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TREMBLEY'S EXPERIMENT OF TURNING THE POLYP INSIDE OUT AND THE INFLUENCE OF DUTCH SCIENCE

BY

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ABSTRACT

Trembley's curious but important experiment of turning the polyp inside out demonstrates the influence of Herman Boerhaave and the scientific community at the University of Leiden. Boerhaave, for whom Trembley had great respect, defined animals as "reversed plants" since they had "inner roots" or "lacteal vessels" for the absorption of food. Playing experimentally with this definition, possibly thinking it could assist him in understanding the polyp's structure, Trembley inverted the hydra. He mistakenly concluded that it would draw nutritive fluids equally well through its inner and outer surfaces, but only through whichever surface was structurally on the inside. He concluded that the polyp was a simple animal, not a "zoophyte" or plant-animal, an idea which he had considered early in his research. Trembley's letters to Bonnet and Réaumur show that he regarded this experiment as one of his most important. His use of Boerhaave's definition shows that, though he is justly regarded today as a model of the disinterested observer, he shared the ideas of an eighteenth century scientific community to which he contributed and drew inspiration. A study of Trembley's and Bonnet's discussion of inversion also reveals the strong links between the Leiden circle and the intellectual life of Geneva.

INTRODUCTION

In the vignette (Figure 1) which introduces the fourth section of Trembley's *Mémoires, pour servir à l'histoire d'un genre de polypes d'eau douce, à bras en forme de cornes,* we see Trembley in his study on the first floor of Count William Bentinck's mansion at Sorgvliet. Trembley is alone with the Count's two sons, Antoine and Jean, one knelling on a chair, the other standing near specimen jars which line the desk and window sills. They attentively watch as Trembley teases a hydra, or polyp as it was then called, cradled in his right hand with the tip of a bristle, held in his left. Trembley is performing his famous experiment of turning the polyp inside out, or "reversal" — an experiment which is still among biologists a matter of interest and debate. (Baker 1952, Macklin 1968, Roudabush 1933). My interest in this experiment, however, is not to provide grist for contemporary hydra researchers, but rather because from Trembley's

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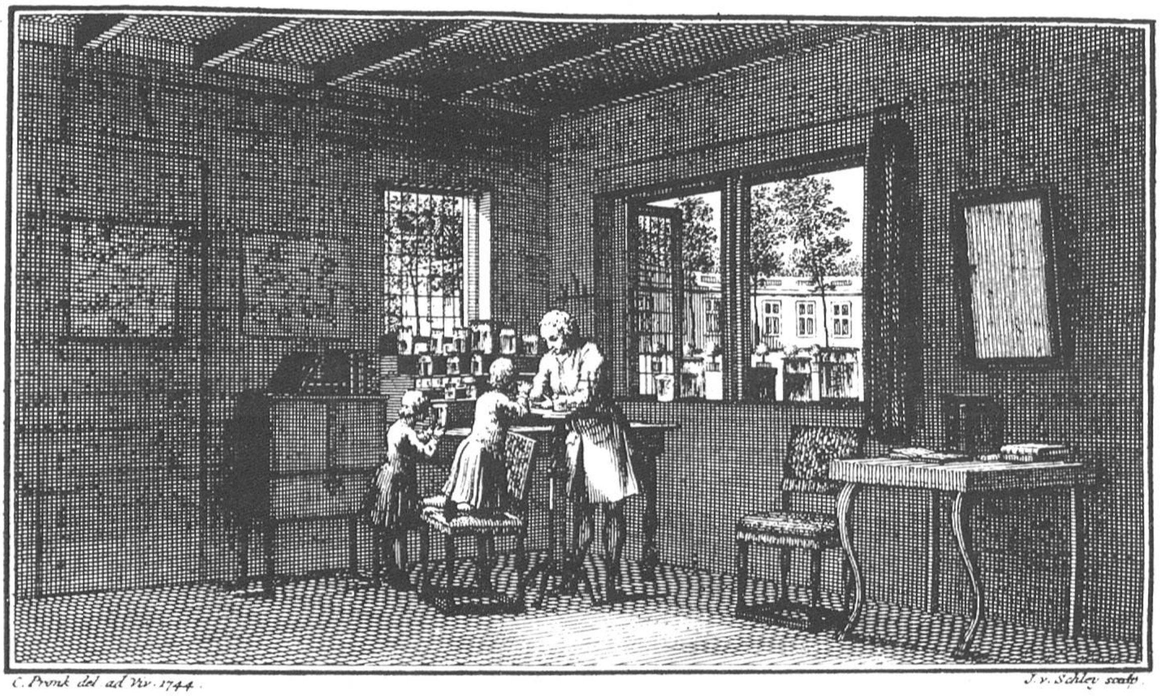

C. Pronk del. ad Viv. 1744. J. v. Schley sculp.

MÉMOIRES
POUR L'HISTOIRE
DES POLYPES.

QUATRIÉME MÉMOIRE.

Opérations faites ſur les Polypes, & les ſuccès qu'elles ont eu.

LA premiére opération, que j'ai faite ſur les Polypes, a été de les couper *tranſverſalement.* On a vu en general au commencement du premier Mémoire *, quel en a été le ſuccès. J'ai renvoié à celui-ci le détail de cette Expérience.

* Pag. 13 &c.

POUR

FIG. 1. — Vignette from Trembley's *Mémoires* showing Trembley in his study at the Bentinck mansion in Sorgvliet demonstrating the experiment of turning the polyp inside out to his two pupils. (Leiden, 1744).

point of view, it was one of the most important he performed. Trembley's discovery that, after sectioning, the polyp had the remarkable ability to regenerate was for his contemporaries an astounding accomplishment. His French patron, René Antoine Réaumur, for example, wrote that when he saw two polyps form from the one he had cut in two, he could hardly believe his eyes, and "it is a fact which I cannot get used to at all, after having seen it over again hundreds and hundreds of times." (Réaumur 1742) However, for Trembley, the experiment of cutting, though extraordinary, paled in comparison to what he thought he had accomplished with the proof of inversion. What led Trembley to perform this experiment, and why it was important to him is related to the influence of Dutch science, particularly that of the important professor of medicine and chemistry at Leiden, Herman Boerhaave (1668-1738).

Trembley's decision to go to Leiden in 1733 was no coincidence. As a member of the tightly knit upper class of the Republic of Geneva, he was educated at the Academy of Calvin, now the University of Geneva. His principal instructors were Jean-Louis Calandrini (1703-1758) and Gabriel Cramer (1704-1752). Both were mathematicians who shared the chair in mathematics and who helped to shape Genevan science. Trembley wrote his dissertation on the infinitesimal calculus under Calandrini's direction, successfully defending it in 1731. For the next two years, he apparently studied theology, though little is known of this period of his life. Nor are his reasons for leaving Geneva entirely clear, though study in Holland by Protestant students was common in the early eighteenth century.

What attracted students particularly to Leiden was the reputation of Herman Boerhaave and William 'sGravesande (1688-1742), the first Continental teachers of Newtonian science. Professor Cramer himself had forged the social and intellectual links with Leiden when he stopped there for an extended visit with 'sGravesande from July to December 1728. Though no specific reference to this has been found, it is likely that Trembley carried letters of introduction to members of the Leiden circle from Cramer and Calendrini who were associated with 'sGravesande through his *Journal Historique de la République des Lettres.* Whether Trembley actually studied with Boerhaave is not clear, though between 1733 and 1736, when Trembley was a student at the University, Boerhaave was still teaching in the Faculty of Medicine and it is unlikely that Trembley would have missed the chance to hear one of Europe's foremost teachers. So great was the renown of Boerhaave, that Albrecht von Haller, another important Swiss who received his medical training at Leiden, wrote of his student years, "I dismissed with disdain a Cartesian instructor, who wanted to make me adopt his fictions, and I became enthusiastic about the views of Boerhaave; clarity, goodness, novelty, style, all combined to give charm to his instruction." (Sonntag, 1983).

It is certain that Trembley carefully studied Boerhaave's important work, the *Elementa chemiae,* published under Boerhaave's supervision in 1732. In addition, shortly before his death in 1738, Boerhaave published the *Biblia naturae* (Leiden, 1737-8) of Jan Swammerdam, a Dutch naturalist of the late seventeenth century.

Trembley's citations of this edition shows that he was thoroughly familiar with Swammerdam's work on insects.

Trembley soon became an intimate friend of Jean-Nicholas Allamand (1713-1787), a fellow Swiss, who was then the tutor to 'sGravesande's children and who would later become the editor of 'sGravesande's collected works and a professor himself at the University of Leiden. Allamand also translated Boerhaave's important *Elementa chemiae* into French. (*Elémens de Chymie,* La Haye: J. Neaulme, 1748, 2 vols.) During his student years, Trembley also became acquainted with Bernard Siegfried Albinus (1697-1770), a renowned anatomist and colleague of Boerhaave, as well as Hieronymus David Gaubius (1704-1780), Boerhaave's student and successor in the Chair of Chemistry. Moreover, Trembley formed a close working relationship with Pierre Lyonet (1706-1789), a resident of The Hague of French-Swiss background, who had also attended the University of Leiden.

It was probably at the University that Trembley also met his future employer, Count William Bentinck. Late in 1739 Trembley moved to the Count's estate at Sorgvliet, about a mile from The Hague, to become the tutor to the nobleman's young sons — a life which appears to have allowed him considerable leisure. Removed from the hurly-burly intellectual atmosphere of Leiden and far from the political troubles in Geneva and family demands, Trembley had time to wander over the dunes in search of unusual insects. He and his young students collected aquatic insects from a stream and fishpond near the mansion. Powder jars filled with his specimens crowded his small study. He carefully observed them without removing them from their accommodations in his jars by mounting a single lens of short focus on a jointed arm. (See Archinard, this journal). With this apparatus, he could position the lens at various points on the outside of the jar, achieving a considerable magnification without interfering with the insect's activities within. In one of these jars in June 1740, Trembley first noticed a curious aquatic creature attached to a piece of weed. This little being would become the nexus of his activities for the rest of his seven years at Sorgvliet.

TREMBLEY'S TIES TO GENEVA THROUGH BONNET

Later that same year Trembley made another discovery which, he facetiously wrote, "gave me more pleasure than that of the rarest insect." (Ms. Bonnet 24, B.P.U.). This was the discovery of his "dear cousin," Charles Bonnet, who was then a student at the Academy in Geneva. Bonnet was ten years younger than Trembley, but it is obvious from their letters that they shared a similar social position in Geneva, and had studied with the same professors. Just how they discovered or rediscovered each other is unclear, but when Trembley read Réaumur's *Mémoires pour servir à l'histoire des insectes* and began his own observations of insects, it was Bonnet who encouraged him to write to Réaumur, with whom he was already corresponding.

For the historian interested in tracing the various influences on Trembley as he studied the vagaries of the polyp, Trembley's friendship and its ensuing correspondence with Bonnet was fortuitous, for it enables us to isolate what characteristics of the polyp were particularly important for Trembley. For example, in the letter to Bonnet, 27 January 1741, in which he first discussed his discovery of the polyp, Trembley wrote:

> I do not know if I should call plant or animal the object which occupies me most at present. I have been studying it since the month of June. It has furnished me with quite marked characteristics of both plant and animal. It is a little aquatic Being. Seeing it for the first time, you would exclaim that it is sensitive and ambulant, and if it is an animal, it can grow from cuttings like several plants. I have cut it in three parts. Whatever part each lacked grew back to resemble the Being before it was divided, and each walked and has made up to now all the movements which I have seen the complete animal make. I said something about it to Mr. Réaumur and since I wrote to him, I have multiplied my experiments and extended a little those which contributed to an understanding of its structure. (Ms. Bonnet 24)

This letter expresses what was a dominant theme in his thinking — the problem of whether his little aquatic being was animal or plant. These perplexing characteristics are what had led him in the first place to the experiment of cutting and to the discovery of its unusual properties of regeneration. However, the letter reveals a second theme. This is Trembley's belief that the key to the solution to this problem of definition was through an understanding of the polyp's structure. The remarkable precision of Trembley's experiments, which we are deservedly celebrating with this volume, are all aimed at uncovering the perplexing internal anatomy of the polyp.

Bonnet enthusiastically responded to Trembley's first revelation:

> Your little aquatic Being is something which is so remarkable and so surprising that it seems to me that it can be regarded as one of the greatest marvels which the study of Natural History can offer. One can say that you have discovered the point of passage from the plant [kingdom] to the animal. The great Swammerdam, in whose footsteps you walk would not assuredly have passed up a similar discovery, he for whom the least things were marvels. I am however pleased that it did escape him, and that it has been reserved for a student of M. de Réaumur. (George Trembley Archives)

Bonnet paid Trembley the highest compliment when he told him he walked in the steps of the great Dutch student of insects, Swammerdam. He also revealed in his letter that he was sharing Trembley's "enigma" with their mutual professors at the Academy and he asked Trembley for information to assist him in locating these curious specimens. Bonnet searched for hydra in the ponds and lakes around Geneva, but he was unable to find any. This must have been a great disappointment; through his discovery of parthenogenesis two years earlier at the age of nineteen, he had already established himself as Geneva's foremost observer of insects. This letter shows that Bonnet immediately lept to the conclusion that the polyp was a "point of passage" between the animal and vegetable realms, an idea which led him immediately to a vision of the chain of being.

While early in his correspondence with Réaumur, Trembley had himself alluded to the possibility that he had discovered a "plant-animal," he appears to have "suspended his judgement" until he had sufficient experimental evidence.

THE IMPORTANCE OF BOERHAAVE'S DEFINITION

It is obvious from his letters to Réaumur, that Trembley continued to be perplexed by the characteristics which his little aquatic being had in common with plants. However, rather than simply concluding that he had discovered the link between the two realms, he carefully considered the teachings of Boerhaave who had also recognized that animals and plants had many similarities. The celebrated doctor had asserted that nutrition was the sole criterion on which he based the separation of the two realms. He wrote to Réaumur, 16 March 1741: "It is currently rather difficult to mark the difference between plants and animals. Mister Boerhaave indicates principally that which is between the situation of the parts through which they draw their nourishment. Plants, according to him, have exterior roots, and animals have interior roots. It is not possible to yet say how our little bodies take food. I have several possibilities which lead me to believe that it is like animals." (M. Trembley 1943, p. 60-1)

Trembley had studied this definition in Boerhaave's *Elementa chemiae* (Leiden, 1732) and he carefully cited it later when he published his *Mémoires* in 1744.

> No more respected authority can be cited at this juncture than the renowned Boerhaave. What effort has this great man not expended in studying plants and animals! Nonetheless, it seems that he has found but a single general and essential difference between these two classes of organisms [*corps organisés*]. This difference . . . consists in the manner in which plants and animals draw their nourishment. "*The nourishment of plants,*" says Mr. Boerhaave, "*is through external roots, that of animals through internal roots. The external part, called a root, which draws nourishment from the substance in which it is situated, is sufficient to distinguish a plant from any animal known until now.*" And in the definition that he gives of an animal body, Mr. Boerhaave says, "*it contains within it vessels instead of roots through which it draws the food material.*" (A. Trembley 1744, p. 306-7)

Probably drawing inspiration from the iatro-mechanistic tradition of Santorio Sanctorius and Lorenzo Bellini, in his *Elements of Chemistry* Boerhaave described animals in terms of fluid mechanics. The animal was a kind of hydraulic machine "which subsists by a constant and determin'd motion of humours through its vessels, and which contains within itself certain vessels, like the roots of Vegetables, by which it draws in that nutriment, which supports its being, and increases its magnitude." (Boerhaave 1735, p. 40). He thought that the bodies of animals were made up of a hierarchy of vessels which carried the various fluids of the body: the sanguiniferous vessels for the venous and arterial fluids, the lymphatics, and finally the lacteal and mesenteric vessels through which the products of digestion moved from the gut eventually into the blood.

Just as in plants which drew their nourishment from the earth through roots, the lacteal vessels were the medium through which the chyle in the stomach was strained to eventually become blended into the blood, a process which Boerhaave, incidentally, thought took place in the lungs. (King 1981). That the lacteal vessels might be so small that they could not always be observed did not prevent Boerhaave from postulating that they *must* exist as the locus for the transformation of the various particles of which the body was composed. Trembley's use of Boerhaave's definition as the criterion by which to judge whether his discovery was animal or plant is important because it shows that Boerhaave's influence in this respect far outweighed the authority of Réaumur.

When Trembley was at last successful in sending live samples to Paris so that Réaumur could judge this enigmatic discovery with his own eyes, he reported that he had "observed them by candlelight for an hour an a half with true satisfaction." (M. Trembley 1943, p. 63). He did not doubt that they were animals and named them for their resemblance to the marine polyp or octopus. While Réaumur appears to have based his decision that the polyp was an animal on locomotion, Trembley did not forget Boerhaave's criterion based on nutrition.

Tied to the question of nutrition was that of the polyp's structure. Trembley's delay in publication of his discovery, despite Réaumur's urging, was his wish to fully explore this structure. (M. Trembley 1943, p. 87). This was itself a process of discovery. For example, at first he thought that the hydra's tentacles were possibly roots through which it drew its nourishment. Then he considered whether the threads were perhaps legs, since they obviously assisted it in walking.

The reason why he did not realize that the tentacles ringed the hydra's mouth has been brilliantly explained by Richard Campbell in his paper in this volume, "Does a hydra have a mouth (When it is closed)?" He explains that the hydra can go many months without eating. When the hydra's mouth is closed, tissue completely covers the opening, making a mouth very difficult to imagine and impossible to see. It was only when Trembley caught the polyp in the act of ensnaring a tiny eel and watched it stuff it into its central cavity which he at last realized was its stomach, that he could write with relief: "They are carnivorous, and certainly very avid." (M. Trembley 1943, p. 78)

But how in this simplicity, was the polyp able to absorb nutriments, if there were no structures within which food was prepared for absorption? Rather than "lacteal vessels," Trembley observed that the body appeared to be composed of tiny granules. He found these granules on the internal and external surfaces of the polyp as well as spread throughout its entire thickness. These granules were the *only* structures within the skin which he was able to find, and he felt justified in giving them close attention because their study furnished him with "the only ideas I have about the constitution of the Polyps". (A. Trembley 1744, p. 60). He studied the granules carefully, but found no vessels within which they were held.

The issue of how digestion occurred, and his search for the so-called "lacteal vessels" in this perplexingly simple creature drove him to an ever more careful series of experiments. The first was to cut the polyp, not transversely as he had done first, but this time, down the length of the body, cutting through the double membrane the length of the central cavity which he now felt justified in calling the stomach. This left two equal halves, each with half the tentacles and mouth, but deprived the animal of its digestive cavity. Thus, he wrote to Réaumur in June 1741, "I arrived at a fact which surprised me more than all that I have seen up to the present in the polyps." (M. Trembley 1943, p. 87). Within less than a day, each half had reformed into a polyp, complete with central cavity and by afternoon, Trembley witnessed each feed on a small eel.

Charles Bonnet found this experiment equally surprising. He wrote to Trembley, 1 September 1741: "The success of your experiment on a Polyp divided into several parts lengthwise strangely surprised me. Although it was one which I had proposed to try myself I had not believed I ought to hope that the animal oeconomy would not be destroyed . . . I had even regarded this test at the beginning as one which could assist in deciding if the animal in question was not rather a plant." (Geo. Trembley Archives).

Why both Bonnet and Trembley should have regarded the lengthwise splitting of the polyp with greater astonishment than that of transverse sectioning is perplexing. It appears that they believed that this lengthwise sectioning would destroy the life functions of the animal, its "animal oeconomy," to use eighteenth century terminology. That the regrowth of the cross sections should have seemed less disruptive of the animal's structure must be related to their belief that the ability to digest food was of prime importance in the functioning of the animal machine. Without that "constant and determin'd motion of humours through its vessels," particularly the motion of nutritive substances, the hydraulics of the animal machine should have been irreparably upset, yet this did not happen at all. The polyp reformed its digestive cavity as easily as it had reformed head and tail in Trembley's earlier experiments.

THE EXPERIMENT OF TURNING THE POLYP INSIDE OUT

The perplexing phenomena surrounding the question of nutrition and Boerhaave's use of nutrition as the criterion on which to base the distinction between plant and animal, led Trembley to what I believe he regarded as his most important experiment — that of *retournement,* or turning the polyp inside out. So important did Trembley regard this experiment, that he immediately sought to demonstrate it in the presence of those whom he judged most competent to judge the veracity of the experiment and his conclusions. "I wanted," he wrote, "to be able to refer to other witnesses besides myself to establish the truth of a phenomenon as strange as this experiment revealed." (A. Trembley 1744, p. 264). Therefore, he chose the highly regarded Allamand, who also succeeded in inverting polyps, and appropriately, Bernard Albinus, Boerhaave's successor and the most important anatomist of the period.

On 11 December 1742 Trembley wrote to Bonnet from the Hague, describing the structure of the polyp and how he turned polyps inside out. "Their body is a sack which could be compared to a hose-pipe. I have turned it inside out the way one turns a stocking or a glove. The interior became the exterior, and the exterior, the interior, and the Polyps on which I performed this experiment lived, ate, and multiplied." (Ms. Bonnet 24)

For Bonnet turning the polyp inside out was the most enigmatic of all the experiments which Trembley had described and he immediately wrote to Professor Cramer at the Academy to share with him, in as much detail as he could, all the particulars. In addition, he discussed with Cramer some of the many problems concerning the structure of the polyp which the experiment posed. He attempted to relate the ability of polyps to turn themselves to other known examples of such inversion in nature, but it was difficult to establish a true precedent for the phenomenon. While it was conceivable that parts of animals might turn themselves, he could find nothing analogous to the complete inversion of an animal. He wrote to Cramer, 21 December 1742:

> O! Please, Sir, what is this? An animal which can be multiplied by cutting, an animal whose young come out of the body like a branch comes from a trunk, finally an animal which is turned inside out like a *stocking* or *glove* and which keeps on *living, eating* and *multiplying.* Here are the marvels, the wonders which we owe to Mr. Trembley. Oh, how will we ever sufficiently admire the surprising work of the Creator? What study is that of Natural History! In truth I have seen nothing like it. But how has Mr. Trembley gone about turning Polyps inside out? How has he managed it? For myself I have difficulty believing that he has reversed them whole. I would believe it more willingly if it were on segments that he operated. These segments, being nearly everywhere of an equal diameter, sorts of hollow cylinders, the thing appears to me thus more feasible. Whatever is the case, our great observer has done this experiment. What can now be said? Is the body of these insects formed of two skins in whose lining or *duplicature* is found all the parts necessary for life? (Ms. Suppl. 384, B.P.U.)

Bonnet charmingly concluded his letter with a variation of the formal closing which demonstrated his devotion to his teacher: "If men could be thus turned, what would not be seen in the interior of the majority! What would certainly be seen within me are my respectful feelings with which I will always be, Sir, your very humble and very obedient servant."

Cramer's response to the revelations of his eager student was equally enthusiastic:

> Let me breathe a little. You are overwhelming us with marvels. Don't you know that in the end your wonders will cease to seem so, if you increase them so greatly. It is annoying, as you say, that Mr. Trembley is so laconic. Do battle with him and make many reproaches on my part. We don't ask for infinite details, but a little more clarity since what he proposes is an Enigma. Like you, I believe that he has turned inside out some portion of these Worms. For if he had turned them inside out completely, their arms would have been hidden in the interior, unless they were implanted exactly on the edge of the sack. (No date, probably written between Dec. 21-27, 1742, Ms. Bonnet 43).

Then Cramer revealed his own familiarily with Boerhaave's work and the necessity for the hydraulic body to be made up of the important digestive vessels. He wrote in the same letter: "It is necessary for the animal to have lacteal veins (or the equivalent), as much outside as within, since the outside must become the inside."

Again Bonnet considered the issue of turning the polyp inside out in a letter to Trembley, 27 December 1742, and chided him for failing to provide information in sufficient detail to satisfy Geneva's intelligensia which Bonnet was keeping abreast of the latest developments:

> In truth, Sir and dear Cousin, you push our admiration to the limit. What! you have new wonders! Here are some Animals which not only can be multiplied by cuttings and whose young emerge from the Body like a branch of a tree comes out of a trunk, but which can even be turned inside out, neither more nor less like a stocking and thus turned do not stop living, nourishing themselves and multiplying. You are very malicious in not telling us more and never speaking to us except in Enigmas. Mr. Cramer, and all here who are scholars and honest gentlemen who admire you make the same complaint of you. You do not have any conscience at all to put our minds in torture this way.

Bonnet asked Trembley to tell him what led him to consider trying such an unusual experiment and he begged him for greater detail. He questioned whether it was possible to turn whole polyps inside out, thinking as Cramer did, that it was easier to imagine the inversion of a segment, rather than the whole body. Bonnet too emphasized the need to understand the polyp's structure:

> On my own account, I would very much like to know how you have been led to perform such an experiment and how you go about it. I do not understand how you could try it with success on entire polyps, and I imagine it better using portions: in truth the structure of these insects is barely known to me.... Is the Body of these Insects formed of a double membrane in whose lining Nature has placed the veins and all the parts which are necessary for life? According to Mr. Cramer it is necessary for them to have lacteal veins or the equivalent as much outside as within. (Geo. Trembley Arch.)

Trembley described his experiment in his letter of 8 Feb. 1743, carefully answering each of Bonnet's questions. Though he did not specifically mention Boerhaave's definition in his letter, once again he returned to the question of structure:

> It is the idea, although very vague, which I have of the structure of polyps, which made the idea of turning them come to me. I had already tried it in 1741, but without success. I returned to it last summer, and after many troublesome attempts, I found a very short and easy method to use. Polyps never turn themselves inside out by themselves. It is on a complete Polyp that I do the experiment. It appears that the state in which the polyp finds itself after having been turned does not please it at all. Nearly always it tries to turn itself back, and often it succeeds. (Ms. Bonnet 24).

Trembley had first attempted this experiment in July of 1741, that is, the month after he had discovered how the polyp took food. In the *Mémoires* he described how he first thought of it when he noticed that the small granules in the lining of the stomach swelled up with nutritive juices after a feeding. Since he thought that the granules on the exterior and the interior surfaces of the skin were identical, he reasoned that they ought to both have a similar ability to absorb nutritive juices. Moreover, he was aware of the (soon to be discarded) hypothesis of Count Marsilli Marsigli in *Histoire de la Mer* that certain marine plants absorb nourishment externally through small glands or vesicles when placed in a sort of nutritive bath.

Since this approach was not successful, he then thought of inverting the polyp so that the external skin would be on the inside. However, his first attempts to try this experiment failed. It was not until he thought to try it after the polyp had been well fed, usually with a small, worm, that he succeeded. At first he placed the polyp in a drop of water in the hollow of his hand and gently pressed on it with a brush near its posterior end. By pushing the worm inside the stomach against the polyp's mouth, he forced the mouth to open and the worm to begin to emerge through the mouth. The second step was to remove the polyp to the moistened edge of his hand, while continuing to force the polyp's body to contract and the mouth to open wider. In step three, Trembley took a thick boar's bristle with a blunt end and, holding it "as one does a lancet to let blood," he pushed the posterior end so that it entered the stomach and emerged through the mouth. "One can visualize that in this situation the inverted Polyp envelops the end of the hog bristle which is now lodged inside it. The exterior surface of the Polyp has become the interior touching the bristle, and the interior surface has become the exterior." (A. Trembley 1744, p. 257). Finally, to prevent the polyp from turning itself back, Trembley pierced its body near its lips with a thin boar's bristle which he tied at one end. He then situated the spitted polyp in one of his powder jars in such a manner that it was prevented from touching the sides or the bottom of the jar and thus could not turn itself back.

Through the experiment of reversal, Trembley concluded, erroneously, I might add in the light of current cell theory which distinguishes between the ectoderm and the endoderm, that the inner and outer walls of the polyp were equally able to absorb nourishment. However, according to Trembley the fact that it was only through which ever wall was on the inside that absorption could occur, confirmed according to Boerhaave's definition that the polyp was an animal because it absorbed its nourishment from within. Trembley concluded on the basis of this experiment that his perplexing aquatic being was not an intermediate form midway between animal and vegetable realms, but a simple animal. His careful study of the polyp did not reveal the structures analogous to those of more complex animals. Trembley found that polyps had within them no nutritive vessels at all, neither roots, if they were to be considered plants, nor the lacteal vessels which Boerhaave had claimed must be found in animals. Trembley did not rule out the possibility that such structures might be so small as to be imperceptible, but rejecting Boerhaave's assertion that such structures *must* exist, he went on to reveal his distrust of generalizations based on analogy. He wrote:

> By analogy one could conjecture that there are such and such imperceptible parts in the skin of the Polyps, but I find it hard to believe that these suppositions founded on simple analogy would be very satisfying. The Polyps have a variety of characteristics where are directly contrary to analogies drawn from so many other animals. May they not also differ from those animals in regard to the nature of the unseen parts of which they are composed, and in the animal economy which results from the structure and functions of these Parts? This possibility seems more than likely to me. (A. Trembley 1744, p. 53)

Trembley denied that the polyp consisted of a double membrane; he concluded that the polyp consisted of a single skin, "shaped in the form of a tube, or gut, open at both its ends." (p. 58). Comparing this simplicity to more complex animals, for example those insects described by Swammerdam, he wrote: "When some other animals such as Caterpillars or sundry species of worms are cut open, they are found to contain various ducts. On opening à Polyp, however, the observer finds absolutely no more than one canal extending the length of the entire body. In other words, as I have already said, this entire animal seems to form but a single vessel, the external surface of which is the surface of the animal itself." (p. 52). Thus, Trembley concluded that the polyp was possibly of such simplicity that it was itself no more than a single hollow nutritive vessel.

To conclude, why have I chosen to focus on an experiment which, unlike the majority of his observations which still surprise biologists by their accuracy, has been called into question by contemporary research? Trembley's failure to distinguish between ectoderm and endoderm led him to the false conclusion that both the inner and outer surfaces of the polyp were equally able to absorb nourishment. Moreover, with the experiment of inversion he thought he had proved that the polyp could carry on all its life processes equally well reversed or right side out. Though he noted that the polyp, after being turned, naturally attempted to evert itself, he thought that by spitting it on a bristle, he had prevented its turning back and concluded that it could take food and reproduce equally well inverted or not. However, research done more recently by the American biologist, Martin Macklin, for example, has indicated that inverted hydra have the ability to turn themselves back with such rapidity that it is extremely difficult to observe. Trembley may have missed this phenomenon, spitting instead a right side out polyp.

However the question of inversion is ultimately settled by biologists, and it is possible that Trembley may yet have the last word on this score, Trembley's work on the polyp, especially his exploration of Boerhaave's idea that nutrition was the sole criterion on which to base the separation of the animal and plant kingdoms, led to a consensus that no absolute separation could be made. While Trembley did not go so far as to challenge Boerhaave's authority, his careful description of the granules found in the body of the polyp and his belief that these granules, not the hypothetical lacteal vessels, were the only structures involved in digestion, shows that he did not accept Boerhaave's assertions uncritically. Trembley's idea that the polyp had a structure like that of a single nutritive vessel shows, however, that he did not move very far from the teachings of the renowned Dutch physician. He believed that the polyp's structure not any inherent properties of matter could explain its various properties. But his work opened the door to newer mid-century vitalistic and materialistic ideas which Trembley himself never found at all palatable. Like Boerhaave, Trembley regarded his little aquatic being as a hydraulic machine, but his exploration of its elusive structure led others, such as Buffon, Needham, Diderot and La Mettrie to more radical conclusions. In particular, it produced a new interest in the problems of generation and revived the debates over preformation and epigenesis. Trembley, however, refused to be drawn directly into the metaphysical debates of his time, though it is clear that he later espoused the preformationist notions of his close friend, Charles Bonnet.

Trembley's experiment of turning the polyp inside out and the ideas that led him to this curious experiment demonstrate that he not only observed in a different world, where observations were made by natural or candlelight and compound microscopes were so primitive that many serious naturalists preferred the use of a single lens for magnification, but he also *thought* in a different world. This is not to be critical of his powers of observation which were extraordinary even by today's standards, but the better to appreciate them. The influence of Dutch science, his luck to fall among a circle of important observers at Leiden, employment at Sorgvliet by a sympathetic and enthusiastic patron, and the simple fact that the hydra grew prolifically in Holland's streams and ponds, but were difficult to find in the waters around his native Geneva, makes his debt to this small Republic all the more meaningful.

The study of the letters of Trembley, Bonnet and Cramer also demonstrates the importance of the Genevan intellectual milieu from which Trembley emerged. Trembley took with him to Leiden a sound training at Geneva's Academy of Calvin. His respect for Boerhaave's teachings did not develop overnight at Leiden, but certainly must have been carefully nurtured under professors Cramer and Calandrini who were both fully informed of all the important scientific ideas of the period through their frequent travels abroad. Nevertheless, Trembley's great skill as an observer set him apart from any of his mentors, either in Geneva or in Holland. His need to confirm their ideas experimentally is what gives his observations their timeless quality — that precision and rigor which we are celebrating with this volume to his memory.

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