

## LAZZARO SPALLANZANI\*

(1729-1799)

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**D**URING the eighteenth century Italy was many times exposed to the invasions of foreign armies. Her states were transferred from one tyrannical rule to another and her university towns were often camps for hostile armies. Yet in a little group of universities in northern Italy the sciences were being hastened in their metamorphosis with more than usual speed. The din of war may have been an added stimulus to those in search of truth and new facts. Science knows no enemy but falsity; truth recognizes no boundary lines. Padua, Pavia, Bologna, and Modena at different periods in the century bloomed with the discoveries of their brilliant philosophers. In the very shadow of these institutions of learning Lazzaro Spallanzani was born at Scandiano, January 10, 1729.

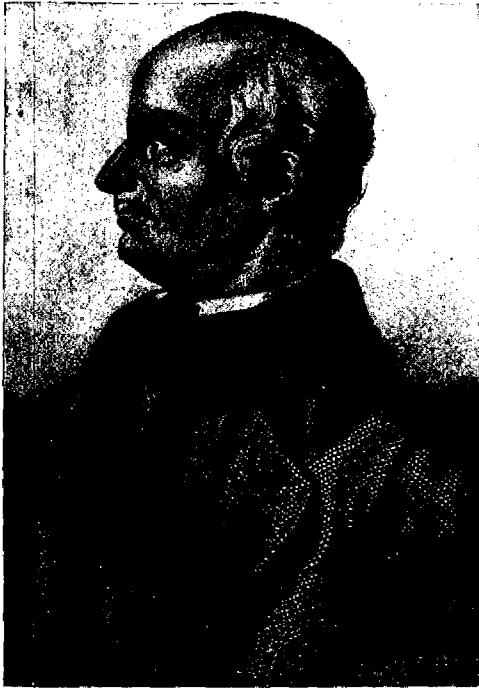
His father was an advocate of considerable distinction. He, rather than the mother,

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seems to have presided over the youth's elementary studies. His genius showed itself early, moreover, as may be inferred from the fact that his youthful companions called him "the astrologer." At fifteen he went to Reggio where he studied rhetoric and philosophy under the tuition of the Jesuits. His ability attracted the attention of the Dominicans who endeavored to induce him to enter their order. Instead, his longing for knowledge led him to Bologna where the critical period of his learning was perhaps directed by his cousin, Laura Bassi, deservedly celebrated for her knowledge of philosophy and mathematics. Not alone was philosophy studied but also antiquity, Greek, Latin and French, and even natural history. To Spallanzani the thing itself was much more interesting and fascinating than anything that might have been written about it. As his father desired that law should be his profession, Spallanzani also studied law. At the point of taking his degree the naturalist, Antonio Valisneri of Padua,

intervened with the father and Spallanzani was allowed to follow the bent of his own talent. That talent was in natural history.

Early in his career he took Holy Orders and is still spoken of as the Abbé. At twenty-five he was chosen professor of Greek, logic and mathematics in the University of Reggio. Even with the strenuous duties of teaching here he did such brilliant work on infusoria as to attract the attention of Charles Bonnet of Geneva and von Haller, then retired to his native city of Bern.



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Modena, Spallanzani's native university, called him to the chair of physics in that institution in 1760. Although only thirty-one years of age at this time he had received offers from various other institutions including the Academy of St. Petersburg. He was attached with considerable sentiment to the Modena University but in 1768 an offer by Empress Maria Theresa, then ruling over Austrian Lombardy, to give him the chair of natural history and keeper of the museum at Pavia proved too attractive to be refused. He held this position until his death thirty-one years later.

During this period (1768-1799) it will be

Tissot (1728-1797) also lectured at Pavia. Volta (1745-1827) at the same institution was studying electricity and two years after Spallanzani's death showed by the invention of the pile the analogy between galvanism and electricity. The energy thus excited is now spoken of as "voltaic electricity." Galvani (1737-1798) was public lecturer in anatomy at Bologna and in 1790 discovered that the contact of two different metals with the nerve of a recently killed frog will excite distinct muscular contraction. Morgagni (1682-1771), the founder of modern pathological anatomy, was a professor at Padua. After the French under Napoleon invaded Italy in 1796 Spallanzani was offered the position of professor of natural history at Paris. This he declined because of his advanced age. February 11, 1799, three days after an attack of apoplexy, having recovered sufficiently to recite Latin verse and having received the papal benediction, he died suddenly at 2:30 A.M. The illustrious Scarpa attended him.

Spallanzani had the ability that characterizes the true philosopher. Nature had blessed him with a magnetic personality. Although a priest and savant he was no recluse. He loved to hunt and fish and in early life was enthusiastic over chess and football. He had a robust frame, was about middle size, and had a high forehead, black eyes and a brown complexion. His countenance was dark and pensive. He was fond of society and enjoyed the company of the *signore* especially when grace and beauty were combined with refinement and a love of literature and science.

His seriousness of mind while yet young is shown in that one of the earliest problems to attract his attention was the origin of vitality. He was teaching in Reggio when Needham (1713-1781) was setting forth his theory of spontaneous generation. Buffon (1707-1788), the French naturalist, claimed that the small microscopic organisms seen in putrefaction and in scum from ponds were but particles of matter arising from the

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possessing the property of movement. He termed these "organic molecules." Needham boiled beef infusion and placed it in a stoppered vial only to find that putrefaction later took place. Since boiling must have killed the animalcules and since the vial was kept well stoppered, he argued that living things must have had their origin in a special vegetative force, spontaneous generation. Charles Bonnet (1720-1793), a naturalist of Geneva whose life must have greatly influenced Spallanzani since the two were the closest of friends, wrote an article in 1762 designed to refute the theory of epigenesis. Bonnet pointed out that in Needham's experiment the vials could not be considered hermetically sealed and that organisms in fluids might resist the boiling temperature for short periods. Spallanzani took up the problem at this point. He showed that Needham was right in his statement that living organisms always appear in boiled infusions introduced into stoppered bottles. He found also that even though the bottles were hermetically sealed with air excluded organisms appeared in the infusion. He suspected that the organisms might exist on the inner surface of the bottles and consequently he heated them in a flame and then introduced the infusion. Still organisms appeared. They might have entered with the air during the process of cooling. Finally to test this supposition he put the infusion into flasks, hermetically sealed the flasks, and subjected them to the heat of boiling water for an hour. No organisms appeared but if the sealing were disturbed so as to let in a bubble of air, organisms were soon found. The conclusion was impregnable: living organisms or their eggs or spores were necessary for putrefaction; the theory of spontaneous generation was upset. He followed the work still further, testing the effect of different temperatures and various substances such as oil of turpentine, camphor, sulphur, brandy, wine, etc. He even subjected the infusion to the electric shocks of a "Franklinian battery." He studied the modes of repro-

duction of these organisms noting that some multiplied by fission and others by eggs or spores. These observations were made over two hundred and fifty years ago when Leeuwenhoek's microscope was first being used by scientists. His methods were convincing and his results indisputable. Our modern methods of canning have a marked resemblance. However the old theory of spontaneous generation has since been rehashed many times.

Spallanzani had a great fondness for traveling and while doing so loved to pry into the secrets of nature. Thus his journeys became a means of discovering useful truths. In an excursion to the Apennines he had the satisfaction of proving his theory of the origin of springs. The rebounding of a stone thrown obliquely upon a body of water (the phenomenon of ducks and drakes) he explained by ingenious experiments and calculations as due to a necessary change in its line of direction produced by the cavity which it forms on striking the water. Elasticity of the water had been the common explanation.

In 1768 his essay, "Sopra le reproduzioni animale," appeared and surprised the scientific world. He showed that the reproduction of lost parts could take place in lower animals to an extent previously unrecognized. He confirmed the multiplied regeneration of polyps and the earthworm (Trembley) and discovered that the fresh water worm reproduced itself *ad infinitum*, each part, however it might be divided, becoming a complete animal of its species. Toads, lizards, and salamanders were shown to recover their paws, their tails, and their jawbones, the water snail its horns and the land snail almost all its members.

In consequence of reading Haller's physiology we find his interest aroused to a study of the circulation. He performed many experiments on salamanders in this connection. He also made important observations on the influence of the heart's action upon the arteries and veins and studied the relative velocity of the blood in the larger,

medium, and small vessels. This work was translated into English after his death.

Fecundation was considered one of the mysteries of nature and beyond inquiry. Even Magendie said in this regard: . . .

This is a phenomenon (fecundation) of which it is impossible that our senses should take cognizance. It is one of those mysteries which at present are, and will probably always remain, inexplicable. But we have the experiments of Spallanzani on this subject which have done as much towards removing the difficulty as perhaps can ever be effected.

Spallanzani, constantly seeking the details from which to gain sound basis for conclusions, could not consent that such a biological mystery should go unscratched. With sperm collected from the male he fertilized the ova of frogs. He fertilized a spaniel bitch by injecting into the vagina with a syringe sperm obtained from a dog. He thus expressed his pleasure when the young were born: "I can truly say that I never received greater pleasure on any occasion since I cultivated natural history." It was Leeuwenhoek's view that the sperm "are living miniatures of the animal from which they are derived, exacting only from the female a matrix for nourishment, evolution and growth."<sup>1</sup> Spallanzani maintained that the ova of the female held the miniature of the species, requiring only the stimulus of sperm to excite it into life.

In the summer of 1779 he visited Bonnet at the latter's "delightful villa" at Geneva. He had long wished for the opportunity to know Bonnet personally and enjoy his conversation. While there he became acquainted with Abraham Trembley (1710-1784), the naturalist, occupied with regeneration in hydra. Jean Senebier (1742-1809), Swiss pastor and naturalist, librarian of the republic of Geneva, was also here. Bonnet was studying asexual propagation in aphids, Spallanzani had been interested in artificial fertilization in amphibia. How interesting must have been the story that each had to

<sup>1</sup> Richerand, A. B. *Elements of physiology*, London, 1807.

tell his fellow naturalists! How inspiring must have been the exchange of ideas on biological questions by these masters! Spallanzani cherished his friendship with Bonnet; each submitted the results of his labors to the other before publishing.

It was in Geneva with Bonnet, Senebier, and Trembley as audience and critics that Spallanzani presented his work on digestion, published in 1780 under the title of "Dissertations Relative to the Natural History of Animals and Vegetables." In the introduction to this work he says:

In the course of my public demonstrations in the year 1777, I repeated in the presence of my hearers those celebrated experiments of the Academy of Cimento (perhaps Redi and Borelli), which show that stomachs of fowls and ducks exert so astonishing a force as to reduce hollow globules of glass to powder in the space of a few hours."

Having confirmed these findings he conceived the idea of extending the observations and applying the method to a study of digestion.

No summary of these dissertations can do them justice. The facts brought out by the experiments may be set down but that strips the work of fine qualities. The philosophic spirit in which it is written together with the discoveries made lend it immortality. To physiologists it is a classic. The author's familiarity with the work of the past century as well as the more recent discoveries of his time cannot be questioned. The findings and opinions of Redi, Valisneri, Magalotti, Pozzi, Boerhaave, and Haller are all carefully considered.

He repeated Réaumur's experiments on gallinaceous birds and showed that trituration was a cooperating factor but not the immediate cause of digestion. He used Réaumur's method of introducing foods to be digested in metallic containers with perforations for entrance of the gastric liquor. Observations were extended to almost every class of animals. He says: "Thus I enjoyed the pleasure of extending my researches to the principal classes of animals, not

neglecting man, the noblest and most interesting of all."

He obtained natural gastric juice by introducing sponges attached to strings into the stomach of various animals. The juice thus obtained was tested for its activity outside the body. The containers were fastened in his axillae to furnish an optimum temperature. Water was always used in one container as a control. He discovered that gastric juice prevents putrefaction, consequently he disproved the idea that digestion was a form of fermentation. He tried to get gastric juice from his own stomach by mechanically inducing vomiting. Some specimens were obtained but the practice was so disagreeable that he could not continue. He says: "I was absolutely incapable of repeating it, notwithstanding my earnest desire to procure more gastric liquor."

The action of the gastric juice on all possible kinds of foods, animal and vegetable, bone, etc., was studied. He himself swallowed perforated wooden tubes containing different food substances, later recovering and examining the contents. Thinking that digestion was probably much slower outside the body than in the stomach where possibly the liquor was renewed, he tried repeatedly dropping gastric juice on the substance to be digested and found "solution took place with exceeding speed."

Almost all of the various samples of gastric liquor obtained must have been mixed fluids containing bile and mucus. He describes it as yellowish in color, bitter and salt to the taste, clear and limpid on standing and not inflammable as Réaumur had suggested. Its acidity was ever concealed to him although many times he suspected and tested for acid.<sup>2</sup> He was thus forced to conclude that it was neutral normally, becoming acid perhaps in cases of indigestion where acid is apparently regurgitated, But this acidity he explained as due to fermentation of the contents. To Scopoli, then professor of chemistry at Pavia, he

<sup>2</sup>The discovery of free hydrochloric acid in the gastric juice was made by William Prout in 1824.

gave a sample for analysis. Thus the first chemical analysis of gastric juice stated:

The gastric fluid contains, first, pure water; secondly, a saponaceous and gelatinous animal substance; thirdly, sal ammoniac; fourthly, an earthy matter like that which exists in all animal fluids. . . . The gastric fluid of the crow precipitates silver from the nitrous acid, and forms luna cornea. This phenomenon might induce us to suppose that common salt exists in the gastric fluid.

Had the specimens been less contaminated, an acidity would certainly have been discovered.

John Hunter criticized this work unjustly. To him Spallanzani was a mere experiment maker who repeated his observations "most unnecessarily." His criticism is rude and without scientific foundation. The facts are not known but perhaps the difference in the general views of the two men may account in part for his attitude. Hunter was an exponent of vitalistic principles; Spallanzani was entirely free from the imaginative factors that for years limited the spirit of investigation. He showed conclusively that gastric fluid is most active when kept at body temperature. Hunter's observations on digestion of the stomach after death led him to believe heat was no factor. In a letter addressed to Caldani at Padua, published in 1788, Spallanzani in a most dignified manner took him to task with an invincible strength of reasoning that threw aside all disguise and left him with no hope of a reply.

Hunter's criticisms may be considered as the expression of a jealous tantrum and not different from his many other fits of anger resulting from an unharnessed temper. Spallanzani's work on digestion is as interesting today as its contributions were valuable at the close of the eighteenth century. He laid down the outlines of digestion, the same that we have today, and only those details have been filled in which the development of chemistry has made possible.

Beaumont<sup>3</sup> makes the following statement:

Suffice it to say, that the theories of concoction, putrefaction, trituration, fermentation and maceration have been prostrated in the dust before the lights of science and the deductions of experiment. It was reserved for Spallanzani to overthrow all these unfounded hypotheses, and to erect upon their ruins a theory which will stand the test of scientific examination and experiment. He established a theory of chemical solution, and taught that chymification was owing to the solvent action of a fluid, secreted by the stomach, and operating as a true menstruum of alimentary substances. To this fluid he gave the name of gastric juice.

An incident is recorded as having taken place in connection with Spallanzani's translation of Bonnet's "The Contemplation of Nature" which illustrates his indisposition to bind philosophy to system. Each professor was required to select a textbook for the use of the students. Spallanzani chose his translation of Bonnet's book. His selection, on being submitted, did not meet with approval in Vienna where biology was taught by system. The professor of natural history at Vienna explained that while he admired the philosophic character of Spallanzani's selection he did not believe it gave the necessary emphasis to nomenclature. Spallanzani was exasperated. His hatred of the systematists he now expressed with the jibe of "nomenclature naturalists."

On request he wrote out an outline of lectures he intended to give on natural history. This outline amounted to a defense of his point of view. The authorities were unyielding. Spallanzani was forced to fall in line on the subject of nomenclature instruction by the bribe of a promised increase in salary.

Early in 1784 he was desirous of making a trip to Turkey and had begun plans for the journey, but he did not succeed readily in getting the proper leave. Meanwhile Valisneri,<sup>4</sup> professor of natural history at Padua, died. Spallanzani was offered his position.

<sup>3</sup> Physiology of digestion, Plattsburgh, 1833.

<sup>4</sup> Son of Antonio Valisneri (1661-1730).

He now brought strong pressure upon his institution asking to be relieved of his post saying that the air at Pavia was unsuitable to his health.<sup>5</sup> Vienna at once, "in order to preserve for the university a celebrated person" promised to double his salary and gave him leave to go to Constantinople. He was gone almost a year on this trip, making many interesting observations. He was received by the sultan and on his way home stopped in Vienna to be presented with a gold medal by Joseph II. His reception upon his return illustrates the high regard in which he was held by his students. They met him outside the gates of the city by loud acclaims and escorted him through the streets of Pavia. The following year his students exceeded five hundred in number.

Knowing his popularity with his students, his renown as an investigator, and his prestige with those in power, it is not at all surprising to learn that he "heard the hiss of envy's snakes." A philosopher soaring in the heights of fame is sure to excite the envy of even the hatred of a few of those lesser individuals who cannot get above the first stratum of clouds. The museum at Pavia was under Spallanzani's care. He had taken great pride in it. Its contents were organized by him and by his efforts alone it had flourished. Much of the material had been accumulated through his correspondence and travel. During his absence in Turkey the curator made the discovery that several objects mentioned in the catalogue were not to be found. He knew that Spallanzani

<sup>5</sup> Cummings states that he enjoyed a "florid state of good health" and such complaints were for diplomatic reasons. The following statement from his "Dissertations" indicates that he may not have been as hardy as he appeared. "Being stronger than common, let no one suppose that my stomach is capable of digesting what that of others cannot digest. I own with concern that it is weak as is usual in those whose pursuits condemn them to a sedentary and unwholesome way of life. My stomach digests food so slowly that I cannot study for five or six hours after a sparing dinner and am liable to indigestion whenever I feed more plentifully than common."

had a private museum at his old home, Scandiano. Secretly he visited this and found there, so he maintained, several of the objects belonging to the museum at Pavia. Immediately a scandal of theft was started against Spallanzani. Care was taken to inform all who might be concerned. His associates, Professors Scopoli, Scarpa, and Fontana were drawn into the conspiracy. Various prominent individuals in other universities were informed of the "atrocious" crime of their famous colleague. An inquiry was opened at the royal palace of Milan. Spallanzani succeeded unquestionably in his own defense. Plausible explanations for all the missing objects were given. He was declared innocent. Volta was deprived of the office of curator and sent away from Pavia. Professors Scarpa, Fontana and Scopoli were censured for their attempt to injure the reputation of a fellow professor. Although silence upon those concerned in the scandal was imposed by royal decree, the Abbé could not restrain himself from discharging some piercing shafts at his accusers. Volta was "a bladder full of wind"; Scarpa, "a plagiarist"; Scopoli, "an intestinal worm." In the summer of 1788 a desire to further enrich the museum at Pavia led him to journey to the Two Sicilies to study the products of Etna, Vesuvius, and other volcanoes. This trip like most of his other travels he says was at his own expense. The report of his trip and findings, Spallanzani's "Travels in the Two Sicilies," makes a good-sized volume. The same diligence and care with which his other work was done he exercised in the examination of lava rock and flowing lava. He describes Messina four and one-half years after it had been laid in ruins by earthquakes. The city was still in the same condition that the earthquakes left it. He pictures the inhabitants as "oppressed and overwhelmed with fears from which they had not yet recovered." He visited Vesuvius while it was erupting. The great heat and fumes made this a dangerous and trying exploration, but he says:

What experiment can be undertaken perfectly free from inconvenience, and all fear of danger, on mountains that vomit forth fire? I would certainly advise the philosopher who wishes always to make his observations entirely at his ease, and without risk, never to visit volcanoes.

While climbing Etna he was overcome by the volcanic fumes and fatigue. After regaining consciousness, he laboriously climbed to the crater rim and gazed into the cup of the stupendous volcano, feeling entirely repaid for his strenuous efforts. He returned to Pavia richly laden with new materials for the museum. It may be mentioned that among the many distinguished guests whom he had the pleasure of showing through this museum was Joseph II.

During the later years of his life he was deeply engaged in the study of respiration. This work, "Memoirs on Respiration" (1803), was published after his death by his friend, Senebier. It will be remembered that Joseph Black had discovered carbon dioxide in 1753. Priestley had prepared dephlogisticated air in 1772. Lavoisier in 1777 called this air "respirable air or oxygen" and discovered the true nature of the interchange of gases in the lungs. He adopted the theory that the oxidation of carbon and hydrogen takes place in the lungs. Lagrange in 1791 showed the untenability of this hypothesis and concluded that oxidation must take place in the blood. Spallanzani had carefully watched these developments and now it was left to his perspicuity to add the final chapter that is in all essentials our modern conception of respiration. He found that snails and other molluscs in an atmosphere of hydrogen or of nitrogen gave off carbonic acid almost as rapidly as if they had breathed air. Here was proof that the blood gave off, at least for a short time, carbon dioxide even in the absence of oxygen. He showed that many animals absorb oxygen and give off carbon dioxide from the surface of their bodies. He demonstrated that tissues breathe. Stomach, liver, ovaries, etc., when excised, he found to take up oxygen and give off

carbon dioxide.<sup>6</sup> By quantitative experiments he proved the effects of activity and temperature upon the respiratory exchange. He was the first to show that the exchange may be influenced by the nature and quantity of food. The seat of respiration was at last made obvious and the study of internal respiration may justly be said to have been founded by these experiments. The imagination cannot conceive a more fitting climax for the life of this great investigator.

How broad his education must have been and how capable he was in the exercise of his mental talents we can readily see from a summary of his many and varied contributions. He distinctly disproved the theory of spontaneous generation which had been done by Redi before the discovery of microscopic organisms had given its exponents a new basis for argument. His work on fertility blazed the trail for future investigators. Mineralogy received distinct contributions from his labors. He was perhaps the first to study the ability of bats to avoid obstacles in flying after they had been blinded. The dissertations on digestion were read in all scientific circles; their contribution to physiology was monumental. The studies on circulation contained original and important observations. By his work on respiration he first showed the real seat of combustion.

Spallanzani was a Fellow of the Royal Society of London and a member of the Academies of Prussia, Stockholm, Göttingen,

<sup>6</sup> Magendie could not have been familiar with this work when he published his physiology in 1822. He says: "The lungs, then, are the principal source of animal heat, as was indicated by the trials of Lavoisier and Laplace."

Turin, Padua and Bologna. His works were read and esteemed in all civilized countries. He lifted the horizon of natural history and extended the boundaries of science. His researches and his eloquence in their presentation, his grasp of philosophy and his magnetism as a teacher gave him a position unapproached among his contemporaries. He possessed the teacher's gift of inspiring his students. Men from every part of Europe came to hear him and went away with a new enthusiasm for science. His lectures were animated and eloquent, embracing the three kingdoms of nature. His European contemporaries were unrestrained in their expressions of tribute to him. Bonnet said he had discovered more truths in five years than all the academies in a half century. "The dying hand of Haller consigned to him the defense of truth and nature." As a huge mountain overshadows the surrounding foothills, so his masterful personality dominated the scientific world in which he lived.

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