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The Early History of Instrumental Precision in Medicine

S. WEIR MITCHELL, M.D., LL.D., Harvard

The Early History of Instrumental Precision in Medicine.

AN

ADDRESS

BEFORE THE

Second Congress of American Physicians and Surgeons

September 23rd, 1891

By

THE PRESIDENT OF THE CONGRESS

S. WEIR MITCHELL, M.D., LL.D., Harvard

Member of the National Academy of Sciences.

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THE PRESIDENT'S ADDRESS.

BY S. WEIR MITCHELL, M.D., LL.D.,

Member of the National Academy of Sciences.

THE EARLY HISTORY OF INSTRUMENTAL PRECISION IN MEDICINE.

Gentlemen of the Congress of American Physicians and Surgeons: —The body over which I have the honour to preside meets now for the second time. Amongst organisations of medical men it stands alone as to quality and peculiarity of construction. It is made up of the special societies, which represent among us all the reasonable divisions of which medicine, in a broad sense, seems capable. Each is a group of acknowledged experts; each possesses the highest fitness. A happy thought has brought them together. The result is a meeting of men whose power to teach others is a pledge to that humility which is ever seeking to learn. It has no medical politics, nor is it embarrassed by useless idlers who look upon such gatherings as merely pleasant social meetings. The critical demands of its component groups dictate its terms of membership. Broadly national, it meets only in the Capital of the nation, with but one object—work, and the training which insures high quality to work. It is here, therefore, that the open-minded man may feel the broadening influence of intellectual contacts with those who have other limitations than his own; for, indeed in our divergent attention to special studies we run some risk that,—contrary to St. Paul,—the eye may say to the hand, "I have no need of thee;" or the head to the body, "I have no need of thee;" for as to us, also, there should be no schism in the body.

Specialisation in medicine is of recent birth. I can remember when older physicians refused to recognize socially a man who devoted himself to the eye alone. To-day we can only look back with wonder at such narrowness.

Specialities in medicine first arose by the wholesome and gradual evolution of the individual specialist out of the general practitioner; but to-day the special physician is medically born, and is too apt to select his branch before he is weaned from the breast of his Alma Mater. You must permit me to think that all such men would be better doctors if they had back of them more years of general clinical labour. A broad-minded student of the eye once said to me: "We should all be the better for an hour or two a day in a general hospital ward," and added, loyally, "the very great relative perfection of the therapeutics of visual disorders is an intellectual risk." And if Cornelius Agnew could say that, we may well fancy—and you will pardon the jest which holds a truth—that a too exclusive study of the eye may result in mental egotism. If men as old as I are ready to acknowledge this danger, believe me that for the young the pursuit of but one line of practice is only too apt to result in an overestimate of their complete fitness, in hasty papers, mere case reports, wild pursuit of novelties, and the production of numberless minor text-books which can have but a selfish use. Said Romberg once to a friend of mine, who gave him a new American book, "Is the author thirty-five? I will look at it; is he forty? I will read it."

We have all come to admit gratefully the value of specialisation in medicine; but he who is watchful over the general interests of his profession must have seen that this subdivision of labour involves for us perils, which are seen on the one side by the general practitioner, and on the other by those who, in a large-minded way, pursue limited lines of work. Medicine does not grow in an even fashion. When watching a saline solution under the lens, you observe some brilliant crystal shoot out in advance and hold its place until the rest, more slowly but surely, join or pass it, you see an image of that which continually illustrates medical progress. To-day it is surgery which wins; a few years ago it was ophthalmology, which, in newly acquired precision and in predictive accuracy and therapeutic gains, set up for us novel standards of exactness and, enriching our symptomatology, cast light in many directions. The mere physician seemed to be hopelessly left behind, but now again it is pure medicine which has gone to the front.

What the specialist learns, until it is commonplace, is not easily enough assimilated by the mass of practitioners. At last, however, comes a time when it is, and then the whole body of medicine feels the gain in nutrition and repays the debt. The masters of our still most perfect art, medical optics, may wisely remember that it was physicians who most distinctively recognized and diffused the knowledge that headaches and some other brain disorders are due to eye strain, and thus, while lessening our own futile labours, crowded the waiting-room of the ophthalmologist.

I could easily show you, by added proof, what we all lose by not keeping close touch of one another's gains. The criticism of the specialist is that the general practitioner does not early enough ask his help in difficult cases. The largely educated and generally occupied physician feels (and you will pardon your critic) that limitation of attention to organs, the eye, the ear, the womb, is apt to lead to a too entire trust in local means, and to neglect of those patient methods which ought more frequently to call for the added counsel of the physician. For, now-a-days, the patient often resorts at once to the specialist, and it is the ophthalmologist who sees, or who ought to recognize the first signs of specific disorder, of spinal troubles, of asthenic states. Whether justly or not, the thoughtful, general practitioner is to-day of opinion that the absence of grave mortality after operations which once were so fatal, has created a vast temptation for the younger surgeons.

This critic believes—Is he right? Is he wrong?—that too often and too promptly the gynæcologist resorts to but one drug, and that steel in the trenchant form, when perhaps the state of the body makes operations doubtful as to their remote usefulness, or that he condemns to sexual neutrality some who, under patient medical treatment with careful inattention to the sexual organs, might have had preserved for them the inestimable possibilities of the wife and the mother. I once saw, almost by chance, with Marion Sims, a girl of eighteen, decreed, after purely surgical consultation, to lose her ovaries next day. I said that patient medical treatment might still offer her a chance of escape. Using a rather strong phrase, with energy characteristic of the man, he replied, "I never murder sex without a pang. Let us give her a reprieve." To-day she is a wholesome, happy wife and mother.

And, too, there is, as I have hinted, the other side of the shield—the general practitioner who sees the beginnings of disease and does not correctly interpret them, or early enough ask counsel. He regards as rheumatic the neuralgias due to the faint beginnings of spinal disease. He treats headache or vertigo by general means, and allays them by drugs, when in an hour the physician of organs would tell him that it is feeble muscles, astigmatism, ear trouble, or nasal disease which is the parent of the malady.

We saw in this city eighteen months ago the need for occasional conferences between physicians pursuing different branches of medicine. Upstairs, the Academy of Surgery, and downstairs the Association of American Physicians discussed at the same time the value of early surgical interference in typhlitis. One body decided for, the other against, the knife, and if I may trust my memory the surgeons were for delay.

Did I not observe signs of broadening in the views of specialists, I should have increasing fears as to the usefulness of these specialisations of practice. Even as to the alienists, I see the growth of a tendency to put aside the title of "Superintendent of Asylum," and to come into relation with neurologists and with a less restricted professional life ; I trust they will not pause there, for as to this I am sure that, until asylums become hospitals, and have their outside staff of attending physicians who do not live in eternal contact with the insane, we shall not develop the best possibilities for the treatment of the alien in mind. Believe me, we cannot safely permit any class of specialists to drift away from general and frequent contact with the rest of us.

As I have mentioned the need for continuous individual cultivation of our multiform science on a broad scale, and for personal consultation, I like to enlarge the plea and call a meeting like ours a general consultation. And this, in fact, it is ; a focal point for condensed opinions, for authoritative statements, for criticism from varied standpoints, and for significant indications as to those accepted gains which ought to become, from time to time, a part of the mental equipment of all other special, and indeed of all general practitioners.

I have said that nowhere else has a plan like ours brought together such a body of experts as I see before me. And the large task which the years offer you—what is it ? Not only is your organization exceptional in construction, but this Congress has national aspects. It is a collection of the ablest men in the American profession. Let us not lose sight of the fact that much of what, in older lands, is acquired knowledge, is with us to be won anew. Our climatology has yet to be medically handled in full, and as to this and the relation of the seasons to disease, we are helped by the growing usefulness of our Weather Bureau. Nowhere else is there a country in which the extent of territory covered by weather reports is such as to make its results medically available in relation to disease. Even in Europe, the influence of seasons on disease has not yet been fully studied. As an evidence of its peculiar effects here, and of the value of the Weather Service reports as an aid to their study, you will recall Wharton Sinkler's interesting proof that the spinal paralysis of childhood is with us a disease of the summer months. I can but allude, also, to the masterly paper of Morris Lewis on the "The Relation of Acute Rheumatism to the Storm Centres," and, if you will pardon me, to my own study of the "Relation of Chorea to the Weather Curves," and of "Traumatic Neuralgia to Storms ;" all of which work were impossible had we not the maps and reports of the Signal Service.

We have, as yet, to investigate our countless mineral springs, many of them, as in the Yellowstone Park, unlike any elsewhere known.

The modifications which race brings into the classical types of disease are also before us for analysis ; and, as you already know, the negro is relatively less subject to malaria than the white, and also to some neuroses, as chorea, and probably locomotor ataxia; whilst, as to him and the Indian, we have still much to learn.

And if in climatic therapeutics we discovered the value of dry cold air for certain lung diseases, and have taught and made available camp life to invalids, securing for such and other noble uses parks as large as some European principalities, surely immense triumphs await us in these directions, when we have more completely studied the large alterative means afforded within forty-five degrees of latitude, and nearly 3,600,000 square miles of varied soil, with every variety as to altitude and geological formation.

The swift social changes of this age and country await too your study in the future, with novel problems as to how the woman is being, and is about to be, influenced by a masculine education, and the acceptance on her part of male standards of work and capacity. All the vast hygienic, social and moral problems of our restless, energetic labour-craving race are, in some degree, those of the future student of disease in America. From this bewildering spectacle of striving millions, I should like now to ask you, as scholars and physicians, to go back with me a little to more tranquil days, and, amidst the stirred dust of unused books, to catch a glimpse of some of the processes which have gone to the final making of what you so well represent—"Precision in Medicine."

It had long been in my mind to use the studies I have made, from time to time, in regard to the introduction into medicine of such accuracy as can only come from the use of instrumental aids. The fact that I was to have before me to-night a set of experts trained to a nicety in modern methods tempted me to think that I should here find an audience appreciative of a chapter of medical history hitherto unwritten. The work grew upon my hands, and my chief difficulty has been so to limit it in the telling as not to task your patience. An hour seems to have been set by common consent as the reasonable limit of human power to listen to one man's talk, and I shall try not to exceed it.

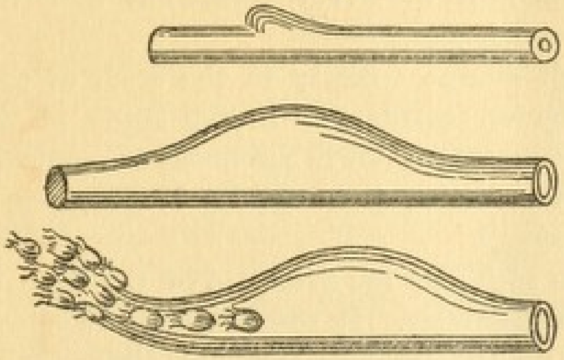
When I was yet a lad there were then alive men who could recall the day when what a patient said, and the physicians saw and felt, were all that a case of disease had to tell him. You cannot now realize the extent of this limitation, because instruments and methods of precision have so interpreted what we merely see, feel and hear, that even though we were again forced to rely upon our unaided senses, we should stand on higher levels of knowledge than our medical fathers. The limitations they suffered under, lured or drove them into attempts to classify, and minutely to multiply the signs of disease, until what they believed they saw and felt represented impossible refinements in symptomatology, and the imagination was called in (as it has been in homœopathic provings) to assist the intellect beyond the boundaries of the possible in observation.

You know, alas! that we now use as many instruments as a mechanic, and that, however much we may gain thereby, our machines are not labour-saving. They force us, by the time their uses exact, to learn, to be rapid, and at the same time accurate. Thinking over the number of instruments of precision, a single case may require, it is clearly to be seen that no matter how expert we may be, the diagnostic study of an obscure case must to-day exact an amount of time far beyond that which Sydenham may have found need to employ. A *postmortem* section used to take us an hour or two, and now, alas! it goes on for weeks in some shape until the last staining is complete, the last section studied, the last analysis made.

These increasing demands upon us are due to the use of instruments of precision, or to accurately precise methods. As in factories more and more exact machines have trained to like exactness a generation of workmen, so with us, the use of instruments of precision, rendering the comparison of individual labor possible, has tended to lift the general level of acuteness of observation. The instrument trains the man; it exacts accuracy and teaches care; it creates a wholesome appetite for precision which, at last, becomes habitual. The microscope, the balance, the thermometer, the chronograph have given birth to new standards in observation, by which we live, scarce conscious of the change a generation has brought about. Certain interesting intellectual results have everywhere followed the generalisation of precision by the use of instruments, like the world-wide lesson in punctuality taught by the railway and made possible by the watch. We have so often timed the pulse that most of us can guess its rate, and constant use of the thermometer enables one to trust better one's own sense of heat, as the hand appreciates it. If, indeed, you use the sphygmograph much, you get to making visual images of the pulse-curves whenever you very carefully feel a pulse. There is a crude illustration of the yearning after this sort of result in a paper on the pulse, as far back as Fouquet, in 1768. Three of his curious diagrams of the pulse-curves, as they appeared to his mental vision, are represented in Fig. 1.

A good example of the training giving by instruments is the fact that a careful study of Harrison Allen's work, with Muybridge's photographs, at last, enables the unaided eye to see in truthful order both the swift changes of convulsive acts and the normal movements of man. The subject is a tempting one and admits of much illustration.

Fig 1



Splenic pulse.

Pectoral pulse.

Intestinal pulse.

Were I not talking to a selected group of experts, I might also dwell on the risks our instruments of precision brıng to the lazy or the unthoughtful; as when one looks only at the readings of his thermometer as placed in the axilla or mouth and neglects the temperature of the extremities, or, cheated into satisfaction by the trusted certainty attained as to single symptoms, loses power or desire to reason on the grouped relation of the complex phenomena of disease. For unless men keep ahead of their instrumental aids, these, to coin a word, will merely dementalize them, and but measurably lift the mass without in proportion advantaging the masters of our art, who were so easily masters in days when the erudite touch was more uniquely advantageous than it is to-day.

Come back with me, then, you who are veterans in observation, drilled to use every engine of research, come and see the first growth of that instrumentally helped precision, which so many here have usefully advanced. The story has its romance; its broken hopes; its failures; its heroes, now lost to memory, and, too, its moral lessons. The pleasure it has given me makes me wish that our great schools possessed chairs of medical history, and that amidst our too busy life more of us could acquire some part of the interest which for me the history of my art has always had. Without the great Library of the Surgeon-General, I should have had no story to tell you; but, even good as is that noble collection, it has failed me in the last year as to some twenty books I wanted. One of them was not in any London library, and one was lost from its place in the great French Library.

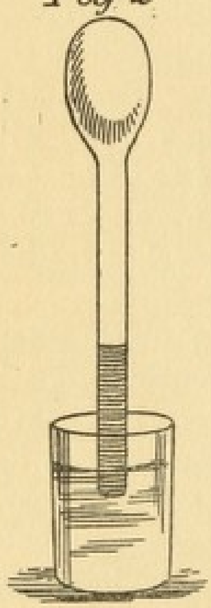
What I shall ask you to hear will be but a sketch, and even of this I must omit in the reading a too large part.

All the lives of Galileo were not in any American library, and it was seven years before Quaritch found for me the one book of Sanctorius I finally needed. A valuable essay could be written about this whole subject. The history of the balance in medicine is yet to be told; that of the microscope has been enough dwelt upon. We want a book about medical discovery somewhat like Whewell's History of the Inductive Sciences.*

I shall confine myself almost entirely to the story of the earlier efforts to attain accuracy by instruments in the study of the pulse, respiration and temperature. It is not in the books of medical history. It is here and there in memoirs, journals, lay-biographies, rare old folios and forgotten essays.

The latter part of the 16th and the first half of the 17th centuries was a germinal period in medicine. It saw advances in anatomy and physiology, which led up to Harvey's splendid discovery. It saw, too, the failure of his thesis to influence medical practice immediately or largely. The same period in Italy beheld the first attempts at precision as regards temperature and the study of the pulse. This was the birth era of instrumental accuracy in medicine, but many a day went by before the infant attained to useful manhood. Most strange it is that the seeds of scientific thought as to the first heat records and the pendulum were cultivated in the garden of medicine. Between 1593 and 1597 Galileo, sometime a student of medicine, invented the crude open thermometer or thermoscope.

Fig 2

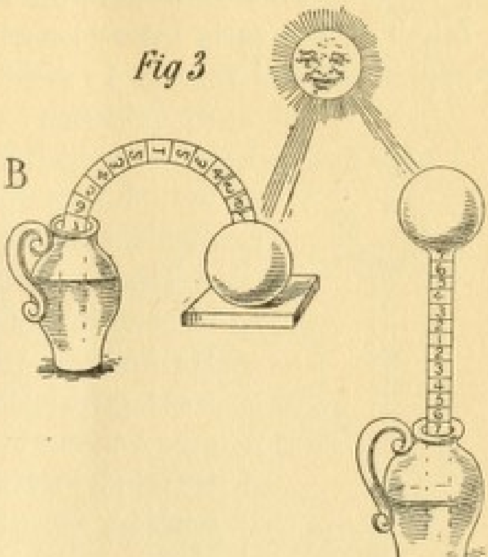


The thermometer of Galileo was, as I have drawn it (Fig. 2), a tube of glass, open below and ending above in a bulb. This bulb having been warmed the open end of the tube was set in water, so that as the bulb cooled, the water rose in the tube. Then any heat applied to the bulb caused the water to descend, the reverse of that which occurs in the more modern instrument. This coarse thermoscope was obviously a barometer as well as a rude measurer of the change of temperature. A slight change in the weight of the atmosphere might easily neutralize an increase of heat. It was not an accurate instrument, nor does Galileo seem to have rated it highly since he nowhere mentions it in his works. Others thought

* A strangely superficial essay, more praised than read.

more of it. The approximate date of this invention is set for us by one Padre Benedetto Castelli, in a letter about the treatment of a wounded man, written to one Cesarini, in 1638.* He calls to mind the fact that Galileo had thirty-five years before shown him the air thermometer.† A Venetian noble, Giovanni Francesco Sagredo, writes to Galileo in 1613 that "the instrument you invented" I have bettered.‡ Sagredo divided the scale into 100 divisions, and two years later seems to have hermetically sealed the tube§ and thus given us the modern instrument. Nevertheless, says Viviani,‖ it was little employed in its improved form; and for years afterwards physicians, as we shall see, made more or less use of Galileo's rude thermometer, of the errors of which Viviani, Galileo's pupil, was well aware. But concerning this invention so carelessly made, raged a battle of words scarcely yet at an end. Renou,** in a very full book on thermometers, does not so much as name Galileo. Bacon,†† Cornelius Drebbel,‡‡ and, as we shall see, Sanctorius have all described the crude open thermometer. Fludd,§§ in a curious, rare book (Philosophia Moysaica, Gouda, 1638), speaks of it, as was then common as the Speculum Calendarium (Mirror of the Seasons), and

Fig 3



* De Nelle, Vita di Galileo, p. 69. † Ibid., p. 70.

‡ Ibid., p. 71. Galileo died in 1642, having said in print no word of his invention.

§ I cannot find that he so sealed it as to leave a vacuum. ‖ Ibid., p. 90.

** M. E. Renou, Histoire de Thermometre, Paris, 1876.

†† Bacon first mentions the open thermometer (as I call it) in the Novum Organum Scientiarum, 1620, and again in Historia Ventorum, and Sylvae Sylvarum.

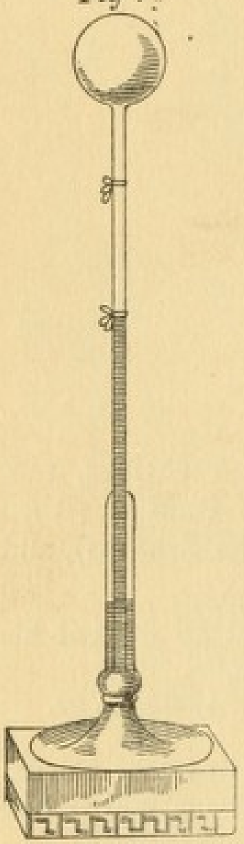
‡‡ Drebbel, born at Alkmaar in 1572, was clearly a charlatan. Of him are told, according to De Nelle (op. cit. p. 83), many wonders. In his works he describes as his own Galileo's instrument.

§§ Fludd was born in 1574 and died in 1637. I have mentioned his claims in the text, and for a description of his instrument see Appendix A. There are numberless diagrams of its crude form scattered through all his queer books. Renou accepts his statements, but in view of his conflicting dates and the mystical character of his writings, as well as the curious metaphysical deductions which he draws from his practical experiments, I think we should be very guarded in founding any argument upon them.

says he got the figure (see Fig. 3) and description from a manuscript more than *fifty* years old. In another of his works, however,* I find him speaking of the manuscript as being at least *seventy* years old ; clearly no accurate deduction as to priority of discovery can be drawn from such conflicting statements. And finally, Paolo Sarpi was claimed by his biographers to have invented the thermometer. No date is set ; but Foscarini, in his work on Venetian Literature,† observes that Fra Paolo in his notes speaks of the thermometer, and, according to his recollection, puts the year of invention at 1617.

Much of the early interest as to the thermometer was due to its supposed medical value. I relegate to my notes, or appendix, the bulk of evidence as to prior discovery, which may not be without interest, because it is just where Wunderlich begins fully to tell the story of the modern medical use of thermometers that I shall leave off.

Fig 4.



That so eccentric a man as Fludd should have been seriously accepted as evidence is odd enough. He had, as others had, a chance to know what went on in Padua. From the days of Elizabeth every man of fashion, and especially the English, traveled in Italy. Here, too, wandered all who studied, or were fond of science, and it was to Padua—which Sanctorius called the Garden of Science—that Bacon came, and Drebbel, and this same Fludd, and the greater Harvey. The towns of Italy were the exchanges of Europe both for commerce and for science. From them men took home what facts they saw or heard, and merely describing them (as did Bacon the air thermometer), left the future critic to settle the question of originality. The temper of the time was not that of our day. Men worked along patiently. There were no journals ; the letter or the lecture were the only means of early publication. The genius who to-day invents a new forceps or a new pessary yearns for instant type, and defends his offspring with virulence. Harvey knew of his great discovery in 1616, and it got into print in 1628. His lecture notes show that long before this date he was certain of the matter and clearly knew what he had done. Whence this seeming indifference? If, after his first lectures, some obscure Italian, hearing them, had gone home and stated in a book the facts

* Medicina Catholica, Tract. II, Sec. 1, Part 1, Lib. i, Cap. i.

† Lib. iii, page 307, note 248.

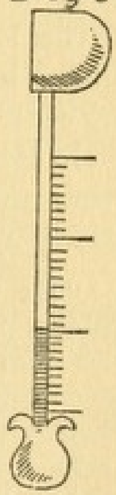
of the circulation, we should have had a controversy more absurd than those which must have made the ghost of Harvey smile, if in that other world men smile at all.

I have stepped aside to point out how it was that as to the minor, and even greater, discoveries of those days so much trouble arose, or has arisen, as to priority of claim. But it is now with the thermometer in medicine that we are concerned. Galileo, an astronomer, half a doctor of physic, made it; and a Prince, a very great person in his day, Duke Ferdinand II of Tuscany, still further improved it, and constructed divers forms for use in medicine. But this was as late as 1646.* In 1876, some of the Duke's pulse thermometers were shown at the South Kensington Exhibition of Instruments of Precision.†

Fig 5

In the meanwhile a new and interesting personage appears on the stage, and with him and the later grand ducal inventions and their applications ends for many a day the practical use of the thermometer in medicine. Santorio Santorini, born in Capo d'Istria, April, 1561, was educated at Venice, and at the age of twenty-one took his degree of Doctor of Medicine at Padua. I have put in the appendix (see Appendix D) all that I have gathered as to this notable man, and regret that I have not time here to discuss his claims in full. In his commentary on Galen,‡ I find a description of the air thermometer. Figs. 4, 5, 6, 7, 8, 9, 10 are accurate representations of the rude figures in his Commentary on Avicenna.

Fig 6



Thermometer with hood.

"We have here," he says, "an instrument with which we may closely measure the degree of the recession of the heat of the external parts, and with which we may daily learn with accuracy how much we vary from the normal; also the degree of heat of your patients." He does not claim the invention, but says no word of Galileo.

"The patient," he adds "grasps the bulb Fig. 8 or breaths upon it into a hood, Fig. 7 or takes the bulb into his mouth Fig. 9 and 10, so that we can thus tell, if the patient be better or worse, so as not to be led astray in *cognitione prædictione et curatione*." He gives no table of temperatures, no records. No real good comes of it. The enthusiasm of the inventor keeps it for awhile before

* See Appendix B (2).

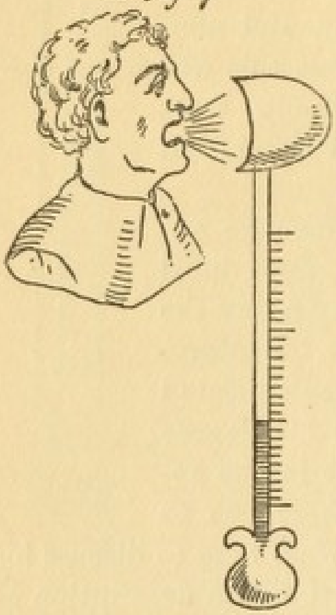
† Science Conferences, Physics and Mechanics. On Instruments from Italy, p. 100 *et seq.* See Appendix B (1).

‡ Ediz. Venet., 1612, p. 229. Edit. Lugdani, 1632, p. 736.

the public, as we have seen happen in our own day. Nevertheless Sanctorius saw what might be the value of the thermometer in medicine. He first taught the lesson of using the mouth to obtain a record of bodily heat, and may clearly be credited with certain improvements in the method of using his instrument.

The thermometer lacked precision, and even when it had grown into this, want of knowledge of the cause of fevers, of their risks and how to lessen them, caused the mass of physicians to neglect an instrument which, as yet, had for them little practical value. Here and there as times goes on, in the physiologies, and soon in the books of practice, we find rare statements as to the heat of man.

Fig 7



And now, again, we have to thank an astronomer when, in 1701, Newton marks the blood temperature at 12° of his scale and uses linseed oil as the fluid. A little later Daniel Fahrenheit altered the scale over and over, and at last set 96° as the blood heat, and here we first come upon the use of armpit temperatures. Boerhaave* is said to have suggested to Fahrenheit the use of mercury in his thermometer, as to which there is some doubt; at all events, the records of the famous Paduan Academy show that long before this date the Italians made use of mercury in their thermometers.

The long silence which now falls upon medical thermometry is broken by a few allusive aphorisms of Boerhaave, and by the doubting sentences of his famous pupil, Van Swieten, in 1745.

De Haen,† who saw Avenbrugger working beside him clinically for years and learned of this genius no lesson as to percussion, more clearly apprehended the value of thermal records. We have re-dis-

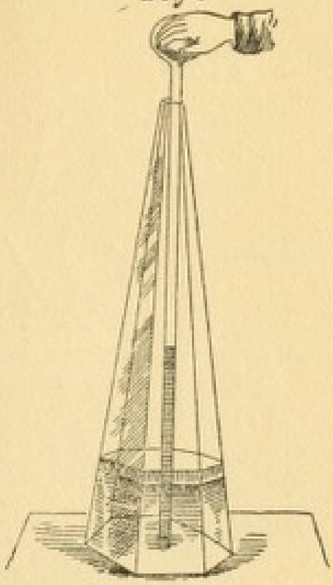
* "Ex votis mihi perfecit D. G. Fahrenheit," Boerhaave, Elements de Chimie, p. 94. Says Renou (op. cit.), Fahrenheit changed his scale under advice from Boerhaave to 24°. The absolute zero was set at 18°, i. e., the extreme cold of the winter of 1709 in Holland. The 24° marked blood heat. Finally, he divided the degrees into fourths, whence came armpit temperature at 96° = 36–37 C. Other changes came later. It seems clear from Boerhaave's Chemistry that he did not suggest the use of mercury to Fahrenheit, for in one place I find that he speaks of this as Fahrenheit's idea, and later of having asked to have made for his own use such an instrument.

† De Haen, Ratio Medendi, ch. xi, pp. 7–9, 12, 17–20, 25.

covered much that is his ; but his methods and instrument were clumsy, and his example proved valueless.

About 1740 appeared in England one of those notable little essays which ought to have had an immense influence. A rude breach is then made in the bulwarks of ancient belief when George Martine* follows Gometius Pereira in the view that heats are not specific, and in the proof that heat in man varies only in degree and not in kind. One must have read long and much to see what a profound hold this doctrine of specific heats had on the mind of medicine. I think there are even yet lingering traces of its tenacity of influence. This book of Martine's is a wonder of able observations. He smiles at the thought of actual ebullitions or effervescences of the blood, as when Willis speaks of it as ready to burst into flame. A poet he thinks may, by his profession (that is good—the profession of a poet !) like Prior in his Alma speak of

Fig 8



"Cor to burn, and Jecur to pierce,
Whichever best supplies the verse."

There is distinct modern good sense in his sarcastic rejection of "the stomach boiling our food by its great heat."† Correcting all former observers, he has the temperature of the skin at 97–98°, over or under, he adds. Boerhaave, who made experiments on the effect of heat on animals, says that they die in an atmosphere at 146° owing to coagulation of the serum, for, he adds, it is disposed to clot at 100° F., and does so not much above that. Around this view was fierce battle, Hales and Arbuthnot siding with the great physiological physician. But, says Martine, "I have seen fevers, most violent, where the blood was, from observation of the skin-heat, 5° or 6° above 100°, without approaching any such danger, i. e., coagulation of the serum, or fatal effects." Is it a modern professor, coolly

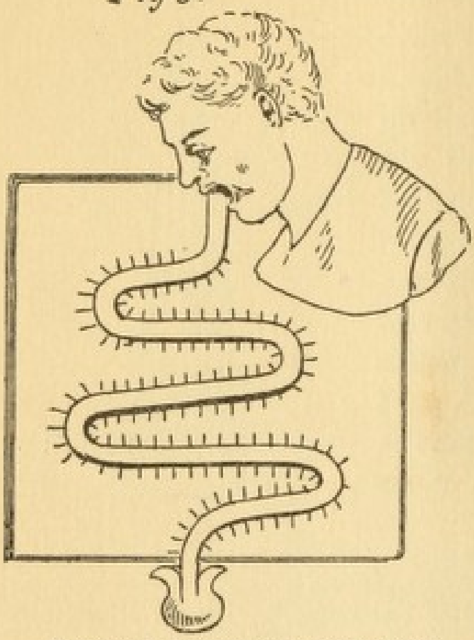
* George Martine, M.D., Essays and Observations on the Construction and Graduation of Thermometers, and on the Heat and Coagulation of Bodies, etc. (see edition dated 1772). Wunderlich gives the date 1740 as that of the first edition ; I have not seen it. The second edition is in the library of the Pennsylvania Hospital.

† Boerhaave, Elements of Chemistry. Translation by T. Dallame, pp. 173, 85–105.

critical, who adds, "Such heat, if neglected or wrong managed, may indeed dissipate the more thin fields or watery parts, and so thickening the whole mass have bad enough effects that way," etc.?* and then he shows that a temperature of 156° is needed to clot serum.

Nor less interesting is it to find amidst notable observations of temperatures these words: "In the ague I had lately, during the height of the paroxysm, the heat of the skin was 106° and that of my blood 107° or 108°," and further, "what is very remarkable, in the beginning of the fit, when I was all shivering and under the greatest sense of cold, my skin was, however, 2° or 3° warmer than in a healthy and natural state."† This all looks like the beginning of practical use of the thermometer, which then was, or very soon became, accurate enough. The germ of thermometric prognostics is in some of his sentences. But again, it falls into disuse while medicine awaits more correct theories of heat. And here we leave the matter. The physiologists‡ and chemists are busy. There is absolute genius in the researches of James Currie as late as 1798.§ But the year 1840 and the systematic work of Andral are reached before that change began, which in Wunderlich's classic made us familiar with the true laws of temperature in disease.

Fig 9.



The mouth thermometer of Sanctorius.

* Martine, p. 146.

† Martine, op. cit., p. 148.

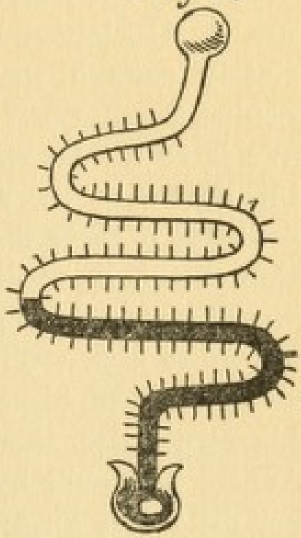
‡ I have no pretension of making the record complete, but cannot refrain from the following brief mention of Hunter: The works of John Hunter show that he was experimenting as early as 1770 upon man and the lower animals with a crude thermometer. The description of the thermometers made for him by Ramsden is interesting; they were "very small, six or seven inches long; not above two-twelfths of an inch thick in the stem, having the external diameter of the ball very little larger than that of the stem on which was marked the freezing point. The stem was embraced by a small ivory scale so as to slide upon it easily and retain any position." He uses it in the mouth, the rectum, the urethra, and on the surface, and extends his experiments to dogs, rabbits, and even fowls and vipers. But in spite of his partial enlightenment he clings to the doctrine of specific heats and combats the view that the temperature is produced by the circulation of the blood.

§ Medical Reports on the effect of Water, Cold and Warm Baths, etc.

And now I turn to a not less amazing story of the early application of instrumental accuracy to the study of the pulse. I can imagine the discomfort with which you look forward to an essay on the pulse. I can promise that it shall not be very dull, and can assure you that nowhere else is it told in full.

An astronomer gave us the first rude thermometer, and it seems to have been another, Herman Kepler, who first, and certainly before 1600, counted the human pulse, or at least left a record of having done this memorable thing. The publications in which he mentions the pulse date from 1604 to 1618. Does it not seem incredible that of the numberless physicians who sat by bedsides, thoughtful, with fingers laid upon that bounding artery, none should have had the idea of counting it? I quote in English what he (Kepler) says.* This great but fanciful man seems to have believed the pulse to have some relation to the heavenly motions, and used the time of the pulse in connection with his arguments in favor of the Copernican system of astronomy. He says :† "In a healthy man, robust and of full age, in one of melancholic complexion, or in a feeble man, generally for each second there is a pulsation of the artery, with no discrimination between systole and diastole; thus there should be in one minute sixty pulsations, but this slowness is rare, commonly 70 may be counted, and in the full-blooded and in women 80, four to each three seconds. Briefly, in one hour 4,000, more or less." The clock with which Kepler counted the pulse must have been such a "balance" clock as his master Tycho Brahe used.

Fig 10



The next epoch marks a pregnant hour in the history of science.

When Galileo,‡ but eighteen years of age, a student of medicine, counted the vibrations of the great bronze lamp swinging in the gloom of the Duomo of Pisa, he conceived them to be in equal time. Desiring to test the truth of his conclusion, he is said to have used his own

* Falconer mentions Kepler as counting the pulse, as also does Broadbent, but neither has any distinct references. I give all the quotations from Kepler which bear on the subject, and for these I am indebted to Professor Asaph Hall, of the National Observatory, Washington. (See Appendix C.)

† Kepler Opera Omnia, p. 248 of Vol. VI, published in 1618. The quotations are from the edition of Dr. Ch. Frisch, 1858. (See Appendix C.)

‡ Viviani, Vita di Galileo, prefixed to an edition of Galileo's Works, published at Florence in 1718. (Page 63.)

pulse as a measure of the correctness of the pendulum. Forty years later, in describing the accuracy of his first clock-work, he says with enthusiasm, "My clock will not vary so much as the beat of a pulse." Says Viviani, his biographer, "The unerring regularity of the swing of a suspended lamp suggested to the young medical student the reversed idea of marking with his pendulum the rate and variation of the pulse. Such an instrument he constructed after a long series of experiments. Though imperfect, it was hailed with wonder and delight by the physicians of the day, and was soon taken into general use."* Unclaimed by Galileo, it was attributed to Paolo Sarpi,† and clearly enough was appropriated at a later date by that notable genius, Sanctorius,‡ who also, like Galileo, called it the pulsilogon. We have no drawing of Galileo's pulsilogon, but it must have been identical with the simpler form as shown in Sanctorius. It is interesting to observe the tendency towards securing accuracy in medicine thus shown by Galileo at the outset of his medical career; Kepler's works were not published until later, and could not have been fully known to him. With his thermometer and the pulsilogon, and with this picture of his testing the accuracy of the swing of the lamp by his own pulse, this marvelous mind passes out of medical history. Where he would have left it had he remained with us, who indeed can say? Of his loss to us, a poet has spoken:

Ah! when in Pisa's dome
He watched thė lamp swing constant in its arc,
He gave to man another punctual slave,
And bade it time for us the throbbing pulse.
Not that grave Harvey whom Fabricius taught,
Not sad Servetus, nor that daring soul,
Our brave Vesalius, e'er had matched his power
To read the riddles of this mortal frame.
And then he left us. Would our strange machine
Had kept his toil, and cheated heaven's fair stars!

With the fame of Sanctorius as the discoverer of insensible perspiration, and with the inconceivable success of his aphorisms we have nothing to do, nor yet with his theories, or his morals, which seem not to have interfered with his appropriation of another man's inventions. His works I shall refer to more fully in my appendix.§

* Viviani, Vita di Galileo, etc.

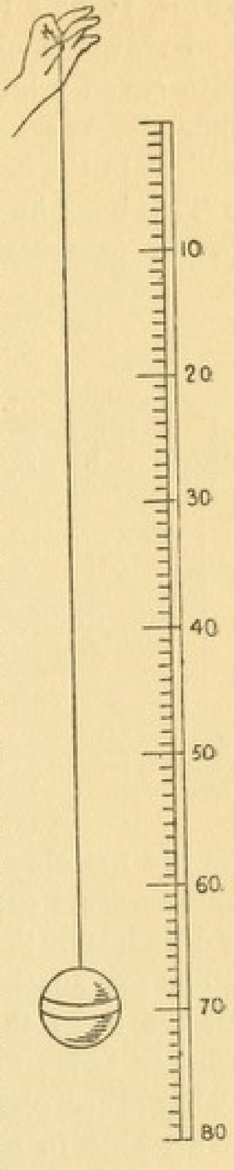
† In the Anonymous Life of Fra Paolo Sarpi, 1750, attributed to Micanzio, and quoted by De Nellé, p. 86.

‡ De Nellé says (Vita e Commercio Litterario, etc., Losanna, 1793, p. 82) that Sanctorius probably learned of this instrument also from Galileo, who at the time of their common residence at Padua had it in mind. Appendix E.

§ Appendix D.

In his Commentary on Avicenna,* he quotes Galen as to "the need to know the amount of departure from the natural state, which is only to be reached by conjecture." But he, Sanctorius, has long been deliberating in what manner the amount of disease could be determined, and has invented four instruments.† In his Methodus Vitandum errorum omnium qui in arte Medica contingent,‡ he has also mentioned these. Then he describes what must have been the form of Galileo's pulsilogon. The diagrams before you almost explain themselves ; the full descriptive text I give in the appendix. (See Appendix D 2.)

Fig. 11.



The pulsilogium of Sanctorius.

Fig. 11 is a scale and a bullet marked with a central white line. We swing the pendulum and note the pulse with the fingers. If the pendulum be faster than the pulse, we lengthen the line ; if slower, we shorten it until they coincide. "Then," he says, "we keep this degree in mind until the next day and compare it with a new record. And so we can study the pulse of health and disease." Also he defines the values and defends the accuracy of the pendulum ; but of Galileo, not a word. He used the beats of his pulsilogon as a measure of the time one must breathe upon his air thermometer. Other forms are also given, Figs. 12, 13, 14, 15.§

Thus we have to-day a pulse of so many inches (or degrees, if you please), and to-morrow it is longer or shorter, and the fever pulse is short, of course, but of results from all this we hear nothing in these huge tomes. The rest of this story is exasperating on account of its omissions. "These other instruments" (Figs. 14 and 15), he says, "record the fre-

* Sanctorii Sanctorii Iustinopolitani olim in Patavino Gymnasio, etc. Commentaria in primam fen; Primi Libri Canonis Avicennæ, Venetiis, 1625. Fen, an Arabic word for part. I chanced to find lately this word in Chaucer, Ed. 1598, p. 65, 2. He says: "But certes I suppose that Avicenne wrote never in no cannon ne in no fenne those wonder sorrows, etc." In his annotations the Elizabethan editor defines "fenne" as a partition. There is no pagination in the Commentary on Avicenna. I refer hereafter to the numbered columns.

† Sanctorii Commentaria, column 21, C.C. Aremberg (Hist. de la Medicine), alone gives any competent description of these instruments.

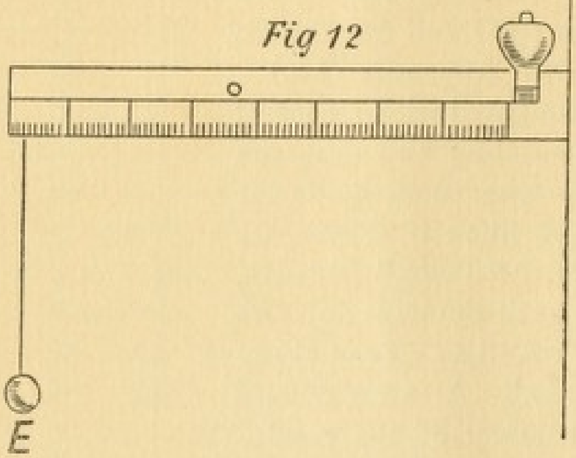
‡ First edition, Fol. Venetz., 1620. Close to the not certain date of Galileo's invention, if De Nellé and Viviani may be trusted.

§ Col. 76 B, and col. 219 C.

quency and slowness of the pulse, and also of the time." "In this" (Figs. 14 and 15), "are seven degrees of the difference of frequency and slowness observed by the index. Then each degree is divided into seven minutes (*minuta*) which are distinguished by the small index." We have described the construction of the instrument, he adds, "in the book on New Instruments for Physicians."*

This book he refers to more than once, and in his Inaugural Lecture (a rare pamphlet) † promises it shortly to his students, and with it also that other, De Jucundissimis Medicinis. As to both one is curious, and especially as to this volume upon the most pleasant remedies. Perhaps these manuscripts are yet to be found among the treasures of some old Italian library. And if so, then only shall we know whether these Cotylæ‡ were rude watches, as seems likely. (See Figs. 13 and 15.) He proposes with them to measure the systole and diastole of the heart. To do this, he says, "We must measure expiration, for this we know corresponds to the systole, as does inspiration to the diastole."

Fig 12



The explanation of the Cotyla§ is brief, and now incomprehensible, but we learn that between expiration and inspiration "the artery pulsates twice or in many three times." Finally we are assured that "what other physicians acquire by conjecture concerning the pulse, we are able to attain unerringly by the infallible skill of the pulsilogon." What a comfort he must have found it!

And here the great Paduan professor, with his thermometer and pulse pendulum, disappears from history, dying in Venice in 1636, of a dysucturia (whatever that may be), in the parish of St. Fortun-

* Col. 76 B, and col. 219 C. Comment on Avicenna.

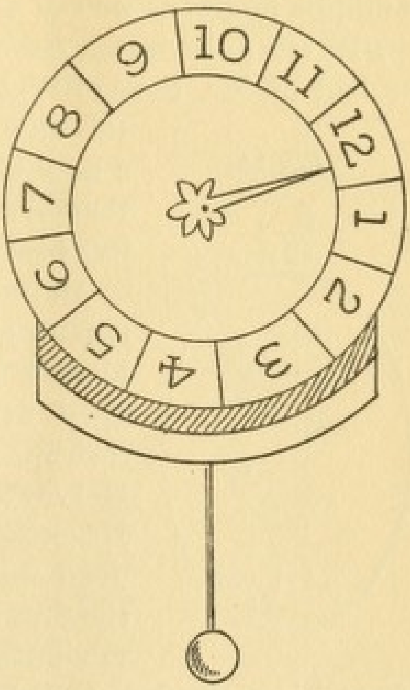
† Appendix D (1.)

‡ Com. Avicen. col. 365, and as to Cotylæ Appendix D (2).

§ I suspect that the dial face in the last Cotyla figured may be merely intended to record the length of the pendulum. But as to this no man can speak to-day with certainty. The passage is not clear; and as concerning this latter instrument he does not say that it takes note of the time as does the one before mentioned.

atus,* a good saint as a stand-by for life or for death. He was laid at rest in the cloisters of Santa Beata Servorum, in a mausoleum which he had made against the time of need. In the early part of this century Napoleon the First destroyed these noble cloisters; what became of the remains of Sanctorius I do not know; his monument I found in the reading room of a literary society the Ateneo Veneto, in Venice. See Appendix D. (1.) A strange proof of vanity is this care as to how the perishable part of man shall be housed in death. And certainly this man thought well of himself, but was also intensely loyal to our "Mistress Art," which he says, in a grandiose way, "is glorious and a helper of men both in peace and amid the din of arms. An art above all others. Folly is it to despise science in general, but to scoff at medicine is not only folly but wickedness—almost the sacrilege of bad hearts."†

Fig 13



And now instrumental study of the pulse fails us for many a day. When Sanctorius died, Sydenham was a boy of nine. There is not a pulse count among all those vigorous sketches which this great Englishman drew with a master's hand, and only once does Harvey speak of their number, which he says is from 1,000 to 4,000 in the half hour.

Time presses, and I must again leave to a note‡ what lies between Sydenham and the year 1707. Here we come abruptly upon a notable book by Sir John Floyer, Knt. It is called the "Physician's Pulse Watch." He dedicates the first volume to Queen Anne, "for without

* And of St. Hermagora.

† From "An Oration delivered by Sanctorius Sanctorius, at his Installation as Professor of the Theory of Medicine, Anno Salutis, MDCXII," appended to a lecture on the Life of Sanctorius by Capello, published at Venice in 1750.

‡ To realize how vast was the advance made by Floyer, one should read "De Variatione ac Varietate Pulsus," David Abercromby, London, 1685, and Schelhammer's "Disquisitio Epistolica de Pulsu," Helmstadt, 1690. These are among the last works of the 17th century on the pulse. The history of the pulse is very well told in the Dublin Med. Journal, VII, p. 96, by Formey, but is nowhere related with competent fulness.

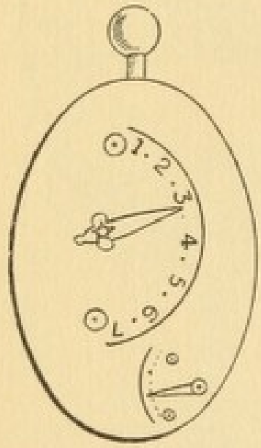
health," he says, "we should have no relish even for the extraordinary blessings of your reign."

He tells us in his preface, "I have for many years tried pulses by the minute* in common watches and pendulum clocks and, then used the sea-minute glass," such as was employed to test the log.

At last he was more happy. One Daniel Quare, a Quaker, had in the last years of the 17th century put on watches what Floyer called a middle finger, as we say a hand.

Floyer's pulse watch ran 60 seconds and, you may like to know, can be had of Mr. Samuel Watson, in Long Acre. The inventor tests this and a half-minute watch which has a cover by a sand-glass which runs for one minute, and finds them not quite correct; one must add, he thinks, five beats.

Fig 14



And now follow pulses of age and youth, pregnancy, exercise, sleep. And we learn how diet, blisters and the weather affect the pulse. Like a good every-day practitioner, he has his fling at science in the shape of a remark on the failure of Harvey's discovery to influence medical practice. Nevertheless, his book on the whole, is full of good observations† thoughtfully carried out. For the first time in medical literature we meet with tabulated results; in fact, there is a modern air about his methods. Clearly he was a shrewd practitioner, a man of scientific accuracy, and knew the world, for he predicts, alas, too truly, that this new method will be sneered at and neglected. As late as 1768, Bordeu‡ dismisses Floyer with something like contempt, and Fouquet qualifies all pulse-numeration as a mere useless curiosity, and sphygmometric instruments as idle toys. Falconer,§ as late in the century as 1796, says, "Floyer's methods were unused until now." And this was nearly true. In the 18th century one finds now and then a pulse count, as when Morgagni describes a pulse which beat twenty-two times in the sixtieth of an hour. Evidently the minute had not yet gotten into the daily life of man.

* He wrote various other books, notably Gerocomica, 1724. In this he alludes to the pulse watch "to be made by making the middle finger of the watch large, and to run round the plate." He gives in this book also tables of his pulse and of weights of urine.

† Save the queer chapter on the Chinese art of feeling the pulse, which seems to have taken the fancy of many able men.

‡ Ed. of 1768, p. 13.

§ Falconer, 1796, who quotes Kepler as to pulse of man 70, woman 80.

If any man wishes to nourish a taste for cynical criticism, let him study honestly the books of the 18th century on the pulse down to Heberden and Falconer, or even beyond them. It is observation gone minutely mad; a whole Lilliput of symptoms; an exasperating waste of human intelligence. I know few more dreary deserts in medical literature, from the essay on the Chinese Art of Feeling the Pulse, with which Floyer loaded his otherwise, valuable essay, to Marquet's method of learning to know the pulse by musical notes, an art in which he was not alone.* And error died hard. The doctrine of the specific pulses, a pulse for every malady, although rejected by De Haen, is in countless volumes, and survived up to 1827, when Rucco† dedicates his book on the pulse to Sir Henry Halford. Meanwhile whole volumes, like Bryce on Asthma,‡ exist without a pulse or breath count; but farther back, in a queer book on the heart by Bryan Robinson,§ I find the first clear statement of the proportional relation of the pulse to respiration. Even those among you given to reading the authors of the end of the last and the first twenty years of the present century, may be surprised to learn that statements of the numbers of pulse and respiration are very rare in Rush, Cullen and their contemporaries. Heberden‖ and Falconer who, perhaps, set too much value on pulse counts, made no impression on their contemporaries. In Corvisart on the Heart we hear little or nothing in this direction, and in seven hundred pages of Laennec there is one pulse count and no numeration of the breathing. It seems incredible; but not until the later French school developed its force do we find in reports of cases the beginnings of those systematic numerations of the breath and pulse which are met with in modern cases.

Fig. 15.

If German science had been as much the fashion as German literature, the remarkable pulse studies of Nick,¶ 1826, would have sooner wrought a change; but it was not until a later day, and under the

* As witness Robert Fludd, who in his curious treatise on the pulse, on page 37, has a section embodying like ideas.

† Rucco on the Pulse, London, 1827.

‡ Robert Bryce, London, 1807.

§ Treatise on the Animal Economy, Dublin, 1732.

‖ Heberden, Med. Trans. Coll. Phys., London, 1768.

¶ Nick, Beobachtungen ueber die Bedingungen unter denen die Haufigkeit des pulses in gesunden Zustand verandert wird. Tubingen, 1826.

influence of the great Dublin school, that the familiar figure of the doctor, watch in hand, came to be commonplace.

I have thought it well to illustrate thus fully the medical history of the watch as an instrument of precision. How small but how essential a part of pulse study are the numerations it enables us to make accurately, you all well know. We could better lose this knowledge than the rest of what the pulse teaches, and yet it is the only pulse sign we can put on paper with perfect precision, as Heberden remarked an hundred years ago.

I have kept you long, and I fear may have been wearisome, but this tale of the growth of Precision in Medicine is not without its moral. In every modern century were men who sought to secure it. The true rate of advance in medicine is, however, not to be tested by the work of single men, but by the practical capacity of the mass. The truer test of national medical progress is what the country doctor is. How useful, how simple, it seemed to count the pulse and respiration, or to put a thermometer under the tongue, and yet it took in the one case a century, and in another far more, before the mass of the profession learned to profit by the wisdom of the few.

A certain sadness surrounds these stories of medical discovery. I have resisted the temptation to tell you more of Currie's notable essay, and of what slight notice it won until Hufeland saw and proclaimed its value. The fate of Avenbrugger, the inventor of percussion, and of his little book, so small, so terse, so wonderful, is yet more pitiful. He foresaw its future and his own, saying in his preface (1760): "Enim vero invidiæ, livoris, odii, obtrectationis, et ipsarum calumniarum socii, nunquam defuerunt viris illis, qui scientias et artes suis inventis aut illustrarunt aut perfecerunt."

Avenbrugger lived on to see his famous colleague, De Haen, write his fifteen volumes without a word on percussion. Van Swieten did it no greater justice. In his huge history of medicine, Sprengel mentions it as rather subtile. Yet were the contents of this booklet of twenty-two pages,* more practically valuable to man than all these men wrote or all the results of the vast and bloody campaigns during which it slept, until in 1808, one year before the grave, contented music-loving German died at 87, Corvisart translated it into French, and proclaimed its undying value to a waiting world.

And now I have done. It seems to me, as I reflect on what I have said, that I have told you a long story of neglected inventions or dis-

* Avenbrugger's book was printed at Vienna in 1761. It was first translated into French by Roziere de la Chassagne. This, and a book on lung disease by the translator, shared the fate of the original treatise. Corvisart's translation was in 1808. So long slumbered a wonderful invention.

coveries, ending sadly in repeated failures to make on their time any permanent impression of the real usefulness of the work accomplished. It is not only the poet who has to wait, and may never see the morning light of recognition break upon his genius.

In my mental wanderings amongst these numberless essays—these great folios—which are too often but splendid monuments, inclosing dead and forgotten thought, I have seen how strong was the resurrective force which now and then existed in some little essay long neglected, how from it, as from seed, arose in after years a fresh growth of vitalizing thought, and how this story repeats itself over and over, until, at last, what one knew and valued becomes the riches of all.

Assuredly in our day this process is more speedy than in the distant past. But be this true or not, there must be many among you who know that apart from large human acceptance, and the material compensations of professional success, there is that in the mere pursuit of truth which mysteriously rewards from day to day. This can no public or personal lack of recognition destroy, no indifference affect. I doubt not that such consciousness of duty done must have sustained many of the men whose failures to see their work result in larger use oppresses one who reads the story of medical discovery. Over and over, they predict their own failure to influence their fellows. The poet is grieved by the indifference of his contemporaries, but the physician seems to be made philosophical by the steadying influence of every-day work, so that not Marcus Aurelius could have been more content than Avenbrugger, whilst a half century passed by neglectful, and would not see the more than royal gift he offered to mankind. I am glad to think he was happy, and to know that for all of us, as for him, this incessant every-day work is a talisman of content, a fact which none know better than those to whom I now say, at last, my thanks and my farewell.

APPENDICES.

NOTE.--The importance of the thermometer and the watch in the acquirement of precision in medical diagnosis, justifies the following contributions towards their more complete history. The works of Fludd and Sanctorius are rare. Few will have the courage to search them as I have done, and as Dr. Robins has done for me with even more assiduous care. The sketch of Sanctorius, for which I had gathered the material is largely Dr. Robins' work, and for it, and many of the translations he has my thanks. Very important additions to our knowledge of Sanctorius have been made of late by Prof. Modistino Del Gaizo of Naples, and from his two essays I have quoted in Appendix I. certain facts and conclusions.

APPENDIX A.

FLUDD'S "SPECULUM CALENDARIUM."

Descriptions of this piece of apparatus, and attempts to apply its principle to the solution of all kinds of physical, medical and metaphysical problems, may be found scattered through Fludd's works. The description which I have chosen as being the most simple and complete is to be found in the Philosophia Moysaica, published at Gouda in 1638, and is in Cap. 2, Lib. i., Sec. 1. After a few preliminary remarks, he says:

"I confess that I found it perfectly described and geometrically drawn in an old manuscript at least fifty years of age. So, in the first place, in the form under which I found it in the aforesaid ancient record, I will place it before you; then I will here describe the shape and position of the one which is commonly known and used amongst us."

"From this it will be seen that these two differ from each other in form only and not in substance: For the solar rays, by their own heat, acting upon the concave globe A at its summit (see fig. 3 on page 11), cause the enclosed air, rarefied by their action to descend through the tube AB into the vessel of water and to emerge over the surface of the water in the form of bubbles; on the other hand, at sunset, and on the approach of the cold night, that enclosed air which on the day before, in the presence of the sun and by its warm action, was rarefied, now becomes cold, is contracted and condensed. But because in the leaden sphere and tube there is not enough air to effect this condensation in proper proportion, since a part of it (as has been said) was exhaled on the day before, that a vacuum therefore may be avoided, as much of water from the vessel C escapes into the leaden tube, as of air was exhaled. Again, when the sun rises on the next day, the air contained in the glass globe and tube is rarefied, and then expanding drives the water, which had descended into the tube, into its former place. And so this alteration by condensation and expansion always presents itself in the same manner more or less, as the sun may be nearer to or more remote from us, or conformably with the wind blowing in the heaven, be it cold or warm.

"The same also takes place with the air contained in the second speculum, for the globe or sphere at the top of the glass is full of air, and may exactly in every respect be compared with the leaden sphere, just as the upright tube, which ascends from the water and is joined to the head, may be exactly compared with the curved tube of the first instrument, so that if the leaden sphere were placed above the vessel, and the curved tube made straight, so that it may ascend from the vessel of water perpendicularly to the leaden sphere there would be actually no difference between the forms or figures of the first and second machines or instruments.

(Cap. 3.) "In the first place it is to be observed that this our experimental instrument is composed of three parts; two of which are proper to the nature of the instrument, namely the Matratium or glass, and the lower vessel full of water, into which the stem or orifice of the glass ought to enter; the other part is entirely incidental, and is so arranged that the glass is sustained in its perpendicular position.

"With regard to the Matratium or glass, it should have a fairly large round or oblong bulb, with a long and narrow neck, whose orifice or mouth should be proportioned to the neck and made and adjusted in a two-fold manner. First, its neck perpendicularly placed, is to be adjusted in a small vessel or bowl full of water, so that its mouth touches the bottom. Secondly, from the surface or summit of the water, up along the neck of the glass ascending even to the globe, we ought to measure until we come to the globe itself be it long or oval, and to divide that neck into fifteen parts, in the middle of which, at that point of course between the head of the tube and the surface of the water which is below, I write the figure I., then downward descending from I. and ascending from I. I count, and I write down 1, 2, 3, 4, 5, 6, 7. Exempli gratia: (see illustration.)

"With regard to the vessel of water, that also with the representation of the tube or neck of the glass or Matratium descending to the bottom, you have depicted in the aforesaid figure.

"And now, with the tube of the Matratium or glass thus divided into parts, you ought to prepare and regulate the glass itself in the following manner, so that it may be rendered magnetic and attractive by cold; and expulsive and dilative by heat. Take therefore, I pray you, the orifice of the Matratium in your hands, and hold its head, be it round or oval, in the fire until it grows very hot. For the heat of the fire will rarefy the air enclosed in the glass, and will cause that a goodly portion of that rarefied air shall escape from the orifice of the glass, and it will remain in that state as long as the glass remains at that degree of heat, at which instant if you suddenly plunge the tip of the tube into the water of the vessel of the instrument, you will perceive that as the Matratium grows cold, so also the water in the neck of the speculum will ascend little by little. It is to be observed also, that the warmer the glass is made, the higher will the water ascend in the neck of the glass, when cold is brought near it, because the more the air is rarefied by virtue of the heat, the less will be the proportion of air, and in consequence, a greater or less proportion of water will be drawn up into the neck of the glass, according to the greater or less predominance of cold in the external air. For the air remaining in the glass after its attenuation, will be condensed by intense cold, and in its condensation will seize and draw up with it just as much of water as was expelled of air from the surface of the water in its dilatation; by which it is manifest that they are deceived, who think the heat to have been the occasion of the attraction of the water upwards, since by this demonstration it may be seen what the action of the heat effects, which drive the water downward from that point to which the cold had made it ascend. However, some impostors, that they may render the thing more wonderful, claim the liquid or spirit to be hidden and moved by itself alone, which, shut up in the glass, by a certain property makes the water in the glass at one time to rise, and at another to fall; that they may conceal this the more craftily, they are wont to color the enclosed water with green vapor or similar colours. What pertains to the incidental portion of this apparatus can be arranged and made in various shapes, or in whatever form or position may please us. My method, however, of making it, I have here described."

APPENDIX B. (1).

How ill the history of the thermometer has been written may be seen by the following extract from Science Conferences, S. Kensington, Physics, 1876, p. 125. Here it will be seen that in the proceedings of the Academia del Cimento is evidence that Galileo busied himself further with the thermometer, using wine in it to replace water. The full story from the Saggi would be interesting. Curious also is it to find that these Italians used mercury in their thermometers, and so anticipated Fahrenheit.

QUOTATIONS FROM "SCIENCE CONFERENCES," 1876, 125.

"Before speaking of the Academia del Cimento, it will not be out of place if I allude to certain measuring instruments which were made use of in its researches, and which are to be found described in the "Libro de Saggi" as belonging to the Academy; but some of which, however, were made before its foundation, according to the directions chiefly of the Grand Duke Ferdinand II. And beginning with thermometers it is useful to notice how even Galileo had substituted wine for water, which by freezing easily broke the thermometrical bulb; while the Grand Duke had replaced wine first of all by colored alcohol; and afterwards, in order that the deposit thrown down by the coloring matter on the inside of the bulb should not render the reading less clear he substituted natural alcohol, which they call "acquarzente." Here is a series of thermometers of that period. But I must tell you that I have only brought from London a very small part of the ancient instruments existing in Florence. This is the thermometer which we owe to the Grand Duke; it is called the "cinquantigrado," because it was divided into fifty parts in a masterly manner by means of these little grains of enamel or glass; and it is exceedingly interesting to observe how the thermometrical bulb was constructed, not merely in a spherical shape, but even in the cylindrical one which has now come into general use; as you may see in this second thermometer, which is also a "cinquantigrado."

As to the way of dividing them into degrees, this is the method employed: They immersed the thermometer, just as we do, into melting ice or snow, and they marked the point to which the alcohol descended, which in thermometers of 50° was about 13.5°; while they remarked that the greatest cold of Florence could reduce it on some occasions even to 7°. Then they exposed it to the rays of the sun in mid-summer, in the open air, without any object of reflection whatever; in this case, the "cinquantigrado" rose, in Florence, to 43° at the highest, and in the shade, at the same season, to 34°; so that the difference between melting ice and the extreme heat was divided into 30°, and these were the points of comparison for their thermometers.

Other thermometers were then constructed with arbitrary scales of 60, 70, 100, 200, or even 400, chiefly by Guiseppe Morani, called on account of his art, "il Gonfia," who was famous for making thermometers of 50° perfectly similar to one another. And such do some of those existing in the Royal Museum of Florence still remain.

Here is a thermometer divided into 470°; and in this other one the bulb is exquisitely worked so as to form a hollow branched stand full of alcohol. To render these delicate thermometers less fragile here is another shape that they sometimes gave to the tube, by twisting it, as you see, spirally. The tube of this thermometer is 230 centimetres long, and yet the total height of the instrument is but 32 centimeters. Here is a thermometer on which is marked the exact temperature which the water should reach in order to be fit for bathing in. This one, is rather a curiously shaped thermometer, or thermoscope; we owe it, also, to the Grand Duke Ferdinand II.; it is described in the "Saggi dell' Accademia del Cimento" as a "thermometer lazier, or more slothful than the others." The tube contains alcohol, besides six little colored glass balls. At the temperature of melting ice these little balls float. At 10° of their 70-grade thermometer one of the balls falls to the bottom; at 20° a second one sinks, and so on. At 70° they are all at the bottom. This other shape, like a small frog, used to be given to similar thermoscopes, in which cases the little balls were regulated so as to mark certain degrees of temperature nearer to one another. The thermoscope was tied as you see, to the pulse of a sick person, and served to show the intensity of the fever. In certain experiments upon the amount of heat transmitted by different substances which were first warmed and then plunged into water, it is mentioned that of the two thermometers used, the one of alcohol, the other of mercury, the first to show any sign was the one with mercury. It is, nevertheless, difficult to establish the precise date at which mercury thermometers were first made.

APPENDIX B. (2).

The following account of the improvements made in the thermometer by the Grand Duke Ferdinand II., is taken from the description given by Father Urbano Daviso in his brochure "Pratiche Astronomiche" annexed to "Trattato della Sfera," and quoted by De Nelle (lib. cit.) pp. 91–93.

"The same most excellent and learned Prince, not satisfied with the perfection to which he had brought the knowledge of the proportion of the weights of bodies, wished also to settle the various differences of their cold and heat, and has been so successful that very minute differences can be exactly measured by him. In the beginning the attempt was made with a vase full of water or other liquid, in which was plunged perpendicularly the mouth of a long and very thin glass tube, which at the upper extremity had a bulb as large as an orange. This bulb, being full of air, and partaking of the conditions of the atmosphere in which it is placed, the contained air contracts or expands as the heat of the atmosphere be greater or less. And the mouth of the tube being plunged into the liquid, it is not possible for other air to enter, and the liquid rises and falls in the tube, showing the degrees marked upon it according to the differences of heat and cold. It is necessary, nevertheless, before the mouth of the tube be plunged into the liquid, to warm with the hands, or in some other way, the air which is in the bulb, for the purpose of later reducing its heat and thus condensing the air and causing its liquid to rise to a certain degree towards the central point, and then descend if the atmosphere be warmer, on account of the greater rarefication of the air in the bulb. This instrument, placed in a room shows, with its ceaseless movement, the diminution or increase of the air which is in the room, from which a thousand useful and interesting facts may be learned. But his Highness, the Prince was not satisfied with this invention alone, but endeavored to bring it to such perfection that nothing more could be desired. He invented a small glass vial, with a neck half-a-palm in length, and so thin that the empty space (calibre) would hardly contain a little grain of millet. This vial, filled up with well-refined alcohol, either plain or colored, and in sufficient quantity to rise to the middle of the neck, and with the mouth hermetically sealed, shows by the rise and fall of the alcohol over the points marked on the neck, the increase or diminution of the heat or cold. This second instrument has many advantages over the first, because it not only shows the quality of the atmosphere but also that of any liquid in which the aforementioned bulb may be plunged. In this way can be determined which of two liquids may be the warmer or colder, how water, a room, or a stove may be heated to a certain degree, and there be maintained, which knowledge may be brought to such a point that we may know when a body has reached the proper perfection when being cooked. By these operations we can almost say that the Chemical Art has been brought to entire perfection. In the same manner, with the same kind of instrument, and one made in the same proportions, we may ascertain the heat and cold of any region or place whatever, a previous observation having been made ; also, standing in a room, we may know that the rivers and springs are frozen, and the thickness of the ice formed in one night. In the winter, his Highness the Grand Duke, when rising in the morning, by examining this instrument, can readily ascertain, by comparison with previously-made observations, whether the cold be greater in this or that place than in Florence or wherever his Highness may be, and in what degree. By this means it has been found that the water of wells and springs, as well as the air of cellars, caves, and other underground places, which in the winter seems warmer than in summer, is of the same quality at the one time as the other. For this reason we are led to affirm that the difference lies in the atmosphere which surrounds us, which alters our sensibility, and not in the changes of heat and cold in them."

APPENDIX C.

The following quotations from Kepler's Opera Omnia are taken from the edition of 1857, edited by Dr. Ch. Frisch, and to which my attention was called by Prof. Asaph Hall, of the National Observatory, Washington.

On page 334 of Vol. ii., Kepler says, 1604.

" But in one hour there are 3600 seconds, in 12 hours the sum is 43,200 seconds. Now what is the proportion of one to fifty thousand? Evidently imperceptible. Likewise, from number 112 of the fourth (book) of Vitello, when a visible object remains for a perceptible time in the same perceptible place, it is considered to be at rest. But this is true of the stars. For a moment, it may be one second, the smallest division of an hour (which generally is equal to a pulsation of the arteries) is a perceptible time, but a place, even the curve of one eye in width, cannot be seen without the use of an instrument." The above passage I found to be obscure, nor did it seem less so to Dr. Hall.

Page 337 of Vol. vi., published in 1618.

" Quibus argumentis probatur fixarum sphæram non moveri? That it is not turned round a center and axis has been shown in Book I. For as much of this as meets the eye we are acustomed to assign entirely to the earth. Other arguments may be sought for there, pages 168, et seqq. Two only we repeat as pertinent in this connexion. One from celerity. For if the outermost sphere has in diameter at least 4,000,000 diameters of the sun, the long circumference will be 12,566,370; which if the whole be revolved in 24 hours, in one (hour) 523,600 (diameters) will be revolved in one minute, 8727, in one second (which generally equals the pulse of a man) there will cross 145 diameters of the sun, which is equal to not less than thirteen thousand German miles; and so in the space of time in which the artery in a double pulse dilates once, and again contracts, the largest circles will be revolved seventy-five hundred thousand miles, and Saturn, in a two thousand times narrower orbit, passes generally through 4000 miles."

APPENDIX D. (1).

SANCTORIUS.

The interesting relation of Sanctorius to the early efforts at instrumental precision in medicine justify me in putting on paper all that we know of this physician. The following data are derived from three sources, viz: (1). The Oration of Arcadio Capello, delivered in 1749 and published in a rare pamphlet in 1750 (a copy of which is in the Royal University Library at Padua); (2). An unpublished MS. in the shape of a letter from Girolamo, Marchese di Gravisi, to the Marchese Giampaolo Polesini, dated 1791, and entitled " Memorie intorno al Santorio." A copy of this is in the Royal University Library at Padua, and a copy of that copy has been added to the Library of the Surgeon-

General of the United States Army at Washington ; An interesting brochure entitled "Ricerche Storiche intorno a Santorio Santorio ed alla Medicina Statica," by Prof. Modestino del Gaizo, published at Naples in 1889, and which contains all that is known of Sanctorius.

Santorio Santorio was the elder son of Antonio Santorio and Elizabetta Cordoni his wife, and was born at Capo de Istria on the 29th of March, 1561 (according to Gravisi ; Capello makes the date April 4th, 1561, and Prof. del Gaizo gives no date beyond that of the year). Capello claims that the family was of noble origin, but Gravisi speaks of Antonio Santorio as being a native of Spilinibergo in the province of Friuli, who became a soldier, and in 1548 removed to Capo d' Istria where he held the position of Chief of Ordnance (Sopromassaro alle Munizione e di Bombardiero), and was the first of his name there.

In 1575 Sanctorius (as he generally called himself) left Capo d' Istria, and proceeded to Venice, where he spent a year, and thence to Padua, where he became a student in the celebrated university. He followed courses in Medicine under Professor Bernardino Paterno, and in Physics under Professor Giacomo Zabarella. His later writings show that he was also proficient in Greek, which he probably acquired under Zabarella, who was a famous Greek scholar.

After a seven years' course, Sanctorius received in 1582, the degree of Doctor of Medicine ; for three years thereafter he applied himself to clinical study and was then admitted to general practice. In 1589 he received a public medical appointment at Capo d' Istria, with a stipend of 200 ducats per annum. Several years later he was offered a professorship in Poland ; whether he accepted this offer or not is uncertain ; Capello claims that he did, and that he rose to considerable eminence there, and in this opinion Prof. del Gaizo concurs. Without doubt, however, he was about this time in foreign parts, as he speaks in his works of observations made in Hungary and Croatia.

In 1602 his first book "*Methodi Vitandorum Errarum omnium, etc,*" was published in eighteen parts in Venice, passed through several editions, and was finally published with the addition of another part (De inventione remediorum) in Geneva in 1631. In 1611 he was appointed to the professorship of Theoretical Medicine in the University of Padua, the chair having remained vacant since the death of Orazio Angenio in 1603, and the same year, by a "ducal decree," he was made professor in chief with a stipend of 800 ducats.

In 1612 appeared his "*Commentaria in Artem Medicinalem Galeni,*" and in 1619 he published his best known work, "*Statica Medicina,*" in which he formulated the laws of natural insensible perspiration, which he had discovered. This book was savagely attacked by one Ippolito Obrizzi of Ferrara, who wrote a pamphlet entitled "*Staticomastix, sive Staticæ Medicinæ demolito.*" Sanctorius, in his turn "demolished" the Staticomastix in the next edition of his book. The "*Statica Medicina*" passed through twenty editions, and was translated into Italian, French, German and English.

In 1616, by a "ducal decree," Sanctorius was elected president of a new college founded in that year at Padua, and in 1617 he was reëlected (his term having expired) to his original Professorship in the University of Padua. As far as can be ascertained, he seems to have held both positions contemporaneously.

In 1622 he resigned his professorships and removed to Venice, but the University continued his stipend as a pension. In 1625 he published his "*Commentaria in Primam Fen primi libri Canonis Avicennae*," so often referred to in the text, and in which are described the Pulsilogia, Thermometers, and Hygrometers with which he had been experimenting, as well as a primitive Trocar and Canula, an instrument for removing Vesical Calculi, and a bed for medical purposes.

In 1630, when Venice was vexed with a pestilence, the care of the public health was entrusted to the veteran Sanctorius, and when the plague was over he made a report to the Health Officer of the City which is still preserved in the General State Archives. A copy of this interesting document is given by Prof. del Gaizo in the appendix to his book before quoted.

In 1632 in collaboration with Theobaldus, Sanctorius published his last book, "*Consultatio de lithotomia, seu Calculi Vesicae sectione.*"

This remarkable man died in Venice, February 26th, 1636,* and was buried in the cloisters of the Church of the Servi. On his tombstone was the following inscription :

Ossa
Sanctorii de Sanctoriis
Is Olim Theoricus Ord.
Primæ Sedis
In Gymnasio Patavino,
Vixit Annis LXXIII,
Menses XI, Dies III,
Obiit vi. Kal. Martii MDCXXXVI.
Hora III Noctis.

A bust of Sanctorius was placed in the same church with the following inscription.

Saĉtorio Santorio
Omni Virtutû. Morûg suavitate
Viro Gravissimo
Qui Med^{na} in P^{a} Sede Patavi P. Añ^{os} 14 Pfessus
Cum Universitatem illā Doctrina e eâdâ
Venetiasque Medendi Arte
Tot Orbê Libr^{is} Edit^{is} et Fama Mire Lustra^{set}
Venetys unica oiû voce celebris
In Memoriâ Posteror Celebrior
Abiturus Obyt
Elisabeta Neptis in Meritorû Decus
Ex Test^{o}
P. Q. P.

It is interesting to follow up the ultimate fate of these monuments. In the early part of this century the Church of the Servi was destroyed by Napoleon, and, del Gaizo tells us, the bones of Sanctorius were entrusted to a physician, one Francesco Aglietti, who preserved them and the bust, until they were placed in the Atrium of the Ateneo Veneto, where they still remain.

* Here again the biographers differ in their dates, as Capello makes the date March 6th, 1636.

There is another bust of Sanctorius with a different inscription in the Church of Il Santo at Padua. This inscription is given in full in the memoir by Gravisi, and yet another inscription was placed, we are told, in the Cathedral at Capo d' Istria.

Sanctorius left a considerable fortune to be divided amongst his heirs. One of his legacies was an annuity of fifty ducats to the College of Medicine in Venice, which bequest was for a time annually celebrated by a public commemoration, with an oration in his praise.

Whatever question of priority there may be as to the invention of the thermometer and the pulsilogium, there can be no doubt that Sanctorius was the first physician who applied the principles which they illustrate to the matter of diagnosis, and in this as in many other matters he was for success too many years in advance of the knowledge of his age. The instruments which he describes in his "*Commentaria*," include some which are marvelously like those used at the present day; one of them which he calls "instrumentum quo extrahuntur illa quæ occludant meatum externum auditus," is by no means unlike the modern Gross' ear instrument, whilst the "instrumentum quo extrahimus aquam hydropicorum per umbilicum," is in no wise different from our trocar and canula save in its crudeness. Credit must also be given to him for his attempt to measure the amount of aqueous vapor in the atmosphere by means of the elementary hygroscope which he invented; this same hygroscope he also used clinically, applying it to the surface of the patient and endeavoring by its use to estimate the amount of sweat excreted in a given period. He was as truly a progressive physician in his age as the man who to-day resects the intestine or taps the ventricles of the brain with a hypodermic syringe.

Of his opposition to astrology, and of his remarkable opinions in regard to the true theory of vision I have found myself unable to speak at proper length. I still hope that some Italian physician will give us such a life of Sanctorius as Henry Morley has written of Jerome Cardan. From what Prof. del Gaizo has discovered and what I myself easily found at Venice and Padua I suspect that there must be still valuable material as yet untraced.

It has been justly said by one of his own countrymen that with Sanctorius began a new formative epoch in Medicine; many of his inventions were soon forgotten or disused, but the effect of his "*Statica Medicina*," was more lasting, and his proof of the insensible perspiration valuable in many ways. Baglivi's excessive estimate of his value but echoes the voice of his time. "Statica Sanctorii, et circulatio Sanguinis Harvejana sunt duo pola, quibus universa regitur Medicinæ moles hisce inventis restituta et confirmata; reliqua potius illam exornant, quam augent."

APPENDIX D. (2).

The descriptions of the primitive thermometer and pulsilogium which follow, are taken from Sanctorius' "Commentaria in Primam Fen Primi Libri Canonis Avicennæ," from the edition published in Venice in 1625. This volume has no pagination, but the columns are numbered and lettered; the references therefore, are to these numbers and letters.

Column 21.

"For a long time I have been deliberating in what manner the amount of disease could be determined from any region whatever. I have contrived four instruments.

"The first is my pulsilogium by which with mathematical certainty, and not by conjecture, I can measure the utmost degrees of variation of the pulse both as to frequency and as to slowness, of which instrument I have given some account in lib. 5 of my Meth. With the aforesaid pulsilogium I have found this to be easily done, as is explained in the first figure. It is composed of a little cord made of linen or silk, to which, as may be seen, is fastened a leaden bullet, which being struck, if the cord be long, the motion of the bullet will be slower and less frequent, if the cord be short, its motion will be quicker and more frequent. When therefore we wish to measure the frequency or slowness of the pulse, we drive the bullet with the fingers, lengthening or shortening the cord until that point be reached where the motion of the bullet exactly coincides with the pulse-beat of the artery; which being found in a certain region to be 70 in degree, shown by a white line on the bullet itself at the point C. This degree being kept in mind, again on the same or on the following day, we can make trial with the same instrument whether the pulsation of the same artery be a very little quicker or slower; we say 'a very little,' because in the use of this instrument we do not seek those marked differences of rapidity or slowness of pulsation which can be carried in the memory of the physician, but rather those very slight ones of which the differences between one day and another are barely noticeable. For the same purpose is another similar instrument of which a representation may be seen in fol. 78, figure E. But it is to be noted that the impelling of the leaden bullet by a greater or less force does not change the slowness or frequency, because, in striking it, what is lost in space is gained in force. With such an instrument we can measure the pulse in a state of health; then in time of disease we note the departure from the natural state, which is especially necessary in diagnosis, prognosis, and treatment. By this means we can recognize the difference between a slow and a weak pulse, in which thing physicians are often deceived; the difference being that in fevers the weak pulse does not decrease in frequency, whereas the slow pulse abates, which abatement, so slight is it, cannot be perceived by physicians without an instrument, and in prognosis they are often mightily deceived. But of its other use in its own place.

"2. The figure is a glass vessel with which with the greatest care we can hourly measure a cold or hot temperature, and can ascertain with precision hour by hour, how much the temperature has departed from the normal state previously measured. This vessel was proposed by Hero for another purpose; we however have adapted it for ascertaining the coldness and warmth both of the atmosphere, and of all parts of the body, and for recognizing the degree of heat of fever-patients. This is done in two ways: in the first, the patients grasp with the hands the upper part of the glass, marked D; in the second, they touch the same part of the glass with the mouth, breathing out as is shown in Fol. 219, first instrument. This is done during a certain brief period, say ten vibrations of the pulsilogium, that we may be able on the following day to ascertain whether, during the same period, the same water being used, it descends to the same point. By the action of cold it does not ascend further than O, on the other hand, by the action of heat, the air being rarified, it descends; then we can determine whether the patient be the better or the worse, when the differences are so slight as scarcely to be apprehended by physicians without an instrument, and thus they may be led astray in diagnosis, prognosis, and treatment. But in the book on instruments we have set forth the other uses and the other and divers vessels of glass adapted to this purpose. * * * * * * * * *

Column 77.

"Figure D is the pulsilogium which we have invented, by which we measure not only the time, but also the frequency and slowness of the pulse. In this instrument are seven degrees of the differences of frequency and slowness, which are observed by means of the index (radius). Then each degree (gradus) is divided into seven minutes, which are distinguished by the small index (radiolum). The construction of this instrument we have described in the book on the instruments for physicians."

"Figure E is likewise a measure by which with great exactness, we make the same observations. B is a cord to which is affixed a leaden bullet E, which being impelled, as the cord be shorter is moved more quickly, as it be longer, move slowly and less often. The index of the degree of the velocity or slowness is the letter O."

Column 364.

"By means of the proposed cotyla, we have a method of ascertaining whether the systole of the pulse be more rapid than the diastole, which before us (as far as I know) has been known of no one. Of what use may be this knowledge, can be gathered from Galen (Cap. 32, Artis. Med.) where he treats of the hot and moist heart, for he has these words: 'In the foul and decaying fluids, the expirations are greater and swifter, and the systole of the artery in the pulses is more rapid.' From a systole, therefore, more rapid than diastole, Galen concludes that excessive moisture and foul and putrefying humors predominate. Therefore when the systole is more rapid than the diastole, it will proceed from the parts drying up, when it is slower, from the parts growing moist. Which being unknown, the physician will not be able to determine from the pulse whether it indicates a moistening or a drying. There is no one who does not know of how much moment this is. The method, therefore, of measuring the swiftness and slowness of the systole (which is most difficult because the systole does not reach our fingers touching the pulse) is deduced from the expiration; the faster this be, the more rapid will be the systole; and so the faster inspiration be, the more rapid also will be the diastole. Now the method of measuring inspiration and expiration is shown in the proposed instrument; for we may measure the expiration with great ease, first with the hand pressed to the chest; then, with the thread to which the little leaden ball has been affixed, and of the proper length, we may observe the movement and rest of the respiration; we say 'of proper length, because, the longer it be, the slower will be the motion; seeing that between inspiration and expiration the artery will pulsate twice, and in many persons three times, it is sufficient therefore that we know that if expiration be more rapid than inspiration, the systole of the pulse also will be more rapid, because expiration corresponds in its amount to systole, and inspiration to diastole, which being known beforehand we may judge from the pulse whether the moist or dry humors predominate."

From "Commentaria in Primam Fen, etc." Col. 219, C.

"We may recognize the warmth or coldness of the heart by means of seven instruments. In the *first* and *second* we thus ascertain the heat of the heart. In the mouth is placed the upper part of the instrument, which is round like a little sphere, and is held in the mouth through the space of three or four vibrations of the pulsilogium, with which we measure the pulse. The *third* instrument is like a flattened cotyla,* from which hangs a thread to which a leaden bullet is attached. Of the *fourth* we have treated before. Then, the water contained in the first and second instruments being reduced, the greater the heat of the heart be, the more will it descend and thus indicate the furthest differences of heat; and thus by daily experiment we may ascertain whether the heat of the heart increase or decrease ; and this is of the utmost value, especially in fever-patients.

"The upper part of the *fifth* instrument is applied to the region of the heart, the same observations being made, as with the two first instruments. Thence we may at once learn whether the heat of the heart increase or decrease, or remain stationary. In the same manner, the instrument being applied to different parts of the body, we may ascertain at any moment of the hour what may be the intensity or declination of the heat. Moreover, we measure the time of the application by the vibrations of the third or fourth instrument, as has been said.

"By the *sixth* glass instrument we can easily measure the heat of the heart by breathing once and violently from the open mouth into the upper part of the glass which is concave, which expiration, if it be warm, will cause the water to descend more or less, as the heat of the heart be more or less intense. For a hot expiration will heat the glass, the heated glass will rarify the air, the rarified air will force the water downward to a fixed degree. By the use of this instrument also, a comparison of heat can be made, and especially of the fever of one day with that of another, or of that of one paroxysm, with that of another. Whence we may with certainty ascertain whether the heat of the fever increases or decreases, and through what degrees.

"In the *seventh* instrument, the upper sphere is grasped by the hand, which is allowed to remain during fixed vibrations of the third instrument, which being observed, we may note what may be the heat both of the sound and of the infirm, and whether the well or the sick gain or lose heat.

"But in observations with the aforesaid instruments, skill in the use of each pulsilogium is required. In the third, from which hangs the thread to which is affixed the leaden bullet, the longer or shorter that thread be, the slower or more frequent are the vibrations. By as much as the thread be long, by so

* COTYLA (*Anat.*) *κοτυλη* *Cot'-y-la*, *Cos'-ty-le*; the same as *Acetabulum*. A hollow or cavity in a bone, which receives the head of another bone, and particularly the *cotyloid* cavity *κοτυλη*, signified a drinking cup, and, indeed, anything hollow, as the hollow of the hand. (Dunglison's Medical Dictionary.)

much the slower and less frequent will be its motion; by as much as it be short, by so much will the motion be quicker and more frequent; moreover the greater and less slowness and frequency can be recognized by the degrees which are shown by the index of the pulsilogium.

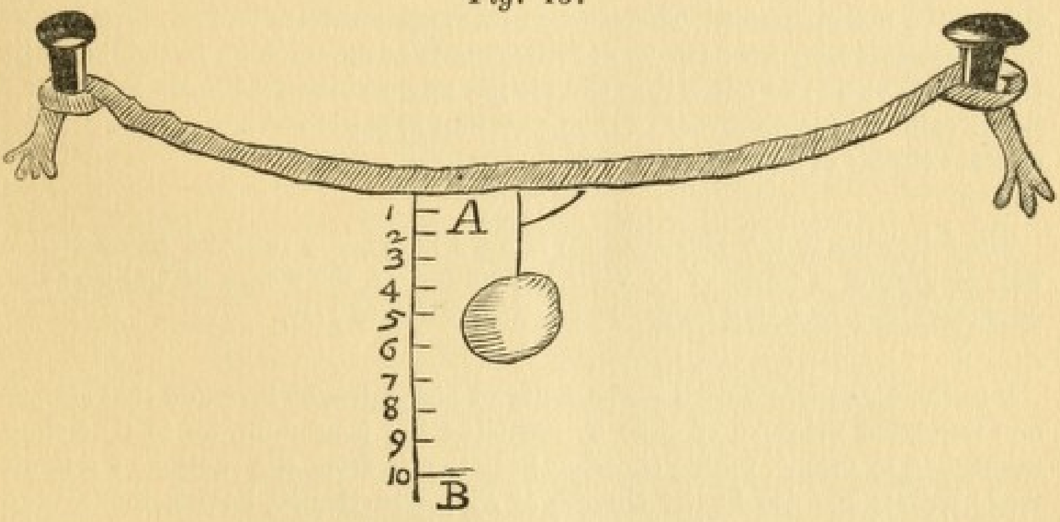
"The same purpose is subserved by the fourth instrument, with which, in like fashion, we measure both the space of time, and the frequency and slowness of the pulse. Moreover, anyone, with these pulsilogia, is able to fix in memory the motion and rest of the pulse, and thence to make a comparison of the pulse of to-day with that of to-morrow or yesterday. Whence we may learn on what day and at what hour the sick will approach or depart from the normal state. We may add that no physician is created with such remarkable skill, that without the aid of the pulsilogium he can retain in his memory the smallest differences of motion and rest of the artery; so that that which other physicians acquire by conjecture concerning the motion of the pulse, we are able to attain unerringly by the infallible skill of the pulsilogium."

From "Commentaria in Primam Fen etc." Col. 21.

"Then we have two methods of measuring dryness and moisture when they depart from the natural state. Of this we have made mention in the fourth aphorism of the second section of our statics.

"The first method is explained by the third figure (See Fig. 16); in this a

Fig. 16.



cord is drawn, or if you please, a line of gut, but it must be coarse. This cord is applied to the belly or other parts, and in the midst is placed a leaden bullet, and near by a scale is marked. When the atmosphere is moist the cord is contracted. When it is dried by the north wind it is relaxed. Sometimes a south wind so moistens and contracts the cord that the bullet is drawn even to the letter A; when the north winds blow, the cord is so dried that it approaches even to B. Thus, notwithstanding that no wind may blow, the scale of moisture or dryness of the air may be daily observed."

APPENDIX E.*

"Vincenzio Viviani in his life of Galileo, page 52, asserts that his master Galileo was the first to observe in the pendulum the isochronism of time, and before all others made use of the same in medicine for the purpose of measuring the greater or less velocity of the pulse. He produces no document to prove his assertion, for it appears that the first to use the pendulum, calling it the Pulsilogium, was Santorio, who in his work entitled "Methodi vitandorum errorum omnium, qui in Arte Medica contingunt," printed for the first time in Venice in 1603, on page 109 writes: "Pro qua cognitione exacte, & cito comparanda instrumentum Pulsilogium invenimus, in quo motus, & quietes Arteriæ quisque poterit exactissime dimetiri, observari & firma memoria tenere, & inde collationem facere cum pulsibus præteritarum dierum, exhibit instrumentum omnes æquatium differentias, &c." From which passage it appears that before all other authors Santorio published the use which could be made of the pendulum in medicine, and it should be remembered that Galileo went to read Mathematics in the University of Padua in 1592, and at that time must have made the acquaintance of Sanotrio, then professor at that University. The affability of the Florentine philosopher, his slight esteem of his many discoveries, and the liberality with which he communicated them to his several acquaintances make it at least probable that Santorio having heard Galileo describe this discovery of his, appropriated it, and called himself its author, just as he did with the thermometer, the invention of which, as will be shown further on, belongs to the divine Galileo. It should be noted here, that in the work of Santorio mentioned above, printed in 1603, he does not speak of any other instruments than the pulsilogium, and never makes mention of the thermometer. Therefore in this year Santorio had not inserted in his works this instrument as he did afterwards in those which he published in 1612. It is also to be noted that Galileo not having practised medicine set but slight value on his discovery of the pendulum in the observance of the greater or less velocity of the pulse."

The following is the passage in Viviani's Biography referred to by Nelle. This biography is prefixed to Viviani's edition of the works of Galileo; the quotation may be found on page 63 of the edition of 1718.

"In the mean while with the sagacity of his genius, he invented that simple and regulated measure of time by means of the pendulum, up to that time unmarked by others, taking occasion to notice it from the motion of a lamp when he was one day in the Duomo at Pisa, and thence, having made very exact experiments, he ascertained the equality of its vibrations, and thus it occurred to him to adapt it to use in medicine for the measurement of the frequency of the pulses to the astonishment and delight of the doctors of that time, and as is still commonly practised to-day. This invention he used afterwards for various experiments in measurement of times and motions, and he was the first who applied it to the observation of the heavens to the incredible advancement of Astronomy and Geography."

* From "Vita e Commercio Litterario di Galileo Galilei," by Giovanni Batista Clemente de Nelle, Losanna, 1793, p. 31, I take this foot note.

APPENDIX F.

EXTRACTS FROM "RICERCHE STORICHE INTORNO A SANTORIO SANTORIO ED ALLA MEDICINA STATICA," BY PROF. MODESTINO DEL GAIZO.

Page 11. So we find in the volume of Favaro "Galileo e lo Studio di Padova," that on the 13th of June 1612, there was at Padua, for the feast of S. Antonio, Agostino De Mula, a well-known Venetian gentleman and a man especially learned in the Science of Vision, which he explained from an opposite standpoint from that which had been espoused by Vitellio and others. Returning home De Mula described the thermometer invented by Santorio, to Giovanni Francesco Sagredo, another Venetian gentleman, a disciple and friend of Galileo. And to Galileo, over date of June 30th, Sagredo in his turn writes of it: "Signor Mula was at Il Santo, and described to me an instrument of Signor Santorio which he had seen, with which one measures cold and heat as with a compass, and finally told me that this was a large ball of glass with a long neck, whence suddenly I am given to make some most exquisite and beautiful forms, namely an 'inghistare,' an 'ampoletta,' and a 'sione di vetro."* The most beautiful which I have made and finished is of the size and design here enclosed in all parts.

Galileo may now have assumed to himself the invention of the thermometer; Sagredo, on the 9th of May, 1613, and again on the 15th of March, 1615, wrote to Galileo concerning the instrument for measuring the temperature, and no longer spoke of Santorio but of Galileo: "Your excellency was the first inventor of it." And this was the case. Viviani assigns as the epoch of the invention of the thermometer, the period which elapsed between 1593 and 1597. Father Benedetto Castelli in a letter of September 20th, 1638, written to Ferdinando Cesarini, proves that he knew of the invention of Galileo about thirty years before, namely about 1603. Galileo in a letter of 1626, to Cesare Marsili speaks of a "*scheizo*," (literally: a jest) with which he was occupied about twenty years before (1606), which could be explained, with analogous phenomena, by the circumstances which had led Galileo to invent the thermometer. And of this instrument moreover, Galileo treats in one of his (Pensieri) "Musings" collected by Viviani; which "Musing" has reclaimed to-day, the attention of learned men, such as Rambelli (1844), Caverni (Intorno all' Invenzione del termometro; Roma 1878) and Favaro (Galilei e lo Studio di Padova; Firenze, 1883), Caverni investigating especially the date at which it was written.

Page 17. Santorio colored the water green in order to observe better the expansion of the air which filled half the thermometer whilst the water filled the index.

Page 18. Galileo invented the thermometer; Santorio diffused its use; in Padua and in Venice, Sagredo and De Mula, friends and disciples of Galileo, before Santorio constructed his thermometer, knew nothing of the invention of their friend and master. Santorio modified the thermometer of Galileo for physico-pathological investigations, and for application to the mouth, and for rendering it more sensitive. Santorio, in fine, was the first who attempted to

* These are technical terms for which I am at a loss to find synonyms.—R. P. Robins.

use on a large scale, the thermometer in medicine; from the letter of Sagredo it is clear that many in Padua, and in Venice used it (sic !). The following refer the invention of the thermometer to Santorio: Paolo Boccone (Museo di Pianti rare, p. 88, Tav. 85 e 86), Giuseppi Biancani (Sphæra Mundi seu Cosmographia demonstrativa ac facili methodo tradita; Bononiae, 1620, p. 111) and the two greatest authorities, Malpighi (Opero Postuma p. 30), and Borrelli (De motu Animalium, Pars II, Cap. xiii., sec. 175.)

Finally, p. 57, we have a letter from Sanctorius to Galileo, date of 1615, sending him the Statics. The tone is respectful and there are allusions to mutual friends.