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Domenico Cotugno (1736-1822), Antonio Scarpa (1752-1832), and Alfonso Corti (1822-1876): The Most Important Discoveries of the Inner Ear Made by Young Italian Physicians—Domenico Cotugno

ABSTRACT

The 18th and 19th centuries bequeathed to modern science fundamental discoveries in microscopic anatomy. The most important findings regarding the ear were made by young Italian researchers: Domenico Cotugno, Antonio Scarpa, and Alfonso Corti. Domenico Cotugno was born in Ruvo di Puglia on January 29, 1736, into a modest family. He was only 24 years old when his first great work, *De aquaeductibus auris humanae internae anatomica dissertatio*, was published in 1760. Cotugno, who worked on fresh ear specimens collected from newborns or fetuses, discovered the existence of 2 aqueducts (Cochlear and vestibular). Thanks to his revolutionary dissection technique, he also detected the constant presence of labyrinthic fluid. He wrote that the aqueducts were filled with liquid and not with air, as was generally held according to the Aristotelian dogma of *aer ingenitus*, uncontested by scholars such as Falloppio, Eustachi, and Willis. Cotugno also stated that the perilymphatic and subarachnoid spaces communicated at the base of the brain. His theory of resonance and his description of anatomical ear structures laid the foundations of today's comprehension of hearing.

Keywords: Domenico Cotugno, inner ear anatomy, 18th-century medicine, cerebrospinal fluid, labyrinthic fluid

Anna Colombo[1]
Valerio Maria Di Pasquale Fiasca[1]
Andrea Cozza[2]
Alessandro Martini[3]

[1]Department of Neurosciences, Section of Otorhinolaryngology—Head and Neck Surgery, University of Padua, Padua, Italy
[2]University of Padua, Padua, Italy
[3]Padova University Research Center "International Auditory Processing Project in Venice (I-APPROVE)", "Santi Giovanni e Paolo" Hospital, Venice, Italy

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Corresponding author:
Valerio Maria Di Pasquale Fiasca
Email: *valeriomaria.dipasqualefiasca@studenti.unipd.it*
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INTRODUCTION

The most important discoveries on the inner ear are probably those published between the end of the 18th and the first half of the 19th century by 3 young Italian scientists: Domenico Cotugno, Antonio Scarpa, and Alfonso Corti. There are also some interesting connections between them: Cotugno had in Morgagni a staunch defender of his discovery; Scarpa was a pupil of Morgagni; and Corti had his ideal mentor in Scarpa.

In his booklet on the Kingdom of the Two Sicilies, Alexandre Dumas wrote, "Towards the end of the last century [18th] Naples could boast three or four outstanding physicians [. . .] The most famous practitioner was Domenico Cotugno, a man of immense erudition."[1] Domenico Felice Antonio Cotugno was born in Ruvo di Puglia on January 29, 1736, into a family of modest means. He received a classical education in the Seminary of Molfetta, and then in 1753 he went to Naples to pursue his interests in medical studies.[2] In the Neapolitan University he was able to attend the lessons of Francesco Serao, who taught practical medicine.[3] He increased his anatomical knowledge since he had the opportunity to be repeatedly present at autopsies and received the privilege of being able to consult a vast collection of scientific volumes in the hospital's library.[4] In 1754, even before graduating, Cotugno got an assistant position in the Ospedale degli Incurabili. He completed his degree in medicine later on in 1756 at the Salerno Medical School (known as one of the first European medical institutions). In those years, Cotugno's fame spread widely, and he even received the offer of a position as anatomy professor at the universities of Pavia and Pisa. He declined all of those to remain in Naples, where he had filled the same position since 1766. He became thereafter director and head physician of the Ospedale degli Incurabili.[5]

At age 25, Cotugno discovered what he called the parabolic-incisive nerve, a nerve that originates from the second trigeminal branch. Then, at the age of 28, he published his second great work, *De ischiade nervosa commentarius*. Cotugno was convinced that there

was a liquid in the cerebral canal (*Spinae cavum circa medullam spinalem completur humore; similis etiam est humor circa cerebrum et cerebellum*—"The spinal cavity around the spinal cord is filled with fluid; it is also similar to the liquid around the cerebrum and cerebellum"). His innovative dissection method, which consisted of avoiding the incision of the dura mater, helped him to observe the presence of cerebrospinal fluid, which would then be called *Liquor Cotunni*.[6] He correctly identified the heart of the problem with the nervous sheaths.[7] Cotugno's interests were extremely varied: through multiple experiments in which he clotted the urine of a patient with acute nephritis, he was able to describe albuminuria and was one of the first researchers to detect urea in urine.[8] He also observed multiple phenomena, as in the study of smallpox pustules (in *De sedibus variolarium syntagma*).[9]

Cotugno (Figure 1) made his debut in the field of anatomical studies at an early age. He published his masterpieces at 25, 28, and 32 years.[6,10] His studies on the inner ear and ischialgia became famous in Italy and abroad, and nowadays they represent astounding examples of the rational empiricism that characterized the times he lived in between the 18th and 19th centuries. To underline his fundamental role in medical science progress, he has been defined as the father of Neapolitan medicine. It is reasonable to place Cotugno's work in the scientific tradition that started with Hippocrates and, through the Salerno medical school, continued into the Neapolitan school of the 17th century, including the "Accademici Investiganti," and in the experimentalists of the early 18th century. A famous quote of his was, "Medicine has no masters, the only master is Nature."[5] His method was to observe the symptoms and effects of diet and drugs, which anticipated modern semiotics. Moreover, it is well known that, as a professor, he preferred hospital wards to university rooms; most of the lessons he gave from 1766 to 1818 were accompanied by dissections in the *Ospedale*. This testifies to the importance that direct observation of natural phenomena had in Cotugno's science. He was against mixing medicine with philosophical and metaphysical cues. His work is therefore a vivid example of the Italian culture of that time.

MAIN POINTS

- The present study reviews the life of Domenico Cotugno, a famous professor and physician who lived and worked in Naples, Italy, in the 18th century. His work represents one of the most important roots of current knowledge of inner ear structures and functions.
- Among his studies, we emphasize his discovery of inner ear fluid. He was able to demonstrate that the inner ear was full of liquid, denying the Aristotelian dogma of *aer ingenitus*. He also stated that this liquid communicated, through the inner ear aqueducts, which he described, with the subarachnoid space.
- Domenico Cotugno made his most important discoveries at the age of 24. He is indeed part of a group of young Italian scientists who, in the 18th and 19th centuries, made some of the most important discoveries regarding the inner ear.

Figure 1. Domenico Cotugno (1736-1822), portrait by C. Nalli. Corrales CE, Mudry A. History of the Endolymphatic Sac: From Anatomy to Surgery. Otol Neurotol. 2017;38(1):152-156. doi:10.1097/MAO.0000000000001273.

He was only 24 years old when his first great work, *De aquaeductibus auris humanae internae anatomica dissertatio*, was published in 1760.[11] It is surprising how such a young man was able to have such a good grasp of the complex inner ear anatomy. In the preface of his masterpiece, Cotugno himself apologizes for describing details unnoticed by previous authors (*Mirum proinde, vel rerum gnarissimis, videri poterit, voliusse me aliquid de hoc organo proferre, quod tantorum Anatomicorum attentionem praeterierit. Aquaeductus enim auris internae exponere aggressus sum, quales ad huc inauditi*—"So it may seem strange, even to those most familiar with those subjects, that he wanted me to report something on this organ, which has come to the attention of so many anatomists. The inner ear aqueduct I decided to exhibit, as it had been unheard of until then"). He observed that findings in the study of the inner ear followed one another quickly, and those discoveries, which appeared definitive, were deeply modified in the following years (*Sed et de aure post Falloppium inaudita protulit Eustachius, nova post hunc Casserius, novaque Folius, meliora Du Verneiyus, illustriora Valsalva et Cassebohmius, ac pleraque longe, post tot tantosque viros, definita, Morgagnus. Nempe, quia naturam nuquam sine fructu consulimus, nec post mille saecula praecludetur inquirentibus occasio nova detegendi*—"As for the ear, Eustachius produced unprecedented things after Falloppius, and other new Casserius after him, and even newer Folius, Du Verney even better, Valsalva and Cassebohmius even more illustrious,

and Morgagni, after many and many men, far more defined. Of course, because nature is never consulted without fruits, nor after a thousand centuries will the inquisitors be prevented from discovering a new opportunity").[12] Cotugno thus noticed, working on fresh ear specimens collected from newborns or fetuses, the existence of 2 aqueducts (Cochlear and vestibular). Thanks to his revolutionary dissection technique, he also detected the constant presence of labyrinthic fluid. He wrote that the aqueducts were filled with this liquor and not with air, as was generally held according to the Aristotelian dogma of *aer ingenitus*, uncontested by men of science such as Gabriele Falloppio (1523-1562), Bartolomeo Eustachi (ca. 1500-1574), and Thomas Willis (1621-1675). Cotugno also stated that the perilymphatic and subarachnoid spaces communicated at the base of the brain. A few, such as his ideal mentor Giovanni Battista Morgagni (1682-1771), had contemplated the presence of a liquid in the labyrinth, but they had always considered air to be present. He acknowledged Antonio Maria Valsalva (1666-1723)[13] and Morgagni's studies on the perilymph.

Domenico Cotugno also provided one of the first accurate descriptions not only of the vestibular aqueduct, semicircular canals, and cochlea but of the internal ear's osseous labyrinth as well. He identified the nerves that reach the semicircular canals and the cochlea.[14] Moreover, Cotugno recognized anatomical structures such as the scala tympani and the scala vestibuli, the oval and round windows, and the helicotrema. In the vestibule, he identified the utricle, even though he wrongly described it as divided into 2 parts, 1 anterior and 1 posterior. His research followed that of previous authors such as Valsalva, but Cotugno disagreed with the latter concerning the cochlea's auditory function. He rightly stated that the auditory receptive surface was the basilar membrane of the cochlea, which became wider as it ascended the cochlea, and that it was made of a large number of cords. His grasp of inner ear anatomy also allowed him to point out how vibrations of cochlear fluids stimulate the acoustic nerve and how, when a sound is generated, only specific cochlear nerve fibers vibrate in unison with that sound. These observations are the basis of today's understanding of the tonotopic organization of the cochlea and the theory of resonance. According to his new theory, the stapes sets the labyrinthine fluid into vibration, which in turn stimulates the basilar membrane fibers and then the acoustic nerve through endolymphatic waves.[15] Cotugno's formulation of the theory of resonance is closely related to the anatomy of the cochlea and its basilar membrane. Years later, in 1862, Hermann von Helmholtz (1821-1894) described his theory of resonance but did not quote Cotugno's studies. More advanced auditory theories were based on new anatomical discoveries but were still connected to Cotugno's original ideas. Indeed, several papers on auditory theories of that period cite the resonance theory as the Cotugno–Helmholtz theory.

Cotugno's studies spread far and wide. Not all of the scientific community of his time accepted his theories. The famous professor Johann Friedrich Meckel (1781-1833) labeled the 2 aqueducts "*diverticula Cotunni*"; Leopoldo Marco Antonio Caldani (1725-1813) from Padua and Jakob Ernst Arthur Böttcher (1831-1889) from Dorpat confirmed Cotugno's thesis. Thus, the saccus endolymphaticus has also been defined as the "Cotugno–Boettcher's sac."[16] Albrecht von Haller (1708-1777) in his *Elementa physiologiae corporis humani*,[17] still considered the aqueducts venous vessels; Antonio Scarpa (1752-1832) did not even consider Cotugno's results in his studies regarding the ear organs (1785-1789).

In 1764, Cotugno traveled throughout Italy and described this voyage (Figure 2 and Figure 3) in his diary *Iter Italicum patavinum*.[18] He had the opportunity to meet some famous scientists of that time, such as Giovanni Battista Morgagni (1682-1771) in Padua, who had founded the study of clinical anatomy and pathological anatomy. Morgagni had been a professor for fifty years. Three years earlier (1761) he had published his life work,"De sedibus et causis morborum per anatomen indagatiis". He was indeed considered the most important anatomical and pathological researcher of his age. The 2 scientists maintained a relationship of cordial and constructive dialogue, which is documented by their correspondence. It is known that as he traveled to Padua, Cotugno received many criticisms for his theories from the scientific community. Cotugno sought the approval of Morgagni, which he obtained. This relationship certainly proves the profound respect and admiration that Cotugno had for the Paduan

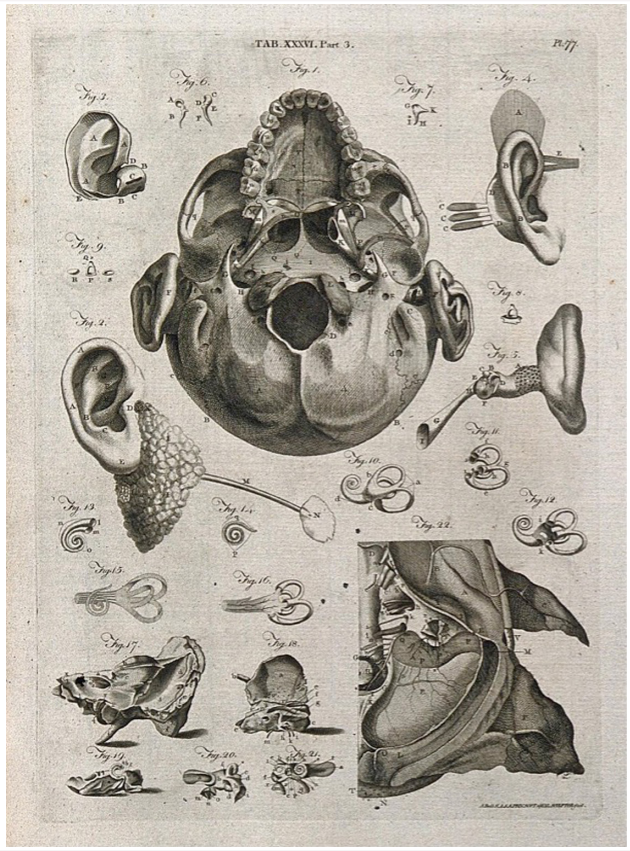

Figure 2. Line engraving by A. Bell "Parts of the ear and base of the skull showing teeth, ear, and nose: fourteen figures," 1798, Edinburgh. Bell A. Anatomia Britannica a System of Anatomy. Comprising the Whole of Albinus's Tables, with Selections from Cowper, and Other Eminent Anatomists; illustrated by one hundred and nine copper plates, from the most celebrated authors in Europe. Edinburgh: Encyclopædia Britannica Inc., 1798.

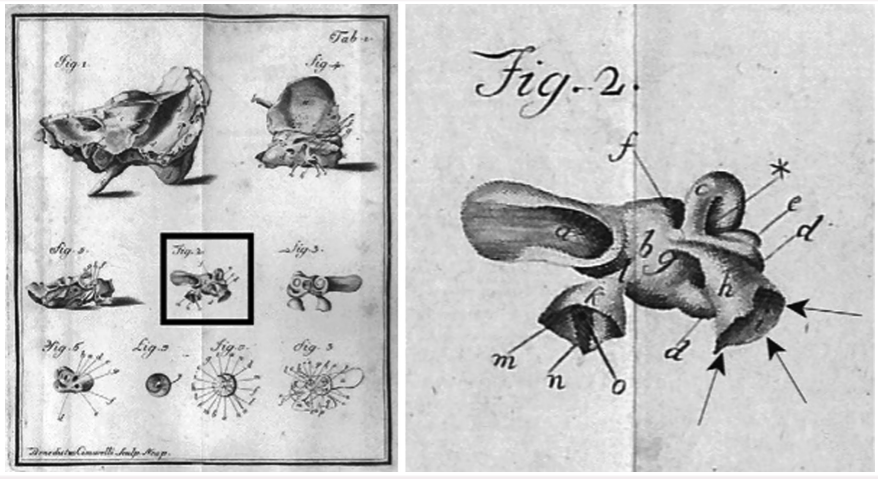

Figure 3. Drawing from D. Cotugno's ***De aquaeductibus auris humanae internae anatomica dissertatio***, 1761, Napoli. Cotugno D. De Aquaeductibus Auris Humanae Internae Anatomica Dissertatio. Napoli: Simoniana; 1761.

professor, who had an excellent reputation in the scientific field. The latter wrote, *Del Sig. Cotugno posso dirle che nella Notomia sente molto avanti e merita d'esser stimato ed amato per le sue cortesi maniere* ("Mr. Cotugno I can tell you that in the Notomia he understands very forward and deserves to be esteemed and loved for his courteous manners").[19] That was not the only trip of scientific relevance: in 1789, Cotugno became chamber physician of the Neapolitan Royal Family and Ferdinando IV di Borbone and followed the king on his travels to foreign countries. As he wrote in the "*Iter Germanicum*", he traveled with the royal family to Vienna, where Gerard van Swieten (1700-1772) worked as chief physician and Emperor's doctor. The Austrian academic was an important inspiration for Cotugno, who dedicated to van Swieten the *De ischiade nervosa commentarius*.[20]

Domenico Cotugno was not only a brilliant researcher. Thanks to his rigorous analytical method, he was able to make numerous discoveries at an extremely young age. He continuously poured over the works of his predecessors and contemporaries, such as Giovanni Battista Morgagni (1682-1771), Joseph Guichard Duverney (1648-1730), Antonio Maria Valsalva (1666-1723), Gerard Van Swieten (1700-1772), and Albrecht von Haller (1708-1777), intently analyzing every single word. He was also a firm believer in seeing things for himself and not just through the eyes of others. His main goal was to analyze the close relationship between anatomical structure and function through "seeing, touching, measuring, opening any part of this organic machine, and through these means gaining an idea of its inner shape, so as to move into it through long-travelled routes."[21] Aiming to see the human body as close to its original state as possible, he realized the importance of dissecting human tissues soon after the time of death. To be able to fully understand bodily fluids in their natural state, he would even dissect living animals.

From the publication of Cotugno's works, there derived an intense correspondence between famous scientists of that time. The correspondence between Cotugno and Caldani and between Caldani and Felice Fontana (1730-1805) is particularly significant. Caldani, Morgagni's successor in Padua, was a profound advocate of Cotugno's discoveries concerning the liquid found in the labyrinth.[21] In his work *Institutiones physiologicae*, Caldani explicitly refers to Cotugno's discoveries, and in the *Dialoghi di Fisiologia e Patologia,* he accurately describes the presence of water in the labyrinth and its function.[22] However, he questioned its functional interpretation in relation to the mechanism of hearing, as he believed that the caliber of the aqueducts was too narrow to allow the movement of the liquid.[23]

Felice Fontana, on the other hand, a scientist who studied the inner ear and worked for the Grand Duke Pietro Leopoldo II of Tuscany, did not leave any written works of his studies. From his letters to Caldani, however, we can see how Cotugno's discoveries and methods stimulated and encouraged him to analyze these findings for himself through the dissection of fresh ears. His sectoral work corroborated Cotugno's discoveries, again confirming the novelty and brilliance of the Neapolitan doctor.[24]

Cotugno dedicated his elderly years mostly to social commitment and politics. He promoted mass vaccination for smallpox as president ad interim of the Società Reale d'Incoraggiamento (an organization that gathered the best scientists and professors of that time to promote public health and development), and in 1806 he filled the role of president of the Comitato Centrale di Vaccinazione.[25] Moreover, he was considered one of the most important researchers of his time by the Neapolitan scientific community and celebrated as the Hippocrates of Naples. He was then elected rector of the University of Naples in 1812, following Gioacchino Murât's reestablishment as rector.[26] He died of a cerebral stroke on November 5, 1822, at the age of 86. He bequeathed over 80 000 ducats—his whole fortune—to the Ospedale degli Incurabili.

He has been described as a "physician humanist"; his interest in arts, architecture, numismatics, and antiquities is widely recognized. He was a true bibliophile too; part of his library remains in the Biblioteca Nazionale di Napoli. In the *Iter Italicum*, he wrote a detailed description of the libraries he found during his travels to Rome, Pesaro, Padua, Venice, Florence, and Montecassino.[27]

CONCLUSION

The scientific effort of Domenico Cotugno is still relevant nowadays. His work represents a milestone in understanding the function of the inner ear. He made his most important discoveries at a very young age. He is part of a group of young Italian scientists who, in the 18th and 19th centuries, laid the foundation of the future knowledge on the inner ear.

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