THE REFLEX HAMMER

In memoriam Robert Wartenberg (1887–1956)

by

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'WITH every tap a peculiar itching or tickling sensation may be perceived in the tendon'. So was the feeling described, ninety years ago, in the first account of the hammer as applied to the patellar tendon.[1] For the well equipped physician had been carrying in his bag some variant of our red rubber triangle mounted on a stainless steel handle quite some time before the words just quoted appeared in Westphal's *Archiv für Psychiatrie und Nervenkrankheiten.* Their author was Wilhelm Erb, who wrote in 1875

> Slightly flexed at the hip and knee, the leg is held fast while all its muscles are relaxed and, with a finger or percussion hammer, a very light and elastic tap is delivered (exactly as in very light and elastic percussion of the chest or in testing for fluid in the abdomen) to the region of the ligamentum patellae. Each tap is followed by a contraction of the quadriceps, immediate like lightning, unmistakable, visible, palpable, and apparently reflex: manifestly and often quite strongly is the shank set in motion. It is extraordinarily difficult to suppress this reflex by a voluntary effort . . .

The reflex was a novelty in the 1870s. But the instrumental hammer was surprisingly old in the diagnosis of disease. Even more surprisingly, its use was older in a disease of the brain than in one of the abdomen or chest, and in cattle rather than man. This remains true even if we believe Josef Škoda,* the great Viennese diagnostician and therapeutic nihilist: 'The abdomen has always been percussed for suspicion of too much gas in the intestine', he wrote in 1839.[2] Percussion of the chest, though, goes no farther back than Auenbrugger. Only then, in the middle of the eighteenth century, doctors seriously began to lay hands on their patients, not just for treatment, but for diagnosis. Auenbrugger's sonorous first axiom was 'The thorax of a healthy person sounds, when struck'.[3] What inspired the friendly doctor to his discovery, we are told, was the customary checking, in his native Styria, for the fluid level of wine in the cask.[4] Chest percussion, when it gave sounds either deeper or duller than the normal, spelt disease: cavities, effusions, and so on. A sensitive and musical man, in a musical country at its most musical period, Dr. Leopold Auenbrugger, Edler von Auenbrugg, had also written the libretto to a comic opera for the court of Empress Maria Theresa,[4] and a treatise *On the Silent Rage or the Drive to Self destruction.* He applied physics to medicine in the day of amateur physicists. Obviously also, he was steeped in the new vogue, morbid anatomy, or the aggressive search for the seat of disease. Auenbrugger's *New Invention to Detect the Diseases Hidden Deep Inside the Chest,*[3] was published in the same year as Morgagni's supreme work on organ pathology (1761).[5]

* Pronounced 'Shkoda'. His home town was Pilsen, Bohemia, where the famous Czech armament works is situated. 'Škoda' means 'damage,' and 'what a pity!'

Auenbrugger did not require a hammer. With fingers held straight, the thorax was to be thumped directly—a fine, yet somewhat coarse way, most effective, no doubt, on rather bony chests, to be covered with a shirt 'drawn tightly', the doctor's hand sheathed with a glove 'made of unpolished leather', to prevent the slapping noise of skin clashing with skin.[3]

Auenbrugger's direct, or 'immediate', percussion, revived in France by Napoleon's personal physician, Corvisart, may have seemed quite refined. But it was to yield to even greater French sophistication twenty years later. Laënnec had meanwhile invented indirect or 'mediate' auscultation of the chest, and employed a gadget, the 'chestviewer' (the stethoscope). Now percussion, too, became indirect, or *la percussion médiate*. The book appearing under this title in 1828[6] described not one but two percussion instruments: a hammer and a resonator. The second of these, called the pleximeter, was the more important, according to the author. It was nothing but a small disk, usually of ivory, to be laid on the thorax and struck. Pierre Adolphe Piorry, the inventor of the disk, did not think the hammer was indispensable for getting a good 'mediate' percussion sound. As long as the pleximeter was used for a resonator, a finger might do the tapping. But he disapproved when 'several English and American physicians who honoured me with attending my lectures tried to simplify my procedure even further, using their left index finger as a pleximeter. It gives less sound', he sadly noted, adding that, 'M. Barry has used a slender rod of ebony, ending in an olive made of gold-beater's skin* and covered with leather . . . But this again is an additional instrument . . .'. Škoda in Vienna gave credit to a Dr. Wintrich** for a little steel hammer with a caoutchouc*** end, but Škoda made use of it 'only for teaching—to enable those standing farther away to perceive the percussion sound.'[2]

The source Piorry gives for the idea of a hammer takes us right back to the Vienna of Maria Theresa. For herself and her country the Empress had wisely appointed a Dutch doctor from Boerhaave's School in Leyden, practically the only clinical school of her day. Hence Gerhard van Swieten, one of Boerhaave's great disciples and commentators, became her intimate adviser. He was allowed, even encouraged, to revolutionize the Vienna medical faculty and the Austrian army medical service.[4]

Van Swieten's professional eminence emerges from Auenbrugger's preface to his own *Inventum Novum*, for it was, Auenbrugger continues, 'to his *commentariis* I had recourse in my difficulties, as containing everything which can be desired by the faithful observer of nature . . .'[3] Granted that the half-full wine barrel gave Auenbrugger his idea of percussing another semi-hollow object, such as the chest, perhaps a passage in van Swieten about the skull, too, may have shaped this trend in his mind. In any case, this passage from van Swieten's *Commentaries*[9] is the one that inspired Piorry (or Sir David Barry) to introduce the percussion hammer. Van Swieten in

* The serous outer coat of the bovine intestine which was placed for support between layers of gold leaf.

** Ebstein makes M. A. Wintrich of Würzburg, i.e. his fellow countryman, the only begetter of the chest percussion hammer around 1840. Piorry's M. Barry of 1828 almost certainly was Sir David Barry (1781–1836)[7] of London and Paris.

*** Caoutchouc, like the simultaneously discovered American Indian, was a mere oddity until the medical profession explored its possibilities in the 1750s, especially in France. From 1820 on, Thomas Hancock, an Englishman, began to manufacture rubber and make it commercially available.

turn gives his source: Johann Jacob Wepfer (1620–1695) of Schaffhausen, a Swiss doctor of the previous century, justly renowned for recognizing apoplexy as the result of a haemorrhage into the brain substance. In the collected material on intracerebral disease Wepfer had included his observation of how local cowherds were systematically hitting their charges' heads with a mallet, a diagnostic test followed by trephining when positive.[9]

Consequently, we owe the percussion hammer to helminthic parasites (such as the well-known echinococcus and cysticercus). They present themselves as intestinal worms, or as hydatid cysts, in various parts of the body of domestic animals and man. *Taenia multiceps*, now called *Hydatis Polycephalus Cerebralis*, causing *Coenurosis*, is less well known. This hydatid, too, gives rise to enormous cavities in the brains of cattle and sheep and may cause obstructive hydrocephalus. In man, where Pierre Marie has observed it (1913), it is extremely rare. Thought to be almost extinct, coenurosis again broke out among Swiss livestock in 1959.[10] 'Many strange, yet not altogether unmeaning terms are given to this disease, as the gid, goggles turn, turnsick, sturdy, giddy, dunt, etc.' an expert wrote in 1837.[11] The enlarging brain of the turnsick animal separates the bones of the skull at their sutures: percussion of the skull elicits what in pediatric practice is known as 'the cracked pot sound'.* To elicit the sound in children, a tap with the finger suffices; in cattle a hammer may well have been the thing.

When finding that upon percussion (Piorry read in van Swieten, who had read it in Wepfer) 'close to the horns some unnatural cavity is present under the skull, the Swiss cowherds immediately trephine the place just hit. They introduce a tube through the hole, attract the fluid (*spiritus*), and so empty the cysts (*vesicas*). If these lie near the brain's surface, the treatment is successful. If they lie deeper in the cerebral substance, there is no hope, and the butcher nearby sacrifices such animals'.[9] The Swiss peasants were actually doing no worse than Sir Astley Cooper, the greatest English surgeon of a century later: 'Much attached to the veterinary art . . . at his farm, near Hemel Hempstead, he used to take much pride in exhibiting a ewe which he had trephined on account of turnsick; and from whose cranium he had extracted a large hydatid. She afterwards brought him five or six good lambs', our veterinary expert of 1837 tells us. James Hogg, 'the Ettrick Shepherd', used the trans-sphenoidal approach. 'As I was frequently knitting stockings . . .' he wrote in 1807, 'I caught every sturdied sheep . . . and probed him up the nostrils with one of my wires . . . cured many . . .'.[11] In Scotland and England, and in sheep, they were making the diagnosis without the benefit of the hammer.

Also less gadget-minded than the Swiss cowherds, eighteenth-century clinicians saw no need for transferring this tool from veterinary neurosurgical practice to human internal medicine. (Besides, Auenbrugger's *Inventum Novum* was not yet being taken seriously.) It was left to Piorry and his nineteenth-century contemporaries to satisfy, somewhat reluctantly, a mounting taste for gadgetry. Today we do our mediate percussion of the chest again with our fingers, but for many decades the 'percussor' remained in the internist's armamentarium, where Professor Dr. Wilhelm Erb conveniently found it, ready to be converted into a 'reflex hammer.'

* Since Friedrich Betz, 1855, according to Ebstein[8]. (Not Vladmir Betz, of the cortical giant cell).

For a considerable time Erb had been noticing the quadriceps reflex: to be elicited 'either above or below the patella, but with particular assurance from the ligamentum patellae'.[11] Although he did not think the phenomenon was new or unknown in professional circles, the literature had remained 'almost completely silent' about it. Hence a short notice on this and similar *tendon reflexes* might not be amiss because of the frequency with which they occurred and the ease with which they might be elicited. But above all he stressed their diagnostic significance, not to be underrated because he found these tendon reflexes 'much more exquisitely brisk in many patients with diseases of the spinal cord'. Indeed they were more reliable than skin reflexes. Lest anyone had any doubt about that matter, he added that they certainly were not skin reflexes, for tapping an overlying raised fold of skin had failed to elicit them. Particularly in sensitive cases, the periosteum of the tibia lower down, not the skin, seemed to be the receptor. Direct tapping of the muscle made it contract, too. This, however, was an exclusively mechanical phenomenon, not to be called a reflex. To elicit reflexes he found the faradic current ineffective, too. Indeed, these reflexes were exclusively confined to the tendons, or perhaps the periosteum—almost any tendon accessible to the hammer, in fact. In the Achilles tendon the phenomenon must be allied to the ankle clonus, previously described in spinal disease by Charcot, and connected by Charcot with Brown-Séquard's 'spinal epilepsy'. Like the tapping, it was the sudden mechanical stretch of the Achilles tendon which produced the clonus, the proof being that plantar flexion of the big toe, i.e. passive relaxation of the Achilles tendon, was invariably capable of stopping the clonus. He agreed with Charcot's and Vulpian's correct explanation, given in 1862, for the self-maintenance of the clonus: a repeated lengthening and shortening of the tendon was caused by the examiner's continued dorsiflexion of the foot, maintained in opposition to spontaneous plantar flexion of the part. In a footnote he added his own parallel observation on the patellar clonus. As the most important question to be answered, Erb pointed to the spinal cord *levels* as presumably corresponding to the reflex arcs of the various individual tendon reflexes; these ought to be established.

Clearly, then, in 1875 tendon reflexes as a concept—if not as a casual observation—were new, while the reflex idea in general was not. Reflexes were a small piece of ground, won gradually during the centuries, in the struggle to push back the frontiers of the soul. Was the soul not the one and only ruler over man's entire behaviour?

Unencumbered by religious dogma and political absolutism, a pagan Hippocrates had felt free to say that 'nature finds by itself, and not by reasoning, the means of . . . winking the eyes . . . Nature . . . does all that is necessary'.[12] Yet Horace's Nature —'Go and drive her out with a pitch fork, she will come back promptly'—had first to be stood on her common-sense head. The next greatest doctor of antiquity, Galen, was already living in the early Christian era and perhaps monotheistically inclined. Respiration, Galen wrote, 'comes from the soul and not from nature, since the movement of muscles is an act of the soul . . . Although it is not possible to hold the breath for ever, one should not for that reason deny that it is voluntary . . .'. And he inveighed against the sophists who had done the denying. The eyelids, too, were 'evidently directed by our soul . . . It would be useless for us to have been given them by nature, if we could not voluntarily close our eyelids when an external object comes to strike or

damage the eye.' He had a point there, or at least half a point, and shrewdly he also considered some acts that seem involuntary to have a voluntary past: those automatisms we have learned through training.[12]

It would be easy to blame Christianity for trying to keep out reflex action and give all motor acts to the soul: yet this view was also held by Aristotle. But the psyche of antiquity and the medieval soul were two different concepts. Aristotle could describe—if not fully acknowledge—a reflex when he saw one.[12] Jean Fernel (1506–1588), a French Renaissance physician, revived the idea of the involuntary nature of the respiratory and the blink reflex.[13] It took another forgetful century for it to take hold. René Descartes, by no means a renegade from the Faith, established a bastion for the concept of reflexes: did not even a friend's hand coming too close to your eyes without warning make you blink?[12] The soul had to reckon with a powerful new rival, better organized than the biblical 'flesh'. As light was 'reflected' from an object and thrown on the retina, so the animal spirit* too, was reflected from the seat of the sentient and volitioning soul (the pineal gland in the centre of the brain) to the nerves and muscles. For both kinds of nerves, already recognized as motor and sensory by Galen, ended in, or issued from the brain.[12] That lesions of the spinal cord could paralyze the limbs had also been known to Galen. But only Willis[14] spoke of the 'sympathy' between the parts and the need for nerves to intercommunicate. And only Winslow[15] compared the sympathetic ganglia to little brains.

Now neatness in the development of ideas would require the discoverer of the light reflex to side with the physiological *avant-garde* of his time. But Robert Whytt, who was that discoverer, did not. In the dispute between the conservative Calvinists with their tenacious animal spirits, and Haller's revolutionary, sweeping, utterly decentralized concept of a *vis nervosa* and a *vis insita* (a power inherent in muscle), Robert Whytt, sided with the defenders of the soul.[16] To him, still or again in 1751, 'the involuntary motions in man are not owing to a principle distinct from the rational mind'. With a nice English sense of compromise he does concede, however, that when a *stimulus* (his term) becomes too strong we lose all previous power over the muscle. Hence, involuntary motions, yes, mechanical laws like those operative in a balance, indeed; a 'sentient principle' rather than a rational one—he would concede that, too. Still, it is the mind which encompasses them all; the soul, 'immediately and without any exercise of reason, endeavours . . . to avoid and get rid of every disagreable sensation . . .'[12]

Also, whether we look into Descartes, Whytt, or any of their successors before the 1830s, their use of the word *reflect* and *reflex*, though taken from optics (i.e., physics), was almost entirely metaphorical. Even when Lallemand[17, 18] studied a live human anencephalic monster, or Legallois[19] his decapitated mammals, they felt the need for involving the soul, at the risk of having to accommodate it in the spinal cord.

Reflex function—part of the title of Marshall Hall's paper of 1833—we finally read, must not be confused with sensations or volition. It is 'characterized by being *excited* in its action, and reflex in its course . . . It appears probable that . . . this

* 'Animal' spirit, *spiritus animalis*, from *anima*, the 'soul' or 'mind', *pneuma psychikon* in Greek. Hence not 'animal' in the usual sense although, according to Galen, animals have it, too. (GALEN: *On the Natural Faculties*. Trans. A. J. Brock, New York, Putnam, 1916, pp. XXXIV, XXXV, 3.)

paper may lead to . . . an accurate inquiry into the origin, course, connection and distribution of . . . the nerves which constitute the arcs of the reflex function . . .'[12]

Reflexes so far had been only visceral and protective, provided by nature to safeguard the vital functions and to prevent instant damage. Before Hall nobody had introduced this impersonal product of stimulus and response into the workings of voluntary muscles. Only an occasional practical joker, with the edge of his hand, had hitherto directed a blow against an unsuspecting quadriceps tendon, and produced a funny involuntary kick. Possibly Marshall Hall may have known of the phenomenon. But he had been dead for eighteen years when Erb in Heidelberg made this single reflex one of the cornerstones of neurophysiology and clinical examination.

Was this truly one of Hall's prophetic reflexes? Did this knee-kick really implicate an anatomical reflex arc in keeping with his definition? Professor Westphal for one did not think so.

In the 1875 volume of the *Archiv* that gave its readers Erb's observations, in fact on the very pages following them, the yearbook's chief editor, Professor Carl Westphal, published a paper of his own.[21] Its title required an explanatory footnote. No wonder, for it read: *On some motor phenomena produced on tendons and muscles by mechanical means.* While preparing his own paper, Westphal tells us in a note that he had received the preceding article by Professor Erb. And to his astonishment he had seen that some of the facts reported by his honoured friend were almost totally identical with those he was about to publish himself. He deemed it necessary, therefore, to remark that already in 1871 he had become acquainted with the *Unterschenkelphänomen*, as he called it, and he had never ceased to follow it since. Visitors were frequently shown the phenomenon; no case record in his *Nervenklinik* was complete without it. Professor Heidenhain, to whom it had thus been demonstrated in 1872, had given his permission to be called upon as a witness. But Westphal also hastened to add his conviction, based on his correspondence with Erb, that the latter's observations had been made quite independently since 1870 and 1871, without any knowledge of Westphal's similar pursuits. Work on his forthcoming textbook had stimulated Erb to peruse his notes, and to publish his analysis now. Erb had agreed both to the wording of the above covenant, and the simultaneous publication of their papers.[21]

Simultaneous discoveries are common. But the exemplary, if guarded, courtesy and the fairness prevailing in this case are made even more noteworthy by the two papers seeing publication here side by side under the editorship of one of the discoverers. The only disagreement between knee jerks in Heidelberg and in Berlin was that Westphal—on thirty pages against Erb's ten—had to reject the view that the phenomenon was a reflex. In this, as it turned out, he was wrong. But he was right in refusing to believe in the essential role of the tendon at the receiving end of the reflex arc; the sensory receptors are in the muscle itself.

Westphal's opinion of a direct percussion effect on the muscle was most convincingly refuted three years later in a series of animal experiments and clinical observations conducted in du Bois-Reymond's 'new' physiological laboratory, and in Westphal's own Clinic at the Charité, both in Berlin. These observations were likewise reported in Westphal's *Archiv* by their young author, Sergei Ivanovich Tschirjew (or Chiriev), a Russian physiologist.[22] Chiriev's elegant work on the rabbit comprised four fundamental experiments:

(1) Cutting the femoral, i.e., the motor nerve to the extensor or quadriceps muscle of the knee. This abolished the 'phenomenon', or indeed, the reflex; it was not an 'idiomuscular' contraction, as Westphal had thought.

(2) Cutting the sciatic, i.e., the motor nerve to the flexor muscles of the knee at the back of the thigh—antagonistic to the extensor quadriceps. This enhanced the extensor reflex.

(3) Cutting the spinal cord at the level where the femoral nerve takes its origin. This abolished the reflex by destroying its centre.

(4) Cutting the cord above this level. This increased the reflex.

These last two experiments in particular confirmed Erb's prediction that the 'tendon reflexes' would allow one to establish the affected level in spinal cord disease. They also explained the difference in Westphal's findings, to the effect that in tabes the reflexes were abolished, whereas they were increased in other disorders of the spinal cord and brain.[22]

Westphal's merit, however, must not be belittled. He was showing both candour and good judgment when he admitted that a patient had drawn his attention to the phenomenon. He was a 'hypochondriac', true, but also a man with 'cerebral symptoms'; he had a spastic leg. 'Sitting on a chair and lightly tapping the region below the knee-cap, he [the patient himself] could make the affected leg slide forward with a sudden jerk'. Westphal noticed (but did not quite appreciate) that an affection of the 'lateral column', a hemiplegia, facilitated both the knee and the 'foot (ankle) phenomenon'. In the case of tabes dorsalis, on the other hand, it was absent; hence the posterior column of the thoracic and lumbar cord had to be intact for the phenomenon to be present.[21]

In 1875 Westphal was *ordinarius*, i.e., head of the Department of Internal Medicine at the Charité in Berlin. Wilhelm Erb, on the other hand, was still far from being titled *Geheimrat* and *Excellenz*, or considered as Germany's Duchenne and Charcot rolled in one, so to speak. Only thirty-five, and by seven years Westphal's junior, Erb was still an *extraordinarius*, or associate professor in Friedreich's famous Heidelberg clinic.[23a, b] His tiny office and laboratory could hold only half a dozen students; for lack of wall space he had to balance a blackboard on his knees. But with Duchenne's death in that year, Erb became the world's unrivalled authority on electrodiagnosis and therapy. He was to lay down a number of neuromuscular syndromes, including dystrophy and myasthenia, and to revolutionize thought on locomotor ataxia, or tabes dorsalis, by statistically linking it with syphilis before the discovery of the spirochete. His clear grasp of things, his thoroughness and authority, not devoid of rudeness, also helped to promote neurology to a fully-fledged specialty, distinct from both psychiatry and internal medicine. It is rather symbolic of his commanding position that he was the first man to wield a reflex hammer and to establish the 'tendon-reflex' as a basic phenomenon.

Amazing how the two companion papers of 1875 involuntarily complemented one another in giving a great deal of the essential clinical information about these basic reflexes. What their authors did not attempt to give—in fact were in no position to give—was the physiological background.

Erb, Westphal and their contemporaries of 1875 were still relatively ignorant about reflex action. They had to be content with only a very general scheme, based on

Marshall Hall's reflex arc, based in turn on Bell and/or Magendie's law, which went back to the early part of the century. Sensory impulses might enter a presumptive 'centre' in the spinal cord via one of the posterior spinal roots, and be 'reflected' there on to the anterior spinal roots. But how to prove this postulated continuity between nerve fibres? And where did the nerve cells come in? For a few decades cells were known to exist, besides fibres, but so far the twain had hardly met. Microscopic support for such speculations was scanty and therefore reluctantly given by responsible microscopists. One of them, Otto Friedrich Karl Deiters,[24] a victim of typhoid fever at the age of twenty-nine, left a brilliant monograph, published two years posthumously in 1865. No one had been better able to advance the evidence than axon cylinders originated from nerve cells, that they were the essential core of the nerve fibres, and arranged contiguously rather than in continuity. But the evidence was still hard to confirm, even for the anterior horn cells that give rise to the fibres going to the muscles. In an article immediately preceding his paper on tendon reflexes, Erb expressed the current knowledge of anterior horn cell loss in poliomyelitis[25]—current then for a few years only. The idea of neurons and their hair-breadth contiguity was yet to be confirmed, the synapse yet to come. As late as 1906 when Golgi and Ramon Cajal both went to Stockholm to accept the Nobel prize, they were taking the controversy along with them.[18] In that year Sherrington's *Integrative Action of the Nervous System* was published. It contained every conceivable experiment to elucidate the nature of reflexes, and the reflex nature of the nervous system. The neuron theory allowed one to view the nervous system as a giant assembly of interrelated and integrated contacts and relays, clutches, switches and shunts. Now there also came an answer to the quest for the incoming limb of the 'tendon' reflex arc. Gowers and others had come to call it 'myotatic', a muscle stretch—not a tendon-reflex.[26a] Sensitivity of muscles, already an Aristotelian concept, had exercised the minds of early nineteenth-century physiologists from Charles Bell (1811) to Ernest Heinrich Weber (1846).[26b] But what were the required nerve endings by which the muscle might 'know'—and let it be known to the spinal cord—that it had just been stretched by a reflex hammer and now must briefly contract?

For forty odd years microscopists here and there had noticed some spindly objects lying between muscle fibres. These, and their myelinated fibres, remained intact after cutting all the motor fibres to the muscle. At last the sensory muscle spindles were traceable to the posterior spinal roots. Here were the long suspected organs for 'muscle sense', a sense with a difference, practically unconscious, 'reflex'.

Erb and Westphal had hit upon the unique spot in the body where scientific purity and simplicity reign because only two neurons are involved in the reflex. They had struck a source of untapped knowledge—knowledge that previous generations of physiologists would have found useless. The source turned into 'a sea of names and claims',[27] a flood of reflexes, none of them in itself directly useful to the human body, but useful in diagnosis. 'Segmental reflexes as such exist only in the doctor's office', Paul Hoffman wrote in 1924[28]* (and he might have added that they do not establish

* He was not the author of 'Hoffman's sign', or reflex. Nor, strictly, was Johann Hoffmann (1857–1919), successor of Erb, (also known for Werdnig-Hoffmann's disease); although he taught the sign to his assistants, it was not he, but one of them who published it. (See 28a).

a diagnosis.) 'Dorland lists nearly two hundred and fifty... Seventy-six new pathologic reflexes were described in the period from 1918 to 1935 . . .'[27] Today fewer than half a dozen are of actual interest beyond those Erb had thought of in his original paper. To elicit them has in itself become something almost 'reflex'. They are an integral part of the 'work-up', suggesting those mysterious hammer blows successively delivered to the undercarriages of stationary trains by railway men.

Together with chest percussion and 'the open season for the "Hunting of the Reflex" ', with competition between authors and manufacturers, the hammers began to proliferate. Their shape really matters little. Austin Flint, the American heart and lung expert gave a list of five 'chest percussors' in 1856. We get 'Trousseau's (of Paris) slender rod of whalebone, with a conical piece of caoutchouc' vying with Bigelow's (of Boston) 'ball of worsted covered with velvet', and Marsh's (of Dublin) 'stethoscope with an India rubber ring surrounding the ear piece'.[29] Laennec had used his stethoscope for direct percussion of the chest.[6] Gowers, the great neurologist at Queen Square, used his for tapping the tendons*; there Dr. Purves Stuart also excelled with a hammer made of gold.[30] Some hammers resembled all manner of miniature medieval weaponry: halberds, battle-axes—symbols all of the fight against disease and disorder; magic wands, T-shaped, L-shaped and ball-shaped; tipped or girded with elastic rings, some constructed even as universal tools. Duplex, triplex and multiplex hammers, with joints and screws providing means of pricking, tickling, and measuring distances between points of stimulation.

Warren Plimpton Lombard, an early Harvard investigator of the 'knee-kick', advocated complex mechanical suspension methods for the extremity, to gain a more accurate insight into the variable phenomenon. He also used an 'instrument with rounded edge which is considerably heavier than the ordinary percussion hammer... Improvements of this method', he added, 'will readily suggest themselves . . .'[31] Just such an improvement (on an earlier, smaller model, vintage 1858, by Vanon) was presented to the percussing world in the 'considerably heavier' shape of the famous 'Queen Square' hammer. In that London Mecca of neurology, around 1925, Dr. Critchley remembers, a Miss Wintle, alias 'Sister Electrical' (she was the head nurse in charge of physiotherapy and radiology) 'hit upon the happy device of fitting a ring pessary to a solid brass wheel, and mounting this upon a stick of bamboo. The result was a heavy, springy, and completely painless hammer . . . For years she made these herself . . . and sold them to post graduate students at four shillings each ($1 then), 2*s.* 6*d.* for resident medical officers . . .'. Commercially available now and more expensive, they are a badge of the ultra-sophisticated practitioner of the art, 'most efficient in eliciting even sluggish jerks in babies as well as adults'.[30] For in the very young, the very old, the tense and the self-conscious, these reflexes may be inhibited or suppressed. To suppress them voluntarily is not even 'extraordinarily difficult', as Erb wrote, while the opposite indeed is, as Sherrington remarked: 'I cannot by any effort of my will evoke my knee-jerk.'[32]

Jendrassik of Budapest got around that difficulty within the first decade of the scientific 'knee-kick.'

* A 'stethoscope, hammer and pleximeter in one piece', for the chest was created by Waldenburg in 1870. (Ebstein, 1913)[7]

I use my experience, [he wrote,] according to which the tendon reflexes, and the knee phenomenon in particular, become considerably enhanced when great strength is produced with the remaining muscles of the body . . . The individual in case, who had no knee phenomenon by ordinary method, I set on the edge of a table with legs as relaxed as possible [*sic*] and, while I tap [*sic*] his patellar tendon, I request that he hook together [*in einander auszuhängen*] the flexed fingers of his right and left hands [*sic*] and pull them apart as strongly as possible *with his arms extended* forward.[33]

The passage suggests some of the no-nonsense attitude of the classical neurologist, especially one with Central European training, against a background of suspect individuals, shirkers, malingerers, and slackers, lurking everywhere. Under the doctor's stern, threatening scrutiny, even the table legs in his office seem to go limp as he goes to work with his hammer.

While neither reflexes nor hammers in themselves were much newer than pitchforks, they helped in the construction of a new edifice: the functioning nervous system as an assembly of interdependent and hence variably active reflexes, each one inhibited or enhanced by others. 'How delicately variable' Sherrington exclaimed over the knee-jerk.[32] Still it must be classified with the 'unconditioned' variety of reflexes. When Pavlov introduced his 'conditioned reflexes', the ultimatum of the eighteenth century was reiterated: man must give up his soul and surrender to the idea of man the machine, to 'reflexology', and so on to the feedback and cybernetics. Some patients even wonder whether the reflex indicates their sanity, as it is known to be lost in general paresis of the insane. Yet between percussion below the knee cap, and sanity, there still is a long stretch of the imagination. Mind and reflex remain difficult to relate. For the student of the reflex the difficulty is as great as it is for the person who notices the effect of a blow on his patellar tendon. But for the opposite reason: the 'subject' does not feel that any reflex is taking part in his immediate experience, and the experimenter cannot see mind taking part in reflex action. To the person looking from the inside out—in 'conscious' awareness—a mechanical analysis of this awareness makes no sense; to the experimenter, looking from the outside in, nothing else does.

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