
Published online September 21, 2012

DOI: 10.3171/2012.8.JNS12387

Copyright:
© American Association of Neurological Surgeons. Published by the Journal of Neurosurgery Publishing Group.

Reproduced with the permission of the publisher and posted for personal academic use only. Permission for reuse of figures, etc. must be granted by the Journal of Neurosurgery Publishing Group.

Link to published article:
http://dx.doi.org/10.3171/2012.8.JNS12387

Date deposited: 18th February 2015
In recent years, there has been a growing interest in the study of white matter anatomy. The development of diffusion tensor imaging for in vivo tractography and the renewed interest in postmortem dissections, usually performed by neurosurgeons, have both contributed to this evolving branch of neuroanatomy. HODOTOPY, the study of white matter connectivity, is of great importance, not only for a better understanding of brain functioning but also to tailor the surgical approach to the individual functional anatomy of each patient.

This article focuses on the pioneering work in neuroanatomy, and white matter anatomy in particular, performed by Raymond de Vieussens (1641–1716), a French anatomist born in Le Vigan. He studied medicine at the University of Montpellier in southern France, one of the most ancient and lively schools of medicine in Europe. In 1684 Vieussens published his masterpiece, the *Neurographia Universalis*, which is still considered one of the most complete and accurate descriptions of the nervous system provided in the 17th century. He described the white matter of the centrum ovale and was the first to demonstrate the continuity of the white matter fibers from the centrum ovale to the brainstem. He also described the dentate nuclei, the pyramids, and the olivary nuclei. According to the theory of Galen, Vieussens considered that the function of the white matter was to convey the “animal spirit” from the centrum ovale to the spinal cord. Although neglected, Vieussens’ contribution to the study of white matter is relevant. His pioneering work showed that the white matter is not a homogeneous substance, but rather a complex structure rich in fibers that are interconnected with different parts of the brain. These initial results paved the way to advancements observed in later centuries that eventually led to modern hodology.

**Key Words** • history of medicine • hodology • Vieussens • white matter • neurosurgical history

**The Life and Times of Raymond de Vieussens**

Raymond de Vieussens was born in 1641 in the city of Le Vigan in southern France (Fig. 1). There is, however, some uncertainty regarding his birth, with some authors citing 1635 as his year of birth. He studied philosophy at Rodez in France before moving to Montpellier, where he embraced anatomical research and medicine. He completed his studies and graduated in medicine from the University of Montpellier in 1670. After graduation, he was appointed as physician to the Saint-Eloi hospital in Montpellier. There, he devoted “ten years of hard work” to the study of the nervous system that eventually led to the publication of the *Neurographia Universalis* in 1684. This first work was well accepted by the European medical community as one of the most important contributions to the field of neuroanatomy of the 17th century. Surprisingly little attention has been paid to the historical role of Vieussens, and there is no readily available study in the literature dedicated to reviewing his contribution to the study of white matter anatomy.

Raymond de Vieussens and his contribution to the study of white matter anatomy

**Historical vignette**

**FRANCESCO VERGANI, M.D.,1,2 CHRISTOPHER M. MORRIS, PH.D.,2,3 PATRICK MITCHELL, PH.D.,1,2 AND HUGUES DUFFAU, M.D., PH.D.4,5**

1Department of Neurosurgery, Royal Victoria Infirmary; 2Institute of Neurosciences and 3Medical Toxicology Centre, University of Newcastle, Newcastle upon Tyne, United Kingdom; 4Department of Neurological Surgery, Hôpital Gui de Chauliac; and 5INSERM U1051, Institute of Neurosciences of Montpellier Hôpital Saint Eloi, CHU Montpellier, France

DOI: 10.3171/2012.8.JNS12387
appointed Vieussens as her personal physician. During the following years, Vieussens continued to work at Saint-Eloi Hospital, where he developed an interest in the study of heart anatomy and cardiology. This led to a series of important works. In 1705 he published the *Novum vasorum corporis humani systema* ("New vessels of the human body"), where he gave an accurate description of the lymphatic and blood vessels of the heart. In particular, he was the first to describe small ducts joining the ventricular cavities to the coronary vessels. Vieussens called these channels "ducti carnosi" (fleshy ducts); as we know today, these channels correspond to the capillaries of the coronary arteries. The other major work on cardiology was the *Traité nouveau de la structure et des causes du mouvement naturel du cœur* ("New treatise on the structure of the heart and the causes of its natural motion"), published in 1715, 1 year before his death. In this work Vieussens described in detail the pericardium, coronary vessels, and muscle fibers of the heart. He also described clearly the clinical picture and the findings at autopsy of patients with mitral valve stenosis and aortic insufficiency. This account was one of the major contributions to the understanding of the pathophysiology of these two clinical conditions.

Vieussens lived in 17th-century France when his country, under the rule of Louis XIV, became one of the leading powers in Europe. The historical period when Vieussens studied and worked was also marked by the birth of the scientific method as we conceive it today, based on the accurate observation of natural phenomena and the experimental reproducibility of these observations to explain the laws of nature. A generation before Vieussens, Galileo set the basis of modern physics, while William Harvey provided us with the method of physiology. A contemporary of Newton, Leibniz, and Locke, Vieussens shared the scientific spirit of his time.

The Medical School of Montpellier: a Rich Cultural Milieu

The Medical School of Montpellier, in southern France, is one of the most ancient medical schools in Europe, second only to the Schola Salernitana (School of Salerno) in Italy. Medicine was being taught in Montpellier as early as 1181, when Gilhem VIII, lord of the city, established the right of teaching medicine. It was in 1289 that the University of Montpellier was officially founded and recognized by Pope Nicholas IV with the bull “Quia sapientia.” The newly created university incorporated the Schools of Medicine, Theology, and Law and Letters. During the Middle Ages, the School of Medicine increased its reputation, combining the teaching of the Jewish and Arabic traditions and attracting students from all over Europe. Important figures of the time were Arnaud de Villeneuve (1240–1311), physician, alchemist, and theologian, and Gui de Chauliac (c. 1300–1368), physician, surgeon, and author of a well-known treatise on surgery in Latin titled *Chirurgia Magna.* During the Renaissance the faculty of medicine acquired more independence from the Church, coming progressively under the influence of the state and of the King of France. Possibly because of this autonomy, cadaver dissections were routinely carried out in Montpellier as part of the teaching of human anatomy. This is confirmed by the building in 1556 of the first anatomical amphitheater in France dedicated to the dissection of cadaveric specimens. The use of human cadavers for anatomical studies was a well-established practice in Montpellier, as witnessed by Vieussens himself. In the introduction to the *Neurographia Universalis,* Vieussens declared that the aim of his medical profession was to investigate the causes of diseases by means of “careful dissections of human cadavers, of which I had large availability.”

Study of White Matter Anatomy Before Vieussens: on the Shoulders of Giants

Andreas Vesalius (1514–1564), the father of modern anatomy, was the first to differentiate between the gray and white matter of the brain. In his main work, *De humani corporis fabrica,* he distinguished between the softer and yellowish cortex and the firmer, whiter substance below it. Nicolaus Steno (1638–1686) suggested for the
Vieussens and white matter anatomy

One of the problems at the time was the preparation of the cadaveric specimens, as dissection of the white matter was technically difficult. This was partially overcome by Marcello Malpighi (1628–1666). Boiling the brains in water, he was able to trace the white matter bundles of the brain and cerebellum. He was also the first to show, using a microscope, that the white matter is organized in fibers. After Malpighi, Thomas Willis (1621–1675), working in Oxford, developed a technique of scraping the white matter to demonstrate the bundles and the intricate arrangements of the fibers. Both Malpighi and Willis were directly acknowledged by Vieussens in his *Neurographia Universalis*.32

**Neurographia Universalis**

The *Neurographia Universalis*, hoc est omnium corporis humani nervorum, simul et cerebri, medullaeque spinalis descriptio anatomica (“General Neurography, that is, the anatomical description of all the nerves of the human body, and also of the brain and spinal cord”) was published in Lyons in 1684 by the editor Joannes Certe (Fig. 2).32 This edition was enriched by beautiful copperplate illustrations created by Jacques Beaudeau, who was one of the foremost engravers in Montpellier (Fig. 3). The treatise is divided in 3 parts: the first volume is dedicated to the brain, the second to the spinal cord, and the third to the nerves (both intracranial and peripheral). From a methodological point of view, Vieussens adopted the scraping method of dissection used by Willis, and improved the technique of Malpighi of boiling the brains, using oil instead of water.28

In Chapter 10 of the first volume titled “De distinctis duabus cerebri substantiis” (“the two distinct substances of the brain”), Vieussens clearly differentiated between white and gray matter, highlighting the different texture between the two: “The brain is composed of two substances, one different from the other; the gray and the white matter; the gray, if observed in its natural state or after boiling in water or oil, appears to be much softer than the white matter.” After heating the brains in oil, he was also able to demonstrate that “the white matter of the brain...is formed by innumerable fibers connected together, and arranged in multiple fascicles; this appears evident after it is boiled in oil.” In Chapter 11, “De cerebro stricte sumpto” (“the brain considered in strict sense”), Vieussens described the hemispheres and the convexity of the brain. He gave a detailed account of the corpus callosum (for which he proposed the name of “verum fornicis”), identifying it as a white matter structure connecting the 2 halves of the brain. He then illustrated the centrum ovale, the oval-shaped white matter lying beneath the cortex and surrounding the corpus callosum and the ventricle walls, as demonstrated in “tabula VI” of the first volume (Fig. 4). The introduction of the term “centrum ovale” is one of the legacies to the field of neuroanatomy left by Vieussens.

The method followed by Vieussens in his description of the brain anatomy is of a “top to bottom” dissection. Starting from the plane of the centrum ovale, he pursued the dissection inferiorly, exposing the lateral ventricles (with the foramen of Monro, termed “vulva” by Vieussens), the septum pellucidum, the fornix, the third ventricle, and the thalami. At this level, Vieussens described the basal ganglia region, where he found tracts of white matter interspersed in the gray matter of the nuclei. Vieussens adopted the term “corpora striata” (striate bodies) because of the presence of white matter fibers. He distinguished between superior, middle, and inferior striate bodies, which possibly correspond to the caudate and lenticular nuclei (Fig. 5). We note here that the terminology introduced by Vieussens regarding the basal ganglia is somewhat obscure, and perhaps for this reason it was not followed by other authors.7 Following the fibers caudally, Vieussens was able to demonstrate, for the first time, the continuity of the white matter through what is known today as the internal capsule, down to the pyramidal tracts and the brainstem (Fig. 6).

The later chapters of the first volume are dedicated to the cerebellum and to the so-called medulla oblongata, with the first description of the dentate nuclei, the pyramids, and the olivary nuclei. Vieussens, following Thomas Willis and contrary to modern terminology, used the term “medulla oblongata” to indicate the deep white matter of the hemispheres, the thalami, and brainstem.

Despite this accurate and precise anatomical description, the physiological explanation provided by Vieussens...
was still strongly influenced by the theories of the “animal spirit” of Galen. In Vieussens’ view, the structural organization of the white matter fibers, running from the centrum ovale to the medulla oblongata and the spinal cord, had the purpose of conveying the animal spirit. “It is possible to see how the animal spirit…which penetrates in the white matter fibers, moves from the anterior regions to the posterior; and through the tracts of white matter that run caudally from the posterior part of the centrum ovale…[the animal spirit] reaches inferiorly the posterior origins of the spinal nerves.” Thus, the intricate arrangements of the white matter fibers explain the different range of thoughts and emotions that the animal spirit can generate. “The white matter is formed by long and curved fibers, that are so mixed and interrelated that they take the form of a spongy body, that the animal spirit permeates in multiple, different and inexplicable ways; so that within it [the spirit] undergoes multiple, different and inexplicable emotions; because of their different arrangements, different thoughts are generated in the mind.”

The Legacy of Raymond de Vieussens

The Neurographia Universalis had a great impact on the study of neuroanatomy in Vieussens’ time. Along with Thomas Willis’ masterpiece, Cerebri anatome (published in 1664), it is considered one of the most complete and accurate descriptions of the nervous system from the 17th century. Many investigators continued Vieussens’ work. With a technical improvement, obtained by hardening the brain in an alcohol solution, Felix Vicq d’Azir (1748–1794) confirmed in his dissections many of Vieussens’ findings. D’Azir also provided a more detailed description of the centrum ovale, which he renamed “centrum semiovale.” More than a century after Vieussens’ work, Johann Christian Reil (1759–1813) introduced the term “corona radiata” to describe the centrum ovale. He clarified the relationship and the continuity between the fibers of the centrum ovale and the internal capsule and cerebral peduncles, at the same time describing the insula and the external capsule.

Surprisingly, the contribution of Vieussens has been in part neglected, and he has been rarely cited in the literature. Relatively few authors were involved in the study of white matter pathways during later centuries, notably Karl Friedrich Burdach (1776–1847), Pierre-Louis Gratiolet (1815–1865), and Joseph Jules Dejerine (1849–1917). Dejerine also gave the first account of a disconnection syndrome, describing a case of alexia without agraphia in a patient with a lesion involving the white matter of the splenium of the corpus callosum. The current standard for white matter dissection in postmortem human brain...
specimens is the technique developed by Joseph Klingler (1888–1966),1,17 who introduced the process of freezing previously fixed brains. The ice that forms between the fibers separates the white matter fascicles, thereby facilitating the dissection. The Klingler method allowed for more accurate anatomical investigations, with the clear identification of the major white matter fascicles. Few authors performed dissections according to this technique until recent years, when a renewed interest in white matter connections arose in the neurosurgical community.29 In the last decade, several fiber dissection studies have been reported, some of these combined with diffusion tensor imaging, providing original data.3,6,14,20,21,28 In particular, the cortical termination of some controversial fascicles has been elucidated.21,27 Continuing the clinicopathological work inaugurated by Dejerine, different authors have also investigated the function of white matter pathways, especially using intraoperative subcortical stimulation.2,11,12,26 Such findings have allowed for the proposal of new concepts in the organization of the human brain, switching from localizationism to hodotopy, with applications in neurosciences as well as in clinical practice, and particularly in neurosurgery, where sparing important white matter fascicles is vital in preserving function.8

One further legacy left by Raymond de Vieussens relates to the relationship between science and philosophy. The methods of Vieussens’ anatomical investigation have been improved on but remain comparable to postmortem dissections performed today. The methods available to him for analyzing the functional aspects of the CNS were vastly different from those that have been developed since. In parallel with this distinction between a comparatively stable technology of anatomical investigation and rapidly changing technology of functional investigation is the distinction between Vieussens’ anatomical and functional theories. His anatomical theories have been refined but remain broadly compatible with our modern interpretations. By comparison, his functional theories appear to have been surpassed from a modern perspective. In the past, medicine adopted a philosophical explanation for biological processes that could not be otherwise explained (for example, the “animal spirit” of Vieussens and Galen). The change in this viewpoint originated in technological development that only secondarily engendered a philosophical change, rather than the other way around. Vieussens lived in the 17th century, when the modern scientific method was at its very beginning. His interest was in an organ system in which the methods of investigation extend from arguably the most constant to the most changing over the intervening centuries.

Conclusions

Raymond de Vieussens opened the door to investigating the white matter of the brain in humans. His pioneering work showed that the white matter is not a homogeneous and indistinct substance, but rather a complex structure, rich with fibers that are interconnected with different parts of the brain. These initial results paved the way to the advancements observed in later centuries that have subsequently found application in so many fields of neuroscience.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Vergani, Morris, Mitchell. Acquisition of data: Vergani. Drafting the article: Vergani, Morris, Duffau. Critically revising the article: all authors. Reviewed
submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Vergani. Study supervision: Duffau.

Acknowledgments

The authors would like to thank Paolo Vergani (graphic designer) for his invaluable help in editing the figures in this article. The authors are also indebted to Dr. Gemma Scozzesi for reviewing the article and assisting in the translation from Latin.

References

30. Vesalius A: De humani corporis fabrica. Basil: Johann Opinus, 1543
32. Vieuussens de R: Neurographia Universalis. Lyons: Joannes Certe, 1684
33. Vieuussens de R: Novum vasorum corporis humani systema. Amsterdam: Paul Marret, 1705
34. Vieuussens de Ra: Traité nouveau de la structure et des causes du mouvement naturel du Coeur. Toulouse: Jean Guillelmette, 1715
35. Willis T: Novum Novum vasorum corporis humani systema. Amsterdam: Paul Marret, 1705

F. Vergani et al.