Leonardo: The Bioengineer

By Max E. Valentinuzzi and Giovanni Pallotti

La meccanica è il paradiso delle scienze matematiche, perché con quella si viene al frutto matematico. [Mechanics is the paradise of the mathematical sciences, because through the former, one gets to the fruits predicted by the latter.]

—Leonardo da Vinci

The above quote is an inspired and foretelling musing about mechanics, as it can be projected nowadays to electronics and biomedical engineering at large. Technology more than 500 years ago was extremely limited, but da Vinci seemed to have seen the future. Leonardo di ser Piero da Vinci (Figure 1) was born on 15 April 1452 in Vinci, a small town located in the province of Firenze, in the Italian region of Tuscany, and died in Amboise, France, on 2 May 1519, at age 67. All of da Vinci's works imply, to a higher or lower degree, an extraordinary synthesis of art, science, and technology, together with theoretical and practical experience, visiting essentially every field of human knowledge. Unfortunately, his scientific and technological discoveries, as well as his inventions, have had very little, if any, influence on current knowledge, perhaps because of his persistent custom of keeping things secret or maybe because of the very limited means of communication available in those days.

The purpose of this article is to bring to light da Vinci's facet as a very early bioengineer who had an interdisciplinary approach to every subject he put his hands or thinking on.

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The purpose of this article is to bring to light da Vinci's facet as a very early bioengineer who had an interdisciplinary approach to every subject he put his hands or thinking on. Many original documents and codices show this side of his monumental personality. Most of our information comes from the beautiful compendium produced by Carlo Pedretti, a world-renowned specialist in da Vinci's works and a devoted and true *leonardist* (daring the invention of a word) [1]. In addition, the Internet is full of information and details of da Vinci's life and production.

The original source material can be traced back to Francesco Melzi, whom da Vinci took as a disciple in 1506. Melzi traveled to France with da Vinci and stayed with him until his death. Melzi inherited da Vinci's artistic and scientific works, manuscripts, and collections as the administer of his estate [2]. These original and valuable documents have been dispersed throughout several collections and museums, which are listed in Pedretti's publication [1]. Regretfully, the collection has not been centralized in one place, such as, for example, in da Vinci's birthplace, where there is a museum devoted to this extraordinary man.

Anatomical and Functional Studies

Leonardo da Vinci's interest in anatomy and the proportions of the body dates back to his apprenticeship with Andrea Verrocchio (ca. 1435–1488), and his work in this area is well known. Verrochio wanted all of his students to study human anatomy; however, da Vinci took his interest a step further. With permission from a hospital in Florence (which was very different from what we think of as a hospital today) [3], he began studying the human body by dissecting corpses. He later engaged in a partnership with a physician and continued performing dissections for many years. Currently, many bioengineering students, if not all, take anatomy courses along with actual dissection exercises.

da Vinci was a scientific genius as well as an artist. In addition to his paintings and sculptures, he also wished to compile a book to be used in the medical field. Medicine at the time was far from having a good scientific background and da Vinci hoped that the discoveries of the Renaissance would project to the arena of medicine. In addition to the human body, da Vinci studied many animals, such as birds, horses, and cats.

IMAGE IN PUBLIC DOMAIN.

FIGURE 1 This portrait of a man drawn in red chalk (ca. 1512–1515) housed in the the Royal Library of Turin is thought to be a self-portrait of Leonardo da Vinci. (Image courtesy of Wikimedia Commons.)

His drawings served as the first anatomically correct representations [well before the recognized anatomist Andrea Vesalio (1514–1564)], and he was the first person to write down descriptions of the skeleton. da Vinci was also the first to note that the sacrum was really a nonuniform fusion of vertebrae. Thereafter, he proceeded with internal organs, such as the lungs, liver, and sexual organs. Leonardo's contributions on the proportions of the body were far ahead of his time. However, he did not stop with anatomy; he went deeper into how the body works, in humans as well as animals and in normal and diseased bodies. Through this, he created theories about bodily functions, such as blood flow and male erections, the mechanics of eye movements, and the flight of birds. He attempted to develop a scientific method by applying mathematical laws to human anatomy [4]–[7].

Can we now claim that da Vinci was the first bioengineer? If so, what an ancestor we have!

The *Codex Leicester* (sometimes referred to as the *Codex Hammer*) contains a collection of da Vinci's scientific writings. It is named after Thomas Coke, the Earl of Leicester (1697–1759), who was a wealthy landowner and a patron of the arts. Coke purchased these famous documents by da Vinci in 1719. The *Codex* provides insight into da Vinci's inquiring mind, as a scientist and a thinker, as well as an exceptional illustration of the link between art and science and the creativity of the scientific process.

Discussion

After da Vinci's death in 1519, Melzi took many of da Vinci's manuscripts and drawings back to Italy. Fortunately, out of this vast collection, more than 5,000 pages of drawings and notes have been able to traverse (although not fully intact) the many obstacles placed by men over the centuries. However, da Vinci's manuscripts today look nothing like they did during his lifetime. Melzi's heirs, after his death in 1579, began to scatter the material. Having no idea of their importance, da Vinci's drawings and manuscripts were stored in a loft and later given away or sold as parts of the collection. Many hands have touched these documents, all adding a dose of chaos, until they ended up in the *Codex Atlanticus* and as part of the Windsor collection. At least four more volumes were created. Long and complicated is the story for which more details can be found in [8]. In short, da Vinci's drawings are now divided into the following ten manuscripts:

- *Codex Arundel:* British Library, London.
- *Codex Atlanticus:* Biblioteca Ambrosiana, Milan. (The drawings are, unfortunately, rather dismembered.)
- *Codex Trivulzianus:* Biblioteca Trivulziana, Milan.
- *Codex on the Flight of Birds:* Biblioteca Reale, Turin, Italy. (In this work, da Vinci analyzed very rigorously the mechanics of flight as well as the resistance imposed by air and wind. It can be dated to approximately 1505.)
- *Codex Ashburnham:* Institute de France, Paris.
- *Codices of the Institut de France.* (This collection also contains information on the flight of birds.)
- *Codex Forster:* Victoria Albert Museum, London.
- *Codex Leicester (*the former *Codex Hammer):* purchased by Bill Gates in 1994.
- *The Windsor Folios:* Windsor Castle Royal Collection.
- *The Madrid Codices:* National Library of Spain. (Although it is difficult to believe, these documents were not rediscovered until 1966.)

The bibliography of information about da Vinci is extensive, but an outstanding book deserves to be highlighted: a translation of *The Notebooks of Leonardo da Vinci* [9]. Amazing aspects are revealed in this book, which can probably be found in the codices mentioned earlier as well. For example, da Vinci made the following observations in notes from this book [9, p. 191]:

- "A man at three years will have reached the half of his height."
- "A woman of the same size as a man will weigh less than he does."
- "A dead woman lies face downwards in water, a man the opposite way."

Are these statements true? We do not know, and we leave them dangling for the curious reader to discover. The same book [9] calls attention to the fact that da Vinci was the first to make casts of the cerebral ventricles, which he did several hundred years before any other anatomist. In [9, pp. 215–218], da Vinci's notes address body relationships, a typical biometric subject. It seems an endless list, indeed.

Conclusions

This brief article is obviously not exhaustive, as it is only intended to show that out of the extremely wide volume of da Vinci's contributions, one significant piece was devoted to what is now clearly placed within bioengineering. Other names have been suggested as "the first bioengineer" in history, such as Hermann von Helmholtz or Carl Ludwig [10], scientists who evidently built the modern basis of the new and growing multi-, inter-transdiscipline. It is well documented that da Vinci was, above all, a scientist and an engineer [11], as he neglected artistic commissions in favor of his scientific interests. However, his influence as such went essentially unnoticed and without any influence, least of all in biomedical engineering. This is a pity, really; but can we now claim that da Vinci was the first bioengineer? If so, what an ancestor we have!

Max E. Valentinuzzi (maxvalentinuzzi@arnet.com.ar) *is with the Institute of Biomedical Engineering, University of Buenos Aires, Argentina, and* ***Giovanni Pallotti (giovanni.pallotti@unibo.it)*** *is with the Department of Physics, University of Bologna, Italy.*

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PERSPECTIVES ON GRADUATE LIFE *(continued from page 8)*

graduation in a year yet to be determined. The next big milestone is to set up my dissertation advisory committee, which is formally a committee set up to guide students through the thesis/dissertation writing process for the duration of graduate work. Informally, it is a group of people who determine your fate and control your destiny. In the process of helping you navigate through the maze of graduate school, this committee also decides when you can defend your thesis (and graduate). I am not sure if there is a lot of strategy for choosing committee members (at least I am not aware of any). My major consideration was to attempt to have a committee of all M.D./Ph.D.s or M.D.s. I assume that they will be more lenient when it comes to allowing me to graduate, since they will hypothetically better understand the need/pressure to finish the Ph.D. degree and resume medical school; however, I am not entirely sure if that is the case in reality.

The advice that I was given is to choose committee members who are experts in diverse aspects of my thesis project. With this setup, I should be able to get support in all aspects of my project. While this seems like a great idea in theory, a constantly evolving thesis project makes it a difficult goal to achieve, especially since my thesis project will still be in its infancy when the committee must be chosen.

Another upcoming potential milestone is to apply for a grant. Specifically, many M.D./Ph.D. students apply for the National Institutes of Health (NIH) F30 grant, which is geared toward M.D./Ph.D. students. In my last column, I talked about some of the unintended benefits of the PQE. Another one of these benefits is that it makes the idea of applying for an official grant a lot less intimidating. This is because the PQE (as with many other Ph.D. programs' qualifying exams) is roughly modeled after an NIH grant's guidelines and formatting. The main concern for actually applying for such a grant is having enough preliminary data, though I am sure that the amount of preliminary data required might vary from project to project. At this point, the idea of applying for an F30 is a distant thought, but it may soon become a reality.

Matthew C. Canver *is currently an M.D./Ph.D. candidate at Harvard Medical School in Boston, Massachusetts.*