# Ludwig: The Teacher

By Max E. Valentinuzzi, Klaus Beneke, and Germán E. González

*Men and women most often seek to project themselves into the future through their biological progeny, but how much far reaching can be the intellectual progeny that only few are able to enjoy.* —*Max E. Valentinuzzi*

This is the third and last article of a series devoted to Carl Friedrich Wilhelm Ludwig's outstanding life (29 December 1816–23 April 1895). The first article portrayed him as a bioengineer [1] and the second as a physiologist [2]. Here, we view him as a teacher, the teacher par excellence, as recognized and commended by Theodor Beer (1866–1919)—a naturalist and physiologist who, incidentally, had a disgraced, sad, and ruined life [3]—making it a dramatic history subject, especially for its several human facets and controversial feelings and beliefs. In his own words:

> Ludwig war der deutsche Professor par excellence, der deutsche Professor im besten Sinne des Wortes, er war nicht nur tüchtig, sondern auch bedeutend, ein Klassiker in seiner Art.

Loosely translated, this means "Ludwig was the German teacher par excellence, the German teacher in the best meaning of the word, he was not only efficient, but also transcendental, a classic in his breed or sort."

We have mainly drawn information from three published sources: a book on Ludwig, written by Heinz Schröer [4], a report from the American Physiological Society [5], and another report, available on the Internet [6], written by Klaus Beneke, a coauthor of this series of articles on Ludwig. All three sources are exhaustive and comprehensive, and only some general philosophical comments seem pertinent to add.

Bernardo Alberto Houssay (1887–1971)—winner of the 1947 Nobel Prize of Medicine and Physiology that was shared with Carl Ferdinand Cori and his wife Gerty Theresa Cori, née Radnitz, for contributions to the better understanding of the mechanisms of diabetes and of glucose metabolism—used to state that, often, any project in life (especially any project in a country, and more specifically, any long-range scientific project) should meet, or better yet, must invariably honor an indispensable practical prerequisite followed by three rules (the "Golden Rules of Science"), not to be altered in their sequential order, if seriously set, and if success is to be expected, that is:

> As a prerequisite, a firm political decision, backed up by enough funding, delivered on time; selecting the right people first; having at hand the necessary equipment immediately thereafter; and finally lodging in a suitable building.

Not uncommonly, these basic rules have been boldly violated, leading to failures and frustrations not exempt of economic losses. Many experiences in Latin American countries, for example, can be found listed in their history, such as unfinished buildings that remain empty and slowly deteriorate, standing shamefully in front of everybody, or buildings that were used for everything but their intended purpose (therefore not really suitable), or expensive equipment stranded for years in customs warehouses because an entrance permit was not cleared on time, while the receptor laboratory or institute could not proceed with its plans. An even worse failure is when equipment is available, but there is no one capable of operating it—someone did not take that detail into consideration! These types of failures could supply material for a long, sad, and painfully distasteful article.

The Leipzig Institute of Physiology stood solidly on its feet as an example that meticulously met the rules, and fruitful results continued for decades, even going through times of upheaval and tense political situations, including destructive wars. The Leipzig Institute of Physiology is now crossing into its second century of a productive academic and scientific life.

## Prerequisites: Political Decision and Enough Funding Delivered on Time

The University of Leipzig (Universität Leipzig), located in the city of Leipzig in the State of Saxony, Germany, is over 600 years old (see Figure 1). The poet Johann Wolfgang von Goethe (1749–1832), the music composer Richard Wagner (1813–1883), and the

**FIGURE 1** Universität Leipzig or *Alma mater Lipsiensis* Motto: *Aus Tradition Grenzen überschreiten* (crossing boundaries out of tradition). The design was created on 2 December 1409. (Image supplied courtesy of Gérman E. González.)

*Digital Object Identifier 10.1109/MPUL.2012.2216974*
*Date of publication: 11 December 2012*

FIGURE 2 Johann Paul Freiherr von Falkenstein, Saxony's Minister of Culture in Ludwig's time. (Image supplied courtesy of Klaus Beneke [6].)

FIGURE 3 Ernst Heinrich Weber. (Image supplied courtesy of Klaus Beneke [6].).

philosopher Friedrich Nietzsche (1844–1900) are some of its famous alumni. Multiple Nobel Prize winners in physics, chemistry, and literature are also among the alumni.

In Ludwig's time, Johann Paul Freiherr von Falkenstein (1801–1882), shown in Figure 2, was the minister of Culture of Saxony, and he wanted an able man to replace Ernst Heinrich Weber (1795–1878), who was about to leave the position of physiology chair (which he had held since 1840). That man was Ludwig, probably recommended by Weber himself (Figure 3). All this was in line with the ideas sustained by King Johann von Sachsen (1801–1873), a

FIGURE 4 König Johann von Sachsen. (Image supplied courtesy of Klaus Beneke [6].)

definite supporter of science and the arts (Figure 4). That was a political decision, and obviously the necessary monies were granted or appropriated, so that in four years, from April 1865, when Ludwig took over, until April 1865, the new building was inaugurated [7]. Ludwig acted as its main designer (Figure 5).

## First Golden Rule: The People

Once the prerequisites are met, the first of the golden rules must be applied: recruit able, experienced, and, most importantly, motivated people. The selection process may take a long time and, in some cases, a concourse, contest, or competitive examination and/or an interview is conducted, supported by the candidates' curricular evidence. Undoubtedly, Carl Ludwig was the man for the job. He was 49, a prime age. He had already gathered solid research and teaching experience while working in Marburg, Vienna, and Zurich, demonstrated by a series of superb scientific contributions and, most relevant, he had ideas, drive, and perception. Those who hired him could not fail, and they did not. Ludwig knew well how to proceed with the recruitment process, for all his collaborators, local or from abroad, met (to varying degrees) the above-mentioned conditions. This included a mechanic, Gerhardt Baltzar, about whom not much is known. He worked with Ludwig for many years, becoming his right-hand man. Another important character was Herr Salvenmoser (first name and biographical information unknown), a laboratory technician ("diener," in German, even though the literal translation would be "servant" or "valet"), who had come with Ludwig from Vienna. He was essential in every experimental preparation and could be as opinionated as he was beloved and useful [5].

**Ludwig was in permanent contact with colleagues in other laboratories worldwide, exchanging information and looking for advice and different opinions.**

Ludwig was in permanent contact with colleagues in other laboratories worldwide, exchanging information

FIGURE 5 The original Leipzig Institute, in Ludwig's time. (Image supplied courtesy of Klaus Beneke [6].)

and looking for advice and different opinions. This is amazing, considering the communication difficulties of those days, compared with the mobility and the almost instant communication of our current lives! Ludwig had an open mind.

## Second Golden Rule: The Equipment

Very early in Ludwig's scientific career, he realized that experimentation, along with good reliable measurements, was essential to reach a truly quantitative physiology. Thus, by 1847 (when he was only 31), the first wave recorder, called the kymograph, was developed [1]. From that period on, several models were tested and developed. There was even a model of the recorder, called the "Ludwig-Baltzar Kymograph," that was industrially produced by the Zimmerman Firm [8]. Sven Dierig [9] brings up a nice and appealing concept, somehow recalling and also related to the ideas developed many years ago by Thomas S. Kuhn [10]—what until now have been separate fields of 19th-century history, that is, the development of experimental physiology, the growth of mechanized industry, and the city where their threads intertwined. The laboratory in the city employed the same technological and organizational approaches to modernize itself as the city used to get industrialized. Laboratory research developed after the introduction of small-scale power engines. With its machines, the industrialized city provided not only the key concept of the 19th-century life sciences but also a key technology that shifted experimental practices in animal research from a kind of preindustrial craft to a more mechanized production of knowledge. With its factory laboratories, the late 19th-century city became the birthplace for the first living data-producing hybrid, part animal and part machine. Mechanical engineering was a tantalizing and predominant technology. The old Leipzig Institute perfectly fit such a view.

**With its factory laboratories, the late 19th-century city became the birthplace for the first living data-producing hybrid, part animal and part machine.**

## Third Golden Rule: The Building

The building took four years to become a reality from when Ludwig was appointed to the physiology chair, and it was a superb building. In March 1870, Henry Pickering Bowditch (1840–1911), a young American physician from Boston who was being trained in Leipzig, described the lab where he had been working for the last six months [5]:

> It was very large—an open U in shape, 120 feet on a side, with two stories and a basement. Working space was about equally divided among the three subjects under Ludwig's ken: microscopy-cum-histology, experimental or physical physiology, and physiological chemistry. The histological section had a large room for beginning microscopists, as well as a smaller one for advanced workers, which was fitted out with sophisticated injection apparatus. Experimental physiology had a large room just for the storage of apparatus, three rooms for general experiments, and two additional large ones for grand-scale experiments on respiration, acoustics and metabolism.

He described other spaces and facilities: animal quarters, a workshop for the full-time laboratory mechanic Herr Baltzar, and an area for glassblowing. The institute was "a perfect physiological paradise," in the words of John Jacob Abel (1857–1938), an American pharmacologist among the many there [5]. The original building was destroyed during World War II. Today, there is a new building and activities continue uninterrupted (Figures 6–8).

## Direct Disciples or Ludwig's "Children"

We counted 251 people who spent time with Carl Ludwig under his scientific supervision, either during his period in Leipzig (1865–1895) or before, in Marburg, Zurich, or Vienna, and who can be called direct disciples (an average of about slightly over eight per year). About 100 were from abroad; unfortunately,

**FIGURE 6** The The Leipzig Institute as it looked in 2003–2004. (Photo courtesy of Dr. González during his stay.)


**FIGURE 7** Dr. González stands in front of the Leipzig Institute's main entrance. (Photo taken during his stay there in 2003–2004. He was the first fellow from South America to spend a training period at the institute.)

FIGURE 8 Some of the Ludwig Institute staff in 2005, when Dr. H.G. Zimmer (second row left, wearing glasses) was its director. Germán E. González (first row, left, in front of Dr. Zimmer), was a fellow at the institute. (Photo taken by and courtesy of Dr. González.)

however, there are no complete details. Some later became prestigious and well-known investigators, establishing physiology schools of their own that, in a sense, should be considered belonging to the Ludwig School or its genealogy, thus producing what could be called "Ludwig's grandchildren," all carrying his imprint. The most outstanding were, for example, Ivan Petrovich Pavlov (1849–1936), who discovered the conditioned reflex (you sound a whistle while feeding a dog, and the next time you whistle, without offering food, the dog would salivate), who won the Nobel Prize of Physiology and Medicine in 1904, Henry Pickering Bowditch (1840–1911), who brought modern physiology to the United States and organized the then new Harvard Laboratory in Boston, Massachusetts (Figure 9), or Luigi Luciani (1840–1919) and Angelo Mosso (1846–1910) who did something comparable in Italy, including contributions of their own (Figure 10).

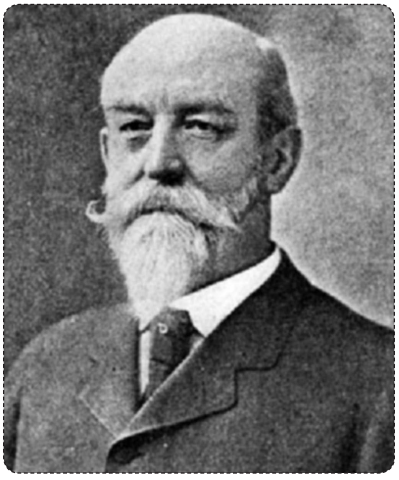

FIGURE 9 Henry Pickering Bowditch. (Image supplied courtesy of Klaus Beneke [6].)

FIGURE 10 Angelo Mosso. (Image supplied courtesy of Klaus Beneke [6].)

The chapter provided in [5] is most helpful and informative regarding the experiences gained by several Americans who were trained under the supervision of Ludwig. Most importantly, Ludwig exemplified how the best investigator gave his life to his investigations and to the research of the students he directed. He was there 24 hours a day, and almost the entire year. The Leipzig Institute hummed even in the dog days of summer. Each morning, Ludwig would visit the tables of nine or ten men and women working in the physiological section. This atmosphere made the institute a little world unto itself. Unfortunately, laboratories can be found where that is not the case, and they pay the price for it; as the Bible states, by the "fruits you shall know the tree."

## Forebearers

Ludwig did not stand alone, without previous influential and/or inspirational sources, as he himself clearly recognized Robert Wilhelm Bunsen (1811–1899) and Ernst Heinrich Weber (1795–1878) as his teachers by working and exchanging ideas with them. They offered him a guiding light in a given direction. Even Johannes Peter Müller (1801–1858), whom Ludwig highly respected but whose philosophical vitalistic position he frankly opposed [along with the three direct disciples of the former (Müller), Helmholtz, Brücke and du Bois Reymond] somehow must also be considered a forebearer. The vitalistic concept perhaps acted as a stimulus to these younger and intellectually hungry minds. There is always someone behind us, even at the very beginning. But who was first?

This atmosphere made the institute a little world unto itself.

## Conclusions

Ludwig was on the crest of the technological and physiological knowledge of the time, always keeping updated and never relaxing in that respect. The varied equipment, one way or another, inspired in others or directly improved in his institute, plus the constant scientific production, as mentioned in our first two parts of this series on Ludwig [1], [2], clearly

demonstrates it. Perhaps more significant has been the intellectual progeny he left, so many that we can speak of his "grandchildren" and even "great grandchildren," a true elite line in the scientific world not inherited by blood but through true hard work, dedication, and mutual respect. All this conforms to a picture of profound human aesthetic beauty. How nice it is to be a true teacher among the many professors!

***Max E. Valentinuzzi (maxvalentinuzzi@arnet.com.ar)*** *is with the Institute of Biomedical Engineering, University of Buenos Aires, Argentina.* ***Klaus Beneke (beneke@ac.uni-kiel.de)*** *is with the Institute of Inorganic Chemistry, Christian-Albrechts-University, Kiel, Germany.* ***Germán E. González (gegonzal@fmed.uba.ar)*** *is with the Institute of Cardiovascular Physiopathology, University of Buenos Aires, Argentina.*

## References

[1] M. E. Valentinuzzi, K. Beneke, and G. E. González, "Ludwig: The bioengineer," *IEEE Pulse*, vol. 3, no. 4, pp. 69–78, 2012.

[2] M. E. Valentinuzzi, K. Beneke, and G. E. González, "Ludwig: The physiologist," *IEEE Pulse*, vol. 3, no. 5, pp. 46–59, 2012.

[3] F. Mildenberger. (2005). Slandered as sexual deviate and pederast: The 1905 proceedings against the naturalist Theodor Beer (1866–1919). *German J. Sex Res.* [Online]. *18(4)*, pp. 332–351. Available: http://www.shfri.net/trans/mildenberger/mildenberger.htm

[4] H. Schröer, *Carl Ludwig: Begründer der messenden Experimentalphysiologie [In German, Carl Ludwig: Founder of Experimental Physiology Based on Measuments]*. Stuttgart, Germany: Wissenschaftliche Verlagsgesellschaft M.B.H., 1967.

[5] R. G. Frank, "American physiologists in German laboratories, 1865–1914," in *Physiology in the American Context 1850–1940*, G. L. Geison, Ed. Bethesda, MD: American Physiological Society (APS), 1987, ch. I, pp. 11–46.

[6] K. Beneke. (2005). *Carl (Friedrich Wilhelm) Ludwig: Mitbegründer der messenden Experimentalphysiologie und Erfinder des Kymographen [In German, Carl (Friedrich Wilhelm) Ludwig: Cofounder of Experimental Physiology Based on Measurements and Inventor of the Kymograph]* [Online]. Available: http://www.unikiel.de/anorg/lagaly/group/klausSchiver/ludwig.pdf

[7] C. Ludwig, *Rede beim Beginn der Vorlesungen in der neuen Physiologischen Anstalt zu Leipzig [Inaugural Lecture in the New Building of the Leipzig Institute]*. Leipzig, Germany: S. Hirzel, Apr. 26, 1869.

[8] R. W. Rieber and D. K. Robinson, Eds., *Wilhelm Wundt in History: The Making of a Scientific Psychology*. New York: Kluwer Academic/Plenum, 2001.

[9] S. Dierig. (2003). "Engines for experiment: Laboratory revolutions and industrial labor in the nineteenth century city. *Osiris (a Journal of the History of Science Society)* [Online]. *18(2)*, pp. 116–134. Available: http://www.jstor.org/stable/3655288

[10] T. S. Kuhn, *The Structure of Scientific Revolutions*, 3rd ed. Chicago, IL, Univ. Chicago Press, 1996.