fig. 1—9.

the contents of a fruitful *Echinococcus*-vesicle were employed. That is to say, free scolices developed by gemmation were taken out of the *Echinococcus*-vesicle, mixed with luke-warm milk, and poured down the dogs' throats; the latter, after having in this manner been made to swallow a considerable quantity of the young of the *Echinococcus*, had some pure luke-warm milk given to them, which they licked up with avidity, so that these continued acts of deglutition made sure of the small *Echinococcus*-larvæ or scolices being washed into the dogs' stomachs.

The examination of these dogs after death proved, that the scolices of the *Echinococcus veterinorum*, when conveyed into the dog's digestive canal, do not perish, but, under certain favorable circumstances, develop into proper sexually matured tape-worms, possessing only a couple of joints. After the feeding, they passed without obstruction from the stomach into the small intestine of the dogs, where, in proportion to the number of scolices administered, they were found in immense numbers fully extruded from their receptacle, whilst, when in the interior of the parent vesicle, they are almost always to be found retracted within it. After remaining from fifteen to twenty days in the dogs' intestinal canal, these scolices, which when administered were without joints, exhibited a two-jointed body. After twenty-two days, the body was divided into three joints, and from this time forward these little tape-worms ceased to increase in length, or to become further divided, whilst the sexual organs began to appear in the two posterior of the three articulations. The development of the eggs in the sexual organs of these little worms was to be seen twenty-six days after the feeding, and the embryo appeared on the twenty-seventh day.

With the maturity of their sexual organs, and the division of their body into three joints (and hence with the production of only two *Proglottides*), I concluded these worms had attained their perfect state) from the circumstance that amongst the three-jointed little tape-worms in the dogs' small intestine, I discovered several individuals which had already, twenty-seven days after the feeding, thrown off the circlet of hooks. The loss of this apparatus amongst *Tæniæ* furnished with it, is a proof of mature age. When I endeavoured to determine the systematic position of the tape-worms which had been developed from the scolices of the *Echinococcus vete-*

rinorum and which did not exceed one, or one and a half lines in length, there was not a single species of *Tæniæ* among the many admitted by helminthologists, with which they agreed. I was soon convinced that this small species of tape-worm had been hitherto overlooked by helminthologists; for it cannot but be admitted that this transformation of the young of the *Echinococcus* into sexually-matured *Tæniæ* may take place independently of artificial feeding. In our slaughter-houses, similar scolices must certainly often find an opportunity of entering into the intestinal canal of dogs, the *Echinococcus*-vesicle, cut out of the viscera of the slaughtered animals and thrown away, being no doubt frequently devoured by the former. It was such a brood of *Tæniæ* developed from the young of the *Echinococcus* that Rudolphi probably saw, when he believed that he had discovered in the intestine of a dog, young tape-worms, which were assumed to have been developed by equivocal generation from the villi of the mucous membrane.[1] The little three-jointed tape-worms which Röll twice found in dogs, and which were not long ago described by him as young individuals of *Tænia serrata*, must also of a certainty have owed their origin to scolices of the *Echinococcus veterinorum*.[2]

The specific form of the hooks of the circlet of the scolices of the *Echinococcus veterinorum*, as well as the very small number of *Proglottides* generated by them, justify me in considering the *Tæniæ* developed from these scolices as a distinct species, which I have denominated *Tænia echinococcus*. (See the 'Zeitschrift für Wiss. Zool.,' B. IV, 1853, p. 423).

If we sum up the results of these experiments on feeding with *Echinococcus veterinorum*, they may be shortly stated as follows:

1. Sexually-developed *Tæniæ* have been produced out of all those kinds of scolices known as cystic worms which have been employed for feeding experiments.

2. From the scolices of the *Cysticercus pisiformis, tenuicollis, cellulosæ*, and *Cœnurus cerebralis*, *Tæniæ* of an ell long have been produced, which perfectly agree with both the *Tænia serrata*, and with the *Tænia solium*.

[1] See his 'Entozoorum sive vermium intestinalium historia naturalis,' vol. i, 1808, p. 411.

[2] See Röll's 'Beitrag zur Entwickelungsgeschichte der Tænien,' in theVerhandlungen der Physikal. Medizinischen Gesellschaft in Würzburg,' Bd. iii, 1852, p. 55.

3. The scolices of the *Echinococcus veterinorum* developed themselves into very small tape-worms, of from one, to one and a half, lines long, which have been shown to be a distinct species, and named *Tænia echinococcus*.

It may seem questionable to many helminthologists and zoologists, that four different kinds of cystic worms, which have hitherto been looked upon as so many distinct species, should only produce one and the same species of *Tæniæ*. But I would ask, are the cystic worms which have been termed *Cysticercus pisiformis, tenuicollis, cellulosæ,* and *Cœnurus cerebralis,* really distinct kinds? After the present inquiries, this question must be negatived. All these cystic worms are only the degenerated embryos and scolices of a single species of *Tænia*. If they who have always regarded these cystic worms as belonging to different species will make the experiment for themselves of detaching the several heads of the four above-named cysticerci, and mixing them together, they will find it utterly impossible to make out any specific difference between them. Further than this, I not only question if the *Tænia serrata* from the intestine of the dog, and the *Tænia solium* from the human intestine are distinct and sharply defined species, (see p. 68), but I also doubt the specific distinctness of the *Tænia marginata* from the intestine of the wolf, of the *Tænia crassiceps* from that of the fox, and of the *Tænia intermedia* from the intestine of martens and polecats. All these five *Tæniæ* certainly belong to but a single species of tape-worm, and only present varieties of race dependent on the influence of the varying circumstances to which the young *Tæniæ* are exposed in the course of their further development, according as they have entered the digestive canal of a man, a dog, a wolf, or any musteline carnivore. If we consider the diagnoses of these five kinds of *Tæniæ* given by helminthologists, we shall be convinced that there is not a single specific mark of distinction to be found between them, and that the form and arrangement of the circlet of hooks of these tapeworms are entirely disregarded. If the heads of the five above-mentioned, so-called species of tapeworm, with their circlet of hooks were submitted to the inspection of the most experienced helminthologist, without betraying their origin to him, I feel persuaded that he would be perplexed in distinguishing those five species of *Tæniæ*, which only differ according to their various habitations. In the genera *Ligula, Schistocephalus, Tetrarhynchus,* and *Echinorhynchus,*

helminthologists have long ago observed that certain species inhabit and attain sexual maturity in the most different kinds of birds and fishes. The conditions of life of the five races of degenerated *Tæniæ serratæ* (with their various œdematous forms of scolex, which are also to be considered as varieties of race), were certainly originally more simply and sharply defined, and must have gradually become impressed with their present complex and indefinite character from the domestication of the animals they infest.

At the same time, the results of these feeding experiments, which I have just cited, contradict the belief that the cysts of these worms have a physiological,[1] and not a pathological signification, for all the *Cystica* mentioned are produced from a single species of tape-worm, namely, the *Tænia serrata*, and it only depends upon the nature of the spot to which these embryos have been transplanted after having completed their immigration, whether they degenerate into *Cœnurus cerebralis*, or *Cysticercus pisiformis*, or *tenuicollis*, &c. When subject to the same external influences, these degenerations will always present the same form; whence it seems justifiable to compare these continually recurring and sharply-marked modes of degeneration of certain intestinal worms with the phenomena of race.

5. ON THE DISEASES PRODUCED BY CYSTIC WORMS, AND THEIR PREVENTION.

After having pointed out, in the introduction, that all the intestinal worms reach the interior of their hosts by immigration, and after having shown by the feeding-experiments, that certain cystic worms are transformed in the digestive canal of dogs into a particular kind of tape-worm, I may be allowed to draw the conclusion that, reversing the circumstances, the young of these tape-worms may, by the help of the alternation of generations which I have already described, be developed into cystic worms, the species of the animals and also the nature of the organs, into which the immigration takes place, exercising a specific influence

[1] Küchenmeister has taken much pains of late to defend this view, in opposition to mine, and has been led away by his zeal, to depart from that calmness of tone which becomes scientific controversy.

on the development and form of the cystic worms, and giving rise to many kinds of distinct degenerations (races).

By keeping in view these highly interesting vital conditions of certain intestinal parasites, we shall be enabled to take more efficient means against the spread of cestoid and cystic worms, in those cases in which their presence is prejudicial to the animals they inhabit, than could be the case so long as no one was aware in what way these parasites, whose entrance it was so desirable to prevent, made their way into the creatures they infested.

What purposeless and useless remedies have been proposed for this same worm-disease, we gather, amongst other things, from the numerous treatises which the disease of the "staggers" in sheep has called forth. On account of not having a correct acquaintance with the natural history of the *Cystica*, there necessarily arose the most contradictory and unreasonable opinions, and upon these a series of prophylactic and curative measures have been founded, which, resulting in no success, have been one after another discarded again. Amidst such irrational proceedings, we cannot blame the sheep owners if they entirely gave up using means for the eradication or prevention of the staggers, and unwillingly submitted to a loss that, amongst rich flocks, was by no means to be lightly estimated, amounting in many sheep-farms to more than ten per cent.

Were I to bring forward all the various causes to which the origin of the *Cœnurus* has been referred, I should far exceed the limits that I have assigned myself in these pages. That the doctrine of equivocal generation played a conspicuous part therein will surprise no one, since there yet exist veterinary surgeons who adhere to that doctrine in all points.

The only mode of insuring the destruction and removal of the worm, and hence the only effectual cure for the disease of the staggers, is trepanning. Unfortunately this process is not applicable in all cases—since it depends upon the situation of the worm, whether it can or cannot be reached by trepanning. The operation is of course admissible only when the *Cœnurus cerebralis* is imbedded in the anterior and upper portion of the ruminant's brain, whilst if, on the other hand, it be deeply seated in the base of the brain, or in the spinal marrow, it cannot be reached by trepanning. For this reason the testimonies as to

the result of this operation vary so widely. Operators who have accidentally fallen in with cases where the *Cœnuri* were superficially situated, have been successful, and so have gained credit, whilst other cases have completely baffled them. Not only the deep-seated position of the *Cœnurus cerebralis* occasions the ill success of the operation, but even postponing it so long that their size is already so great as to have produced much disturbance in the efficiency of the brain, may render the removal of the worms useless. Further, trepanning may also have come into discredit as an inefficient means of cure for the staggers, from having been applied on the appearance of dizziness which had been produced by other causes than the existence of a *Cœnurus cerebralis*.

Here I cannot refrain from remarking, that in the south of Germany, namely, in the Suabian part of the kingdom of Bavaria, the *Cœnurus cerebralis* not unfrequently appears in oxen; whilst in the north of Germany this disease is scarcely known in cattle. The common occurrence of the staggers amongst these domestic animals is probably the reason why trepanning has been recently tried as a cure for calves affected with the staggers. I have to thank Dr. Gierer, the provincial veterinary surgeon at Türkheim, who has performed the operation with success on several oxen, for his very interesting communications on this subject, amongst which the following points appear particularly worthy of notice.

M. Gierer is persuaded that the disease of the staggers amongst oxen is by no means of very unfrequent occurrence, but as hitherto no certain means of cure has been found for this evil, all the calves affected with the disease have been sold betimes to the butchers. Even M. Gierer, before he succeeded in curing by the trepan, had heard remarkably little in his own circle of the appearance of this disease amongst oxen; now, however, after having thoroughly cured eight and twenty oxen out of thirty which he trepanned, he is able to form some idea of the frequency of the complaint amongst the animals, being consulted oftener than ever about the cure of this disease.

I have compared several examples of *Cœnurus cerebralis* which Gierer obtained by trepanning from young oxen, mostly of from about two to three years old, with the *Cœnurus cerebralis* of sheep, and have found no specific difference between the two; so that I conclude that the *Cœnurus* of the ox also originates in the

Tænia serrata. Beyond this, the cysts of these *Cœnuri* were of extraordinary dimensions, since they would have exceeded the size of hens' eggs if, when in a fresh condition, they had been filled with water. They, moreover, contained a remarkable number of scolex gemmæ, which covered the interior surface of the cyst in masses thickly pressed together. Very many of the already developed scolices were everted, so as to project considerably on the exterior surface of the parent cyst, a phenomenon which I have seldom observed in those of sheep.

Although the fact has been proved, that the disease of the staggers, arising from the presence of *Cœnurus cerebralis,* can be cured by trepanning, still sheep-owners must not always reckon upon the absolute success of the operation, since, as has been already stated, the result must depend upon the situation of the parasite; and as it is impossible to know if two, or even several cysts, may not have established themselves at the same time in the nervous centres of the affected animal, of which one alone could be removed by trepanning, and that the cyst which lay nearest to the surface. Furthermore, even though the animals can be cured by the removal of these parasites, the question arises, if such animals, the vital powers of whose brain have been disturbed by the presence of this cyst, can be said to be cured in the full meaning of the word? Do the diseased changes which a considerable-sized *Cœnurus*-cyst engenders, through displacement, pressure, and wasting away of the substance of the brain, become so entirely removed after the extraction of the worm, that the vital powers of the brain can be again restored in their full integrity? Will there not still remain traces of changes engendered by the disease in such a brain, which although causing no striking interruption of the animal's nervous energies, may yet more or less affect its strength, duration of life, and fruitfulness, and render it inferior to a thoroughly healthy individual of the same race.

From what has been stated, it follows that the cure of the staggers, when it has once broken out, is always a difficult, and very often an impossible task; hence it would be much more worth while to take precautions for preventing it. The only rational prophylactic treatment must consist in employing such means as may prevent the immigration of the young of that tapeworm from which the *Cœnuri* are developed. As, according to my experiments, the *Cœnurus cerebralis* changes, in the digestive canal

of dogs, into the *Tænia serrata,* I venture to assume that the young of this tape-worm, after its immigration into ruminants, becomes developed in their nervous centres into the *Cœnurus cerebralis,* which, according to the situation it occupies, produces either vertigo by pressure upon the brain, or the phenomena characteristic of pressure upon the spinal marrow.

The *only prophylactic measure* against the morbid conditions induced by the *Cœnurus cerebralis* must therefore be—*to guard against the immigration of the young of the Tænia serrata.*

It will possibly be objected that, even if the generation of the *Tænia serrata* out of the scolices of the *Cœnurus cerebralis* had been proved, the production of the *Cœnurus cerebralis* from the young of the *Tænia serrata* must first be demonstrated, in order that, from the facts before us, we may have the right to consider immigrated young *Tæniæ* as the cause of the staggers proceeding from *Cœnurus cerebralis.* The laws of propagation of these animals long since suggested the view I have just put forth, but recently I have been put in possession of facts which directly support it. Dr. Haubner, professor at the veterinary school in Dresden, has in fact had the goodness to communicate to me that in that establishment, on the 7th of January of this year, several lambs were fed with perfect joints of the tape-worm of dogs, containing ova, and that on the 20th of January the first appearances of the staggers manifested themselves at the same time in all, whilst the remaining animals of the flock to which those lambs belonged continued healthy. The diseased lambs were killed and examined in succession at intervals of eight days, by which proceeding Professor Haubner obtained the following results :[1]

"At the commencement of the disease various symptoms of irritation and inflammation of the brain appeared, which perfectly accorded with those which Dr. Haubner had already become fully acquainted with in cases of the so-called spontaneous development of this disease. In this stage the sheep might either die, or else the irritation of the brain might pass away, and the *Cœnurus*-cysts proceed to further development. Upon dissection after three or four days, reckoning from the first appearance of the disease, Dr. Haubner found many cysts in the

[1] A short communication upon this subject has just been made by Professor Haubner to 'Hamms Agronomische Zeitung,' 1856, No. 10, p. 157.

brain, about the size of a pin's head. They lay partly free on the vessels in the convolutions of the brain, partly imbedded in superficial canals formed of exuded matter, the substance of the brain representing the bottom, and the exuded matter the covering of the canals. The whole animal (heart, lungs, muscles, &c.) was at the same time permeated by the encysted young of the tape-worm. Later dissections showed fewer but larger cysts in the brain. Mr. Haubner conjectures, and rightly so, that the rest were abortive and died away. After fourteen days, always reckoning from the first morbid symptoms, the same observer discovered several dark spots in a few of the cysts, which were probably the projected heads. After four weeks all the cysts had separate heads with distinct suckers; and, as it appeared, with the circlet of hooks in course of development."

After having thus proved by facts that the immigrated young of the *Tænia serrata* in ruminants can develope into *Cœnurus cerebralis*,[1] I feel justified in advising, as the most important preservative against the *Cœnurus*, that the immigration of the young of the *Tænia serrata* into ruminants should be prevented. The utility of this advice will certainly be admitted by every one who has made himself acquainted with the history of the intestinal worms in the foregoing pages of this pamphlet; but beyond this, persons will be also desirous of knowing how it can be practically carried out. When I consider the many hidden paths by which most of the intestinal worms make their way during their existence, I must confess once more that it will be a most difficult task for those engaged in the breeding of cattle to prevent the excessively small young of the tape-worm from passing into their oxen and sheep.

It may be safely assumed that the young of the tape-worm pass with the food into the digestive passages of the ruminants whilst they are eating and drinking. How easily the fresh as well as the dry fodder of ruminants may become contaminated with the ordure of dogs containing eggs of the *Tænia serrata*; especially when we remember that these eggs possess great tenacity of life, and are able to withstand for a considerable time external injurious influences, such as cold, heat, drought, &c.

[1] Through the kind communication, by letter, of Professor Leuckart, of Giessen, I have just heard that he has succeeded in generating the *Cysticercus fasciolaris* in the livers of white mice, after having given them sexually developed joints of the tape-worm of the cat (*Tænia crassicollis*) to eat.

If we fix our attention upon sheep, which are unfortunately too often exposed to the dangerous attacks of the *Cœnurus cerebralis*, we shall find that very frequently when a flock of sheep is attacked by the *Cœnurus cerebralis*, it is the sheep-dog who has guarded them year after year who is answerable for the mischief; in this case the shepherd's dog is infested by the *Tænia serrata*, whose young, after being passed by the dog in the neighbourhood of the flock, are easily caught up and swallowed by one sheep or another without being observed. The surest means, then, of keeping off the *Cœnurus cerebralis* from a flock of sheep would be to do away with the sheep-dog. To this, however, the sheep-breeders would hardly agree, since the services of a first-rate sheep-dog are not to be easily replaced by any other kind of help. But that the sheep-dog is really concerned in the devastations which the *Cœnurus cerebralis* makes in a flock is borne out by the fact that those sheep-flocks which, in the true sense of the word, are stall-fed, and consequently unattended by a dog, are never, or at least very rarely, troubled with the *Cœnurus cerebralis*. Those sheep-breeders who are disinclined to give up keeping dogs to guard their flocks, could urge as an objection that their dismissal would afford no sure guarantee for keeping off the parasite, inasmuch as the pastures where the sheep feed might become contaminated by the young of the *Tænia serrata* through other dogs, such as hounds and mastiffs; perhaps, indeed, even by wolves, foxes, or martens, and other animals of prey (see page 76).

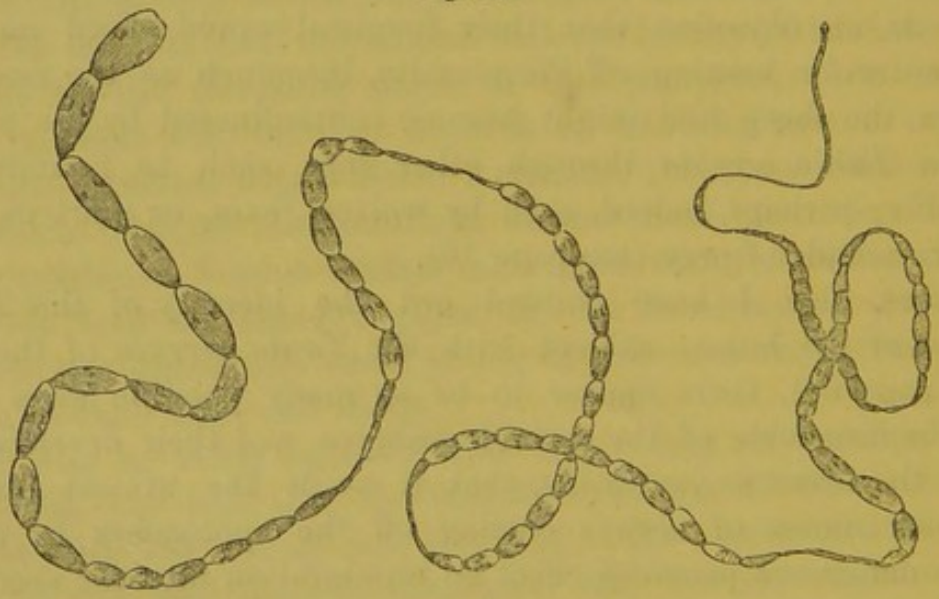
Since, also, I have pointed out the identity of the *Tænia solium* of the human subject with the *Tænia serrata* of the dog (see page 68), there appear to be so many possible ways open for the dispersion of the cestoid embryos and their development into the *Cœnurus cerebralis*, that it needs the utmost care to discover means of always cutting off the approaches by which these dangerous parasites effect an immigration into the sheep.

If, after these objections, which I have myself raised, I am the less inclined to think that the doing away with the sheep-dog would be an absolute preventive against the *Cœnurus cerebralis*, yet, I at least believe that, as a rule, and as a wise precaution, it might be recommended to those sheep-owners who employ dogs in the care of their flocks, to exercise a watch over them. If the dog be troubled with the *Tænia serrata*, the worm should be expelled before the animal comes in

contact either with the flock or their food. This supervision of the dog will be continually necessary, since although, according to my experience, the period of the parasite's existence is confined to only a few weeks, the opportunity for its immigration into the dog may frequently occur again. For the rest, I have pleasure in thinking that I have pointed out the true cause of the origin of the *Cœnurus cerebralis,* and hinted to the sheep-breeders in what way the worm creeps into their flocks; and I now leave it to intelligent proprietors to employ those means which are best fitted for the purpose of arresting the enemy, according to the locality, the style of farming, or to the condition of the animals. Having furnished a statement of the natural history of the *Cœnurus cerebralis,* I must leave it to experience to show if there are really means of preserving a flock of sheep from this cestoid parasite, and if so, what kind of means.

The *Tænia serrata* of the dog, whose presence in the sheep-dog is most particularly to be guarded against, is easily distinguishable from the other, harmless, tape-worm of the same animal,

Fig. 36.



the *Tænia cucumerina;* the first having its developed joints always white, and of a quadrangular or oblong shape, with only a single irregular marginal sexual aperture, varying in its position on each, whilst the developed joints of the *Tænia cucumerina* are elliptical

Fig. 36. *Tænia cucumerina,* from the intestines of a dog, with perfectly developed joints, natural size.

in form, are commonly of a pale-red colour, and have on every joint two marginal apertures opposite to each other.

The evidence that I have given in the foregoing chapter of certain cestoids becoming changed in the digestive canal of dogs into sexually developed tape-worms, suggests the idea that, most probably, the greater number of the human tape-worms enter as scolices into the intestine of man. That the opportunity for such an immigration may readily occur is plain, if we reflect how easily a *Cysticercus* may get upon the lips of a butcher or a cook in handling pork containing these parasites. In fact, it appears from the medical reports that persons engaged in slaughter-houses and kitchens very commonly suffer from tape-worms,[1] which indicates that, although the use of "measly" meat for the most part never produces dangerous results, yet that especial care should be taken regarding it. In any case, encysted pork, when boiled or roasted, can afford no opportunity for the production of a *Tænia solium* in the human digestive canal, since the *Cysticerci* will be completely destroyed by the degree of heat necessary for the preparation of the meat; but it is quite a different case with smoked sausages, in the manufacture of which many butchers make use of measly meat.[2] With the present clever and expeditious method of smoking them, how easily may a sausage stuffed with this meat be eaten so soon and in such a fresh condition, that one or another scolex may have preserved its vitality, and awakening from its trance in the human digestive canal, proceed to its development as a tape-worm. From what I have stated in the earlier chapters with regard to the internal relation of the scolices to the tape-worms, it is now explained how that in no country are men more tormented by these parasites than in Abyssinia, it being well known that the Abyssinians eat a great deal of raw meat. Dr. Bilharz, formerly a pupil of mine, some time ago wrote to me from Cairo, that in Abyssinia the tape-worm was so common that a native would regard it as an abnormal condition if he were to expel no tape-worm joints; and that no slave was purchased there without at the

[1] Compare Wawruch, 'Praktische Monographie der Bandwurmkrankheit,' Vienna, 1844, p. 197.

[2] The shrunk *Cysticerci* in such sausages are very easily to be found; they form milk-white bodies of the size of a needle's head, which, when pressed between glass plates and seen through the microscope, show the circlet of hooks and the four suckers of the scolex very distinctly.

same time receiving a packet of cusso to remove his tape-worm. That the flesh of our cattle affords the principal opportunity for the immigration of the *Tænia solium* into man, is borne out by the experience of Reinlein,[1] a physician of Vienna; who for ten successive years professionally attended the Carthusian monks, who never partake of either meat or milk, but live mostly on fish; he had never seen a single person who had suffered from tape-worms, and was assured by the oldest fathers that they never remembered any of their associates to have been troubled with them.

But it is not alone in the torrid and temperate zones of our globe that man is visited by these parasites, for even in the polar regions the cestoids find means of reaching him. Dr. Schleisner, who a few years ago published a medical topography of the island of Iceland,[2] makes mention of an epidemic liver complaint or hydatid disease which made great ravages among the Icelanders. In the short account of this complaint, which is more commonly met with in the interior of the country than on the coast, I recognise a tape-worm which is imbedded not only in the livers, but also in the abdominal organs and in the skin of these islanders. Professor Eschricht, of Copenhagen, wrote to me lately that the sixth part of the whole population of Iceland suffered from this disorder of the liver, and that with many of them, after dreadful and protracted sufferings, it terminates in death. From a more particular description and illustration of this disease produced by the tape-worm, for which I am indebted to the kindness of Eschricht, I conclude that the parasite is one of the *Cysticerci*, and has its origin in the *Tænia serrata* (*solium*). In Copenhagen, people's attention has already been drawn to this cestoid disease, so highly fatal to the Icelandic population, and they appear to be desirous of taking energetic measures for its prevention. I entertain the belief that, bearing in mind the natural history of the *Cysticerci* as I have represented it in these pages, it may be possible to prevent the immigration of the cestoid young—to which, from the Icelanders' mode of life, they

[1] See his 'Bemerkungen über den Ursprung, die Entwickelung, die Ursachen, Symptome und Heilart des breiten Bandwurmes in den Gedärmen des Menschen,' Vienna, 1812, p. 25.

[2] See his 'Forsög til en Nosographie of Island,' Kjöbenhavn, 1849 A short abstract of this work will be found in 'Janus,' the 'Central-Magazin für Geschichte und Literär-Geschichte der Medizin,' vol. i, 1851, p. 300.

are so fatally exposed—into the inhabitants of this island. How this may be effected the following remarks may serve to show. It is well known that the Icelanders carry on an extensive breeding of cattle and sheep, in which the canine race are in many ways serviceable.[1] I presume that the Icelanders, when slaughtering their cattle, never have the dogs far off, and thereby it readily happens that these voracious animals, in swallowing what is thrown aside, take in various *Cysticerci;* from these the *Tænia serrata* is developed, and their young, by means of the oxen, give rise to many evil consequences to man. If the dogs of the Icelanders were kept under supervision and free from the *Tænia serrata,* not only would the propagation of the young of this tape-worm be certainly prevented, but also their immigration into man and cattle, and their injurious degeneration into *Cysticerci.*

It can now be no longer regarded as wonderful, or considered as fabulous, when physicians inform us that after raw meat had been prescribed for certain of their patients, they had found them to become troubled with tape-worms.[2] In the cases that were met with, it was explicitly said to be the *Tænia solium* that was expelled, which exactly supports the opinion that this tape-worm, so rare in St. Petersburg, has there been developed by the adoption of a diet of raw meat. The statements would have been much more to be suspected if, in the tape-worms that were passed, the *Bothriocephalus latus,* so general in Russia and Poland, had been recognised, since this worm is never met with amongst our cattle in a scolex condition. Formerly, the geographical distribution of both these human tape-worms, the *Bothriocephalus*

[1] What important services the numerous dogs spread all over Iceland render to the inhabitants in their husbandry, is given in the more or less detailed accounts of travellers. Compare Hornebow, 'Zuverlässige Nachrichten von Island,' Copenhagen, 1753, pp. 143 and 164; further, Hooker, 'Journal of a Tour in Iceland in the Summer of 1809,' London, 1813, vol. i, p. 339.

[2] Compare, upon this subject, the communications made by Weisse (in the 'Journal für Kinderkrankheiten,' vol. xvi, 1851, p. 384), which, in spite of Braun's objections (ibid., vol. xviii, 1852, p. 78; or in Froriep's 'Tagesberichten,' 1852; 'Geburtshülfe und Kinderkrankheiten,' p. 281), are worthy of all belief. The opinion expressed by Andral in favour of the doctrine of equivocal generation ('Grundriss der pathol. Anatomie,' Leipzig, vol. i, p. 393), that from external mechanical influences (a contusion) affecting an organ, its necessary nourishment may be disturbed, so that the organic particles are not fully assimilated, and become metamorphosed into lower kinds of animals (into a *Cysticercus*)—an opinion in which Professor Uhde, of Brunswick, also coincides (see 'Deutsche Klinik.,' 1851, No. 40, p. 434)—is thus thoroughly refuted.

latus and the *Tænia solium*, was declared to be very sharply defined; the appearance of the former being supposed to be confined to Switzerland, Poland, and Russia; but now, if the *Tænia solium* were to show itself in these countries, it would not be a matter of astonishment nor appear unworthy of belief, since, through the importation of cattle infested with *Cysticerci*, from countries where only the *Tænia solium* is found, this tape-worm may easily be introduced in its scolex form.[1]

After this statement of the history of the tape-worms, and of the *Cysticerci* which stand in such close relationship with them, I trust that I may have so strongly shaken the many false views and prejudices so deeply rooted amongst physicians, veterinarians, and economists, with regard to the origin, development, and propagation of these intestinal worms, that they may henceforth be renounced as untenable. I have thereby not only the satisfaction of having uprooted the very foundations of a *château en Espagne*, filled with the most marvellous hypotheses, but of having erected in its place a structure compacted of facts and based upon experimental demonstrations, which throw a light upon a path hitherto wrapped in profound obscurity, but which may now be profitably followed.

[1] According to a written communication, for which I am indebted to Dr. Baumert, during his stay in Neuchatel, the *Cysticerci* are almost unknown in pigs in the western parts of Switzerland, viz., in Neuenburg, whilst all those pigs that are introduced there from France are abundantly infested with them.

INDEX OF TAPE AND CYSTIC WORMS.

LIST OF THE WORKS PUBLISHED BY THE SYDENHAM SOCIETY FROM ITS FOUNDATION IN 1843,

IN THE ORDER IN WHICH THEY WERE ISSUED.

FOR THE FIRST YEAR, 1843-4.

* "*Hecker's Epidemics of the Middle Ages.*" 1 vol., 8vo, pp. xx, 380.
* "*Louis on Phthisis.*" 1 vol., 8vo, pp. xxxv, 571.
"*Th. Sydenham Opera Omnia.*" 1 vol., 8vo, pp. xxx, 668.

FOR THE SECOND YEAR, 1844-5.

* "*The Seven Books of Paulus Ægineta.*" Vol. I, pp. xxviii, 683.
* "*Observations on Aneurism.*" 1 vol., 8vo, pp. xii, 524.
* "*Simon's Animal Chemistry.*" Vol. I, 8vo, pp. xx, 360, plate.

FOR THE THIRD YEAR, 1845-6.

* "*Simon's Animal Chemistry.*" Vol. II, 8vo, pp. xii, 560, 2 plates.
* "*Paulus Ægineta.*" Vol. II, 8vo, pp. xi, 511.
"*Hasse's Pathology.*" 8vo, pp. xvi, 400.

FOR THE FOURTH YEAR, 1846-7.

"*The Works of W. Hewson.*" 1 vol., 8vo, pp. lvi, 360, portrait and 8 plates.
"*Dupuytren's Lectures on Diseases and Injuries of Bones.*" 1 vol., 8vo, pp. xvi, 459.
"*The Works of W. Harvey, M.D.*" Complete in 1 vol., 8vo, pp. xcvi, 624.

FOR THE FIFTH YEAR, 1847-8.

* "*Paulus Ægineta.*" Vol. III, pp. viii, 653.
"*Feuchtersleben's Medical Psychology.*" Pp. xx, 392.
"*Microscopical Researches of Schwann and Schleiden.*" Pp. xx, 268, 6 plates.
"*Memoirs of the French Academy of Surgery.*" Pp. x, 293.

FOR THE SIXTH YEAR, 1848-9.

"*Rhazes on the Smallpox and Measles.*" 8vo, pp. viii, 212.
"*The Genuine Works of Hippocrates, translated from the Greek.*" Vol. I, 8vo, pp. x, 466.
"*The Works of Sydenham, translated from the Latin.*" Vol. I, 8vo, pp. cvi, 276.
"*Rokitansky's Pathological Anatomy.*" Vol. II (the first issued), 8vo, pp. 375.

FOR THE SEVENTH YEAR, 1849-50.

"*The Genuine Works of Hippocrates.*" Vol. II, pp. 406.

"*Essays on the Puerperal Fever, and other Diseases peculiar to Women.*" 8vo, pp. 552.

"*The Works of Sydenham, translated from the Latin.*" Vol. II, pp. 396

FOR THE EIGHTH YEAR, 1850-1.

"*Rokitansky's Pathological Anatomy.*" Vol. III, 8vo, pp. xvi, 467.

"*Hunter on the Gravid Uterus.*" 1 vol., folio, 34 plates, with descriptive letter-press.

FOR THE NINTH YEAR, 1851-2.

"*Unzer and Prochaska on the Nervous System.*" 1 vol., pp. xvi, 463.

"*Annals of Influenza.*" 1 vol., pp. xvi, 406.

"*Rokitansky's Pathological Anatomy.*" Vol. IV, pp. x, 398.

FOR THE TENTH YEAR, 1852-3.

"*Romberg on Diseases of the Nervous System.*" 2 vols. Vol. I, pp. xvi, 368; Vol. II, pp. viii, 450.

"*Kölliker's Manual of Human Histology.*" Vol. I, woodcuts, pp. xix 498.

FOR THE ELEVENTH YEAR, 1853-4.

"*Kölliker's Manual of Human Histology.*" Vol. II, woodcuts, pp. x, 434.

"*Rokitansky's Pathological Anatomy.*" Vol. I, 2 plates, pp. xvi, 446.

"*Dupuytren on Lesions of the Blood-vessels,*" &c. 1 vol., pp. 378.

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"*Oesterlen's Medical Logic.*" 1 vol., pp. xii, 437.

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"*The Works of Aretæus,*" Greek and English. 1 vol. pp. xx, 510.

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"*Von Siebold and Küchenmeister on Intestinal Worms and other Parasites.*" 2 vols., 8vo, with numerous illustrations, plain and coloured. Pp. xix, 492—xvi, 287—xx, 88.

*** *Those books to which an asterisk is affixed are out of print; of the others copies are still on hand, and may be had at reduced prices on application at* 45, Frith Street, Soho.


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