# Physiological Records Projected on a Screen

By Max E. Valentinuzzi

*Signals from inside the body are the organ's scriptures with messages telling what they do and how they feel, sometimes gladly, eventually in pain, but always without doubt; it's only us who often do not know how to read 'em.*

— Max E. Valentinuzzi

Every day, in teaching classrooms and large conference auditoriums and on operating room monitors, scientists and medical professionals make use of in vivo physiological projections that allow the audience to follow whatever event or procedure is going on. Even physicians many kilometers away from the patient can do the same and decide what treatments should be applied; practical, indeed, and amazing, for sure, should a 1950s medical student or teaching assistant suddenly revive his/her years in school or younger practice days. Yes, physiological events such as blood pressure, electrocardiogram (ECG), electroencephalogram (EEG), muscular contractions, respiration, and other variables were quite possible to obtain and *were* obtained, but a considerable amount of sweat and blood had to be invested. Today, the available equipment is by far more versatile and easier to operate. Let us rewind to the early development of the projected physiological record (PPR) to improve the teaching saga.

In my last column in *IEEE Pulse*, I recalled the blackboard and chalk as basic teaching elements that, perhaps showing some improvements, continue to be used although perhaps less frequently than in older epochs [1]. With chalk, the teacher writes and draws on a blackboard, thus producing an image, and that is truly a significant fact, even if conceptually it sounds simple and naïve. Carl Ludwig (1816–1895) was the first to bring forward a scripture from the heart—the arterial blood pressure record—in 1847, by means of the kymograph [2]. The instrument soon spread throughout the world, becoming a must in any self-respected physiology laboratory, both as a teaching and research tool, persisting well into the mid-20th century.

However effective the kymograph was as the instrument of physiology, it was poorly adapted to display before more than a very small group of students. So Jean Baptiste Auguste Chauveau (1827–1917), a well-versed and experienced French veterinarian, set out to devise and construct a modified version of Ludwig's kymograph that was able to project three channels onto a screen in front of a class to show three physiological variables while the experiment was actually ongoing, i.e., in vivo. His favorite demonstration was the registration of intracavity pressures after catheterization of the right atrium and ventricle through the jugular vein and the left ventricle via the carotid, employing the ingenious and faithful intravascular pressure sounds his close collaborator Etienne Jules Marey (1830–1904) had devised.

Chauveau employed the apparatus extensively in his teaching, especially at the École Nationale Vétérinaire de Lyon, France, and it is known that when, in 1886, he accepted a new position in Paris as general inspector of veterinary schools and comparative pathology professor at the Muséum d'Histoire Naturelle (French National Museum of Natural History), he installed a second model in his new laboratory there. As far as it is known, none other than Sir Charles Scott Sherrington (1857–1952), British neurophysiologist and Nobel Prize winner, copied the technique and equipped the lecture room at the University of Liverpool with a model of much the same construction. No trace of it could be found to the best of our knowledge [3].

## The Projecting Kymograph

Figure 1 shows a sketch of the ingenious idea, a real bioinstrumentation development that fits well into the current biomedical engineering concept. A smoked horizontal plate of glass took the place of Ludwig's rotating cylinder. A carbon arc lamp and a 45° mirror produced an intense vertical light beam that traversed the glass, was collected

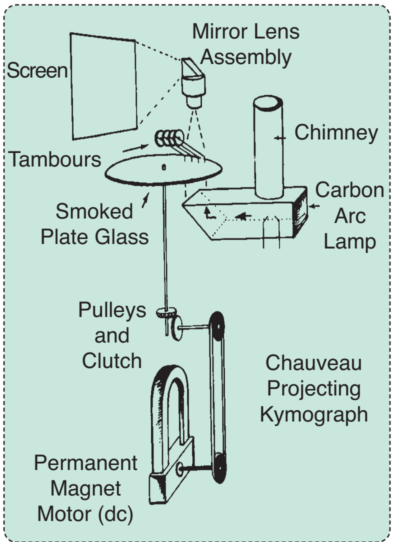


**FIGURE 1** Chauveau's projecting kymograph scheme. The air-filled tambours were described by Marey in 1881 [4] and can also be found in an excellent textbook by Leslie Alexander Geddes [5].

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by an upper prism-lens assembly, and was finally projected enlarged onto a large white screen placed in front of the audience. Incidentally, optics were rather well developed in the second half of the 19th century; microscopes and telescopes had come along with numerous other optical devices (such as glass prisms) and discoveries (such as the polarization of light). When fully smoked, obviously no light could pass, but any scratch on the surface would appear as a white line. A permanent magnet dc motor and a mechanical pulley clutch system drove the clockwise circular glass motion. The chimney on top of the lamp provided ventilation for gases and heat. Four pneumatic tambours controlled the radial movements of four light styluses that scratched the soothed surface, three to record blood pressure in different cardiac chambers and a fourth used for time marks. There is no documented date of the actual construction and the first use of the apparatus, but it must have been around 1875 or 1876. Figure 2 shows a lateral view of the machine, which clearly shows the projecting head on top and the four tambours below. To the right, there is the ventilating chimney. Figure 3 shows a posterior view with the equipment in operation. (Many years ago, in 1968, its curator Prof. J. Bost in Lyon, France, kindly reassembled the whole unit at our request and put it back to work; see [3]). White lines can be seen on the front screen. Exciting and amazing, indeed!

Chauveau did not describe the instrument himself; only his pupil J. Tissot's brief account remains of it [6]. Unfortunately, no biographical information could be found regarding Tissot. His translated words recall,

> The plan to build a laboratory [at the Muséum] included a special very large room, where he built simultaneously with the laboratory itself, a huge calorimeter for the study of heat production in the horse.

[As a side note, the calorimeter is now in the Department of Veterinary Physiology in Lyon. Sadly, when France was occupied, it was used during World War II (1939–1945) to test lethal gases!]

Next to this room, he ordered another room, located on the first floor (ground level), to be used for operations on large animals and with the main objective of continuing his research upon the physiology of the heart in the horse and with the idea of demonstrating the function of the heart to the public. With this idea in mind, he installed in the upper part of this room a huge recorder, based upon the first model built by himself at the Veterinary School of Lyon; then, he built a gallery on a second floor, where on one side, he installed the large recorder (Figures 2 and 3). From the gallery one could follow all the details of the surgery performed upon the horse. At the back of the gallery was installed an arc lamp, which projected on a screen the records inscribed on a smoked glass plate that moved in front of the lamp by means of an ingenious system.

Believing that there might have been traces of the instrument either in Paris or Lyon, after considerable letter exchange by the slow snail mail (there was no e-mail in the 1960s, 1970s, or 1980s, even though some young reader might kindly smile), we learned that the Lyon unit had been well preserved. Moreover, the cardiac sounds (tambours) and the foot-operated lathe that Chauveau had used to make the instrument were also there.

The pneumatic sound invented by Marey deserves some brief explanation because it proved to be very faithful in the reproduction of the hydraulic pressure variations due precisely to its significant characteristic of being filled with air (Figure 4). A good point to remember is Pascal's principle of transmission of fluid pressure, which states that pressure exerted anywhere in a confined, incompressible fluid is transmitted equally in all directions throughout the fluid. The law was established by the French mathematician Blaise Pascal (1623–1662). Marey's transducing pressure gauge was another early contribution clearly within the area of biomedical instrumentation. Consider how conceptually ahead of his time he was, making use only of mechanical gadgets of limited possibilities with almost no technology to back him up. In those days, researchers often acted also as engineers.

In 2007, the IEEE Engineering in Medicine and Biology Society (EMBS)

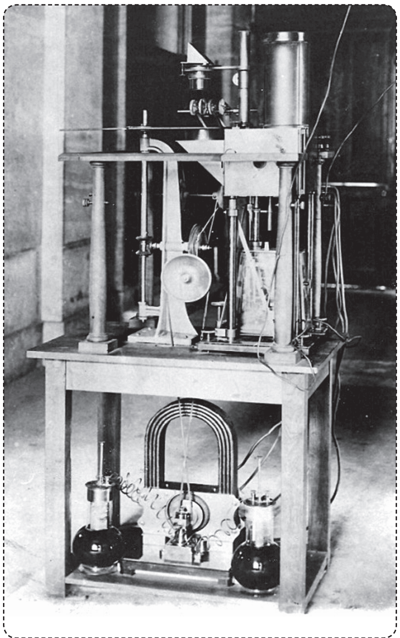

**FIGURE 2** A left lateral view of Chauveau's projecting kymograph. The bottom of the photo shows the dc motor and two bottle-type glass capacitors. (Photo courtesy of Prof. J. Bost.)

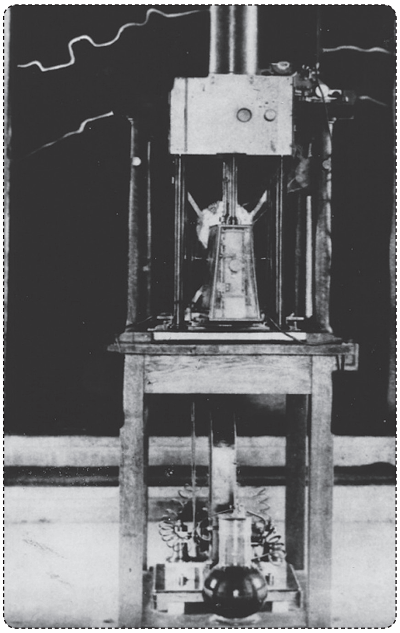

**FIGURE 3** A posterior view of Chauveau's projecting kymograph. The machine is projecting a record on the screen in front of it. (Photo courtesy of Prof. J. Bost.)

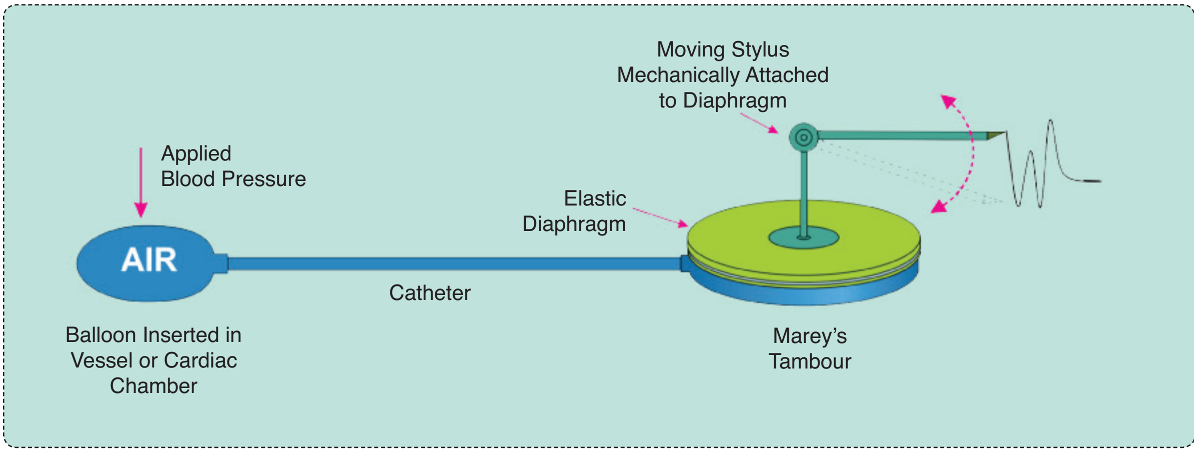


**FIGURE 4** A schematic of Marey's ingenious pneumatic system for blood pressure records. Pressure is transmitted from the balloon through the air (Pascal's principle) to the tambour, a small, rather flat cylindrical box with an elastic diaphragm on one of its faces; a mechanical lever system ending in a light stylus was soldered on the center of the membrane so that when pressure was applied to the balloon, movement of the membrane reflected on the stylus, which in the end scratched the sooth of the rotating cylinder or glass plate. (Image courtesy of Gustavo Idemi.)

International Conference was held in Lyon, France, where the History Committee organized and displayed a booth showing several old pieces of biomedical equipment, and among them, was Chauveau's projecting kymograph. Prof. André Dittmar, a Lyon native, was instrumental in localizing and gathering all the material shown there. For me, it was a particularly exciting and emotional time to actually be able to see and touch Chauveau's recorder and, in a way, revive it after many years of searching for it (see Figure 5). Figures 6–9 illustrate some of its parts.

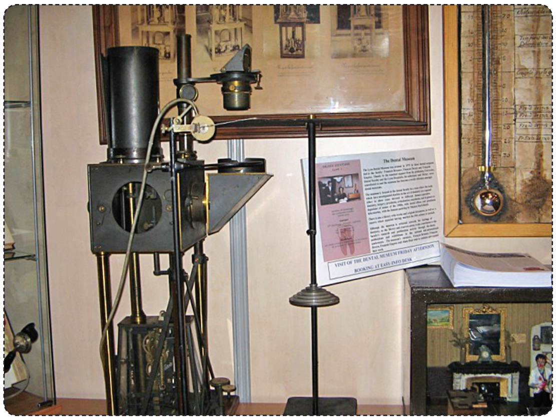

**FIGURE 5** Chauveau's original projecting kymograph during the 2007 IEEE/EMBS Lyon Conference. The optical head is shown on top, and below it, with a clearer yellowish color, the rounded Marey's tambour and darker tubing falling down to the left can be seen.

## The Projecting Physiograph

By the initiative of Dr. Hebbel E. Hoff, then chair of the Department of Physiology at Baylor College of Medicine in Houston, Texas, in 1967, I undertook as a special graduate student project the idea of adapting a regular physiograph (by Narco Bio-Systems, previously named E&M Instruments Company in Houston, Texas), either three-, four-, or six-channel equipment as an updated projecting unit similar to the one developed by Chauveau. Hence, we adapted a built-in overhead projector for the dynamic display of physiological events as they were written out on a moving acetate film that replaced the then-usual paper strip (Figure 10). Overhead projectors were widely used in lecture rooms from the 1960s until the 1990s. Today, they have practically vanished, and young people perhaps do not know what they are.

The instrument produced bright images that were clearly visible in a fully lighted classroom or laboratory. A light source originated a beam, which, following the optical pathway, reached a Fresnel lens on top of the main frame. This horizontally placed lens focused the light beams on the overhead assembly. A Fresnel lens is a type of compact lens originally developed by the French physicist Augustin-Jean Fresnel (1788–1827) for lighthouses. Its design (which resembles the stripes seen when an onion is cut transversally) allows for the construction of lenses of large aperture and short focal length without the mass and volume of material that would be required by a lens of conventional design. This kind of lens can be made very thin, in some cases taking the form of a flat sheet. A 45° slanted mirror on the overhead assembly reflected the beams, producing a 90° final rotation of them; thereafter, the beams crossed another lens that, in the end, projected the traces images on a vertical screen.

The instrument was presented during the American Physiological Society Congress held in Houston

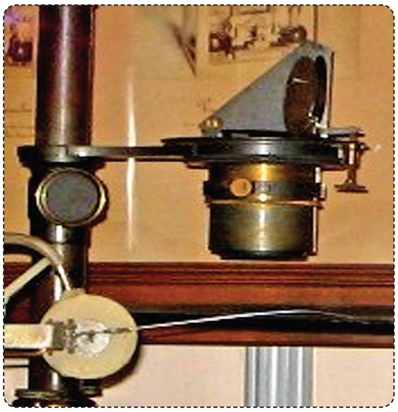

**FIGURE 6** A closer view of the projecting optics and, below and to the left, one tambour and its stylus.

**FIGURE 7** Max E. Valentinuzzi standing next to one upper portion of Chauveau's kymograph.

**FIGURE 9** From left: Ron J. Leder (chair), Max E. Valentinuzzi, and Prof. André Dittmar, then members of the IEEE EMBS History Committee, standing at the booth in the exhibit conference room at the 2007 IEEE EMBS Conference.

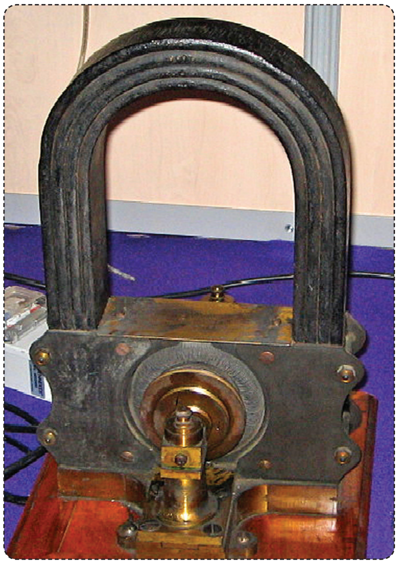

**FIGURE 8** The permanent magnet driving dc motor showing a handsome U-shaped magnet.

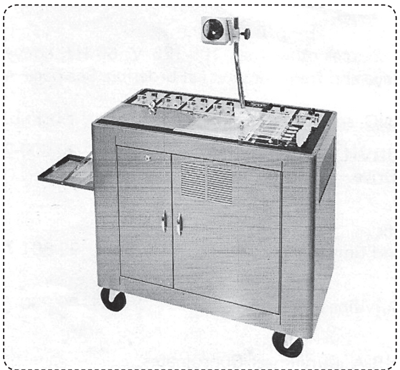

**FIGURE 10** An adapted physiograph with an overhead projector. The acetate film ran from right to left, first under the writing pens and, after being written, crossed the Fresnel flat lens to be collected on a folding tray (see the left side).

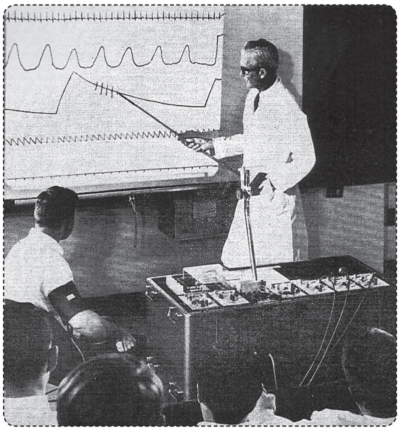

**FIGURE 11** An experimental demonstration with a medical student acting as patient carried out at the Department of Physiology of Baylor College of Medicine, Houston, Texas, in 1968, when the first prototype was tested. Four noninvasive variables were recorded: ECG (top channel); respiration by the impedance technique (second channel); indirect blood pressure using an arm cuff that displayed the Korotkoff sounds on the decaying cuff pressure (third channel); blood pressure using finger photoplethysmography (fourth channel); and time marks (bottom channel).

in 1969, eliciting a highly favorable response from the audience, so much that Narco Bio-Systems decided to produce the instrument on a regular basis, standardizing its manufacture and improving many details that in the prototype were rather weak. For several years, the instrument was on the market apparently with success (Figure 11).

## Chauveau's Demonstration Room Revived

The Department of Physiology at Baylor College of Medicine, between 1959 and 1974, had close connections and exchange of ideas with Texas E&M Instruments and also with the large-animal clinic of the veterinary school at Texas A&M in College Station. It was a highly fruitful time in research projects, technological developments, and academic papers. Every year, in June and July, on the occasion of the Baylor summer course established by Dr. Hebbel E. Hoff and Dr. Leslie A. Geddes with the support of a National Institutes of Health grant and other minor contributions, a field trip was organized to the animal clinic to run a long experiment on a horse, quite similar to what Chauveau used to do. Approximately 40–50 participants came from different places, from countries abroad and from the biomedical and engineering sciences alike; it was truly interdisciplinary and intensive. Hence, Chauveau's demonstration rooms in Lyon and Paris were recreated, and obviously updated, at Texas A&M and were used for a few years after the projecting physiograph entered the market (Figure 12).

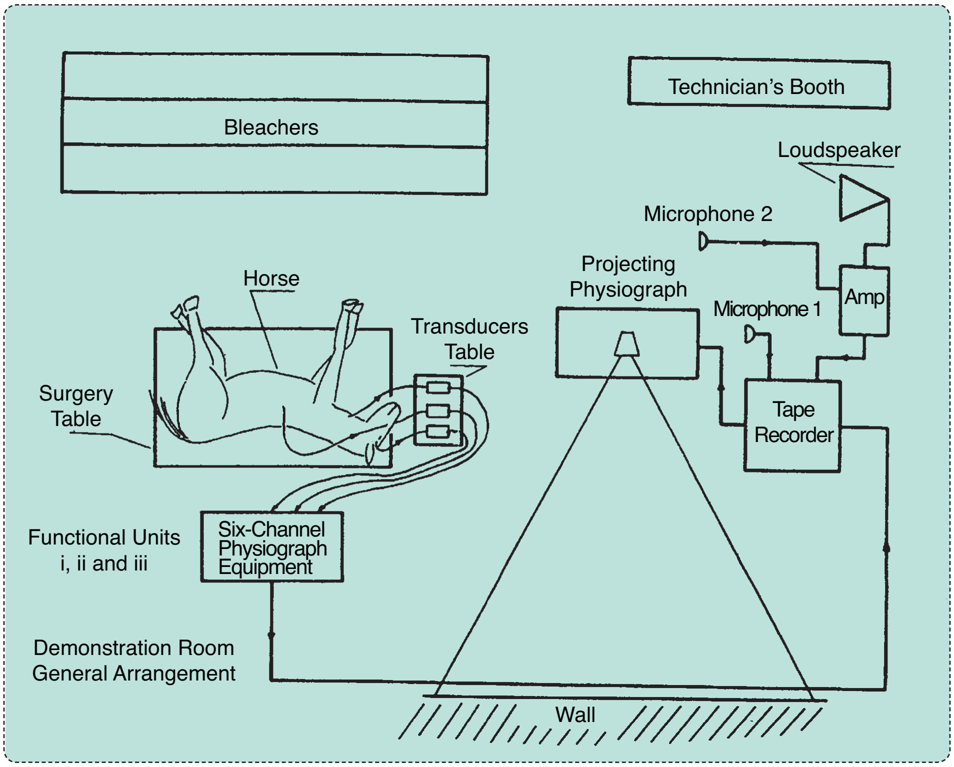


**FIGURE 12** The revived demonstration room at Texas A&M University.

briefly told in a previous column [1]; thereafter, a quicker and more practical method was slowly and steadily developed: the scripture, better known as handwriting, first using rather complex symbols until reaching the much simpler modern alphabets. No doubt, all handwritings are images, again underlining that the visual channel represents the main avenue to get to our cortical level.

The members of the animal kingdom differ from the members of the two other kingdoms of multicellular eukaryotes, plants, and fungi in fundamental variations in morphology and physiology. This is largely because animals have developed muscles and, hence, mobility, a characteristic that has stimulated the further development of tissues and organ systems. The two latter systems also generate signals of varied nature: electrical, mechanical, chemical, and thermic; these usually change as time proceeds, and they carry important and highly significant information that, if adequately read and interpreted, may lead the knowledgeable reader to describe the animal's condition as good, poor, or bad, i.e., to diagnose and eventually prescribe a given treatment. The physical sciences supplied the means to pick up such signals as faithfully and quickly as possible as well as their image appearance, i.e., their writing or scripture; in this case, perhaps the second word is better applied, for our health is sacred to us as sacred are the scriptures in their more traditional meaning. And so we arrived at the physiological recordings.

After more than 100 years of intense and hard work carried out by many devoted researchers all over the world, here we have in front of us the inner body signals, which, if the recording system is really faithful, will tell us what the body does and how it feels, sometimes gladly,

Figure 12 is a sketch of how the lecture room was set up. The horse was handled by three or four veterinarians and placed on the traditional rotating surgical table after anesthesia was injected. Transducers (usually ECG electrodes and Statham blood pressure in the carotid artery as well as Statham in the femoral artery, electrodes for the detection of respiration by the impedance technique, and sometimes electrodes to pick eye nystagmus) were inserted by Baylor faculty members. A six-channel physiograph (with ink and paper recording) amplified the signals from the transducers, and its outputs went to a tape recorder. Both vagus nerves were exposed so they could later be stimulated by means of an electrical stimulator (also part of the physiograph set). Outputs from the tape recorder drove the projecting physiograph, which projected the written records on a white wall facing the bleachers where the audience sat. One microphone allowed comments to be added to the taped records, and a second microphone linked to a public address system (power amplifier and loudspeaker) was used by the instructor to explain what was being done and what the events were. A technician's booth kept all the auxiliary material and units, offering support to the experiment, which lasted in the order of 12 hours, starting with the horse being fully awake early in the morning until an anatomical dissection was performed at the end. The classic Chauveau–Marey maneuver (manual compression of the abdominal aorta via the rectum) was applied in the standing tranquilized animal and also in the anesthetized situation. This maneuver meant the birth of the so-called Marey's law of the heart, which relates a decrease in heart rate to an increase in arterial pressure and which was further studied in a dog in 1972 using an intra-aortic inflatable balloon [7], [8]. The collection of data was large, and a long report was produced every year that often led to projects. Quite enlightening!

## Discussion and Conclusions

Humans started to draw images thousands of years ago, leaving a message with an enormous amount of information (still to be fully deciphered), as we eventually in pain, but always without doubt and in the end relying on how we understand them.

In this new century and new millennium, almost all, if not all, said here is obsolete and belongs to the past; it sounds more like a kind and sweet reminiscence. New digital, faster, and more powerful techniques and technologies have taken over that are easier to operate and far more reaching. Tablets, advanced cell phones, and other similar devices offer possibilities limited only by human ingenuity. I do not dare to imagine what and how it will be lest I make a gross and embarrassing mistake.

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## References

[1] M. E. Valentinuzzi, "The good old blackboard and chalk," *IEEE Pulse*, vol. 6, no. 3, pp. 58–60, 2015.

[2] M. E. Valentinuzzi, K. Beneke, and G. E. González, "Ludwig: The bioengineer," *IEEE Pulse*, vol. 3, no. 4, pp. 68–78, 2012.

[3] H. E. Hoff, M. E. Valentinuzzi, L. A. Geddes, and A. G. Moore, "A modern version of JBA Chauveauís demonstration laboratory," *The Southwestern Veterinarian*, vol. 23, no. 4, pp. 313–322, 1970.

[4] E. J. Marey, *La Circulation du Sang*. Paris: G. Masson & Companie, 1881.

[5] L. A. Geddes, *The Direct and Indirect Measurement of Blood Pressure*. Chicago, IL: Year Book Medical Publishers, Inc., 1970.

[6] J. Tissot, "Auguste Chauveau, professeur au muséum (1886–1916)," in *Archives du Muséum National des Sciences Naturelles de París, 8ème série*, vol. VII, pp. 173–204, 1931.

[7] M. E. Valentinuzzi, T. Powell, H. E. Hoff, and L. A. Geddes, "Control parameters of the blood pressure regulatory system (Part I): Heart rate sensitivity," *Med. & Biol. Eng*. vol. 10, pp. 584–595, 1972.

[8] M. E. Valentinuzzi, T. Powell, H. E. Hoff, L. A. Geddes, and J. A. Posey, "Control parameters of the blood pressure regulatory system (Part II): Open-loop gain, reference pressure and basal heart rate," *Med. & Biol. Eng*, vol. 10, pp. 596–608, 1972.