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The power of torpedo fish as a pathological model to the understanding of nervous transmission in Antiquity

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Abstract

The torpedo effect was known long before electricity was discovered. How was it explained? In early accounts on the subject, Émil du Bois-Reymond found remarkable observations and hypotheses. In Antiquity, zoological interest is illustrated by Aristotle and followers, who were intrigued by torpedo's behaviour and capacity to act from a distance. Alexandrian physicists were more interested in the propagation, as for light, of its effect in matter, conceived as either corpuscular or continuous. The theory of nervous action is linked to these conceptions and separated in various hypotheses among which that on qualitative alteration. However, the medical approach of toxicology takes over this debate and brings back torpedo's property in the frame of pathology. ***To cite this article: A. Debru, C. R. Biologies ••• (••••).***

Résumé

La torpille, un puissant modèle pathologique pour la compréhension de la transmission nerveuse dans l'Antiquité. L'effet de la torpille était connu avant la découverte de l'électricité animale. Comment l'expliquait-on ? Émil du Bois Reymond trouvait dans les témoignages anciens des observations remarquables et des hypothèses oubliées. Dans l'Antiquité, l'intérêt zoologique est illustré par Aristote et ses successeurs, intrigués par le comportement de la torpille et sa capacité d'agir à distance. Les physiciens alexandrins se préoccuperont d'avantage à son sujet, comme pour la lumière, de la propagation dans une matière conçue comme corpusculaire ou continue. La théorie de l'action nerveuse s'y rattache, partagée entre plusieurs hypothèses, dont celle de l'altération qualitative. Mais elle cède à l'approche médicale de la toxicologie, ce qui ramène la propriété de la torpille dans le cadre de pensée pathologique. ***Pour citer cet article : A. Debru, C. R. Biologies ••• (••••).***

Keywords: Torpedo; Electric chock; Animal electricity; Numbness; Propagation; Quality; Physiology; Poison; Pathology; Hippocrate; Aristotle; Galen

Mots-clés : Torpille ; Choc électrique ; Électricité animale ; Engourdissement ; Propagation ; Qualité ; Physiologie ; Poison ; Pathologie ; Hippocrate ; Aristote ; Galien

Torpedo fish has been a lasting subject of electrophysiological investigations. However, before the concept of animal electricity, how was the torpedo shock, long known to fishermen, understood? Emil du Bois-

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Reymond (1818–1896) was already interested in animal electricity when he went on writing his inaugural dissertation on the galvanic flux of the frog and electric fish. He wished to make clearer a field complicated with irrational speculations. His memoir was divided into two parts. The first necessarily in Latin, entitled *Quae apud veteres de piscibus electricis extant argumenta*, was dedicated to historical aspects [1]. The second part was scientific and written in German [2]. Du Bois-Reymond had a solid background in Humanities. He gathered many evidence from literary, philosophical and scientific sources on torpedo and its enigmatic power described in Greco-roman antiquity. He was pleased ancient descriptions did not show irrational elements and was astonished to discover that many observations had been forgotten until their recent rediscovery.

Ancients were interested by torpedo's power, its transmission to man and they often speculated on its property. What was it? How did it reach its target, how did it propagate? Torpedo's power also served to question theoretical aspects of the matter, the transmission of properties both in physics and physiology. How physicians explained the narcotic effect of torpedo fish? Following and extending du Bois-Reymond's memoir, we will trace back the zoological, physico-physiological and pathological aspects of these questions in Antiquity [3].

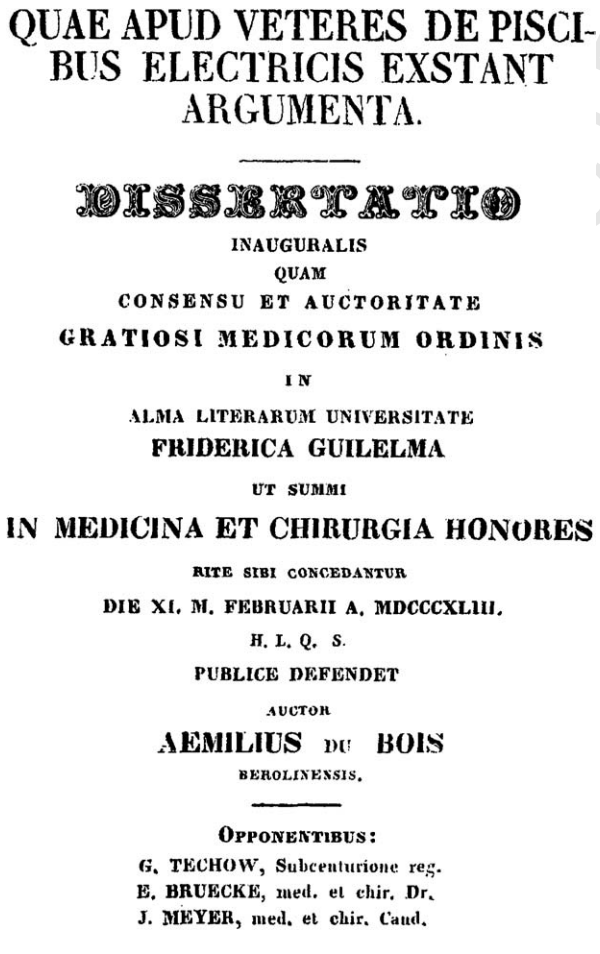
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Fig. 1. Title page from du Bois-Reymond's *Quae apud veteres de piscibus electricis exstant argumenta*, Berlin, 1843.

Torpedo fish was already mentioned in hieroglyphs of Egyptian rolls. It was known and feared from Mediterranean fishermen. The Greek name of torpedo, *narkè*, meaning numbness, indicates that the fish was known to produce such effect. Which of these two meanings, numbness or the fish' name, is the oldest? The name of the symptom comes from a verb meaning 'to numb' or 'to get paralyzed'. Homer describes a warrior falling, when hit by a stone: "his wrist was numbed. He fell on his knees and dropped his bow" [4]. A few centuries later, Hippocratic texts term pathological numbness '*narkè*'. The same word refers to torpedo fish, mentioned only for its particularly digest flesh. Thus, torpedo fish was probably named after the notion of numbness, because it was shown to produce it, as other animals and plants, some of which were toxic and similarly named by botanists.

The medical meaning of *narkè* played an important role in the interpretation of torpedo fish' power. In the Hippocratic Corpus (5th–4th century B.C.) *narkè* was described as an unpleasant sensation and a functional deficiency of body parts, such as head, belly, legs, arms, tongue and most often hands, or the whole body. Numbness is also mentioned for mind (*gnomè*). Associated sensations are heaviness, slowness, physical or psychic impotence. In many instances joint deficits were mentioned, such as "slowness of speech, numbness of hands", which are said to announce apoplexy, epilepsy, loss of memory [5]. If the clinical picture was detailed, the causes of such deficits are little discussed. Numbness is attributed both to the blockade of air, considered as the agent of sensation and movement, by the author of the medical treatise devoted to epilepsy [6] or to the blockade of blood flow by compression. Besides these explanations, numbness is associated with cold, especially in female diseases, since women are considered of a cold nature. The anaesthetic effect of cold water and numbness are well known: "A moderate numbness can stop pain" [7]. In case of severe headache, physicians prescribed to put head on a living torpedo fish, or on feet to fight gout, a use of animal electricity rediscovered by Faraday, according to du Bois-Reymond.

The most ancient mention of torpedo fish' power is amusing and mysterious. In Plato's philosophical di-

alogue, where Menon was embarrassed by Socrates, Menon says he feels his body and mind numbed, as those who approach and touch torpedo. Socrates replies he resembles torpedo only if the fish is itself numbed before numbing others [8].

The zoological interest in torpedo began with Aristotle and his systematic inquiry of animals. Torpedo was classified with other cartilaginous fish and its anatomy, reproduction, and most of all, its behaviour, described. When hidden in sand or mud, torpedo numbs fish 'swimming around' as it does with men who touch it [9]. This property was taken from observers as real and not myth or fantasy. The Greek writer Plutarch (1st century A.D.) described torpedo's strategy in a very interesting text. "Without attacking nor risking anything, it wraps its preys in a circle and sends a fluid straight which poisons first water, then the animal, by way of surrounding water, the fish being unable to defend, nor escape, being restrained as tightened by bounds or pierced" [10]. To du Bois-Reymond's great admiration, Plutarch also reports the common fishermen's experience of a shock being transmitted when water is poured on torpedo, as numerous observations in the 18th century confirmed it. Greek philosophers in favour of Providence organising Universe were impressed by torpedo. Stoics took torpedo's exemplary intelligence as a great animal faculty [11].

However, neither Aristotle, nor his followers, tried to explain physically or physiologically torpedo's power. They contended themselves with the fish 'power', 'capacity', 'property' (*dynamis*). The great naturalist Theophrastus may have associated torpedo's power with an abrupt coolness, in the frame of his analysis referring to hibernation [12].

In the Hellenistic period (3rd and 2nd century B.C.), sciences evolved with contacts between scientists, and exchanges between fields of enquiry. Mathematicians meet philosophers, astronomers, grammarians, technicians, architects, physicians, etc. There was a systematic use of dissection and vivisection on animal and sometimes humans. Scientists seek in its body an explanation of torpedo's power. Clearchus of Soles' lost treatise contained a long monograph dedicated to torpedo. Another Greek author, Diphilus of Laodice, is supposed to have demonstrated by various experiments the body part responsible for torpedo's property [14]. Unfortunately, these lost texts, only known by late citations, do not allow us to go further.

However, we perceive another important change. The explanation of torpedo's property in the field of zoology is asked in the context of ideas on the propagation and movement of an effect through matter. Is matter continuous or corpuscular? This fundamental debate was raised by first atomists, and held by Democritus in the classical epoch. It is again debated in Hellenistic period. Theophrastus' successor, the physicist Strato of Lampsacos, defended a corpuscular theory where each matter corpuscle is surrounded with interstitial empty spaces allowing elasticity and compression. One of the authors inspired by such view, Hero of Alexandria, both explains his own ideas and applies them to concrete questions. Interstitial empty spaces are demonstrated by mixing water and wine or the movement of light through air, water and matter. Torpedo fish is used here as a proof of the structure of matter. Du Bois-Reymond complains that he could not read the Greek text stating that "light even goes through copper, iron and all solid bodies, as happens with torpedo" [15]. On the contrary, according to a later testimony, "the Stoics say that the air is not composed of particles, but that it is a continuum which contains no empty space. If struck by a puff of breath, it sets up circular waves which advance in a straight line to the infinity, until all the surrounding air is affected, just as a pool is affected by a stone which strikes it. But whereas in this case the movement is circular, the air moves spherically" [16]. More than other philosophers, Stoics imported the question of propagation of action through matter in the field of living bodies. According to them, the soul was made of pneuma, a subtle air-like matter spreading in space through the limits of the body, as to the limits of the universe. While supporting continuous matter against supporters of discontinuous matter, they argued that transmission required contiguity. Sensation, as well as movement under the command of a hegemonic centre, was propagated by means of the pneuma. To illustrate these ideas, they used animal metaphors as that of spider or octopus.

However, Stoics were poor anatomists and their theories could not take into account new anatomical and physiological discoveries made in Alexandria. Those concerning experimentations on the nervous system, the central role of brain, the distinction between sensitive and motor nerves renewed conceptions on great body functions, and asked novel (?) questions. If nerves conducted sensation and movement from brain, how transmission occurred? Were nerves empty, as seemed the visual nerve? Did nerve carry pneuma, which was thought to be located in the cerebral ventricles? Or did they carry information another way? How?

Several centuries later, the great Greek physician Galen of Pergamon, also supporter of continuous matter, raises the same questions with three hypotheses on nervous transmission. First, nerves receive pneuma from brain, which rapidly flows in. Second, pneuma,

naturally occurring in them, is hit and moved by additional pneuma coming in from the brain, and the alteration is then transmitted as far as the moving members. The third is that sensation and movement are transmitted by "qualitative alteration". The first two hypotheses use a substance, while the last only uses a property (*dynamis*). He alludes to transmission of light for the last hypothesis: "The transmission of qualities to continuous bodies by alteration they call a flow of power, as when in the surrounding air some transmission of quality sets out from the light of the sun and reaches every parts of the air, while the actual substance of the sun remains in its place. I pointed this out in my treatise on *Demonstration*" [17]. The other directive analogy is that of the magnet, whose action was often under debate in Antiquity, since it raised two important physical problems: the existence of a faculty to attract in matter, and its corpuscular or continuous nature. Concerning the nervous transmission, Galen admits that he is unable to find the right solution: "I have no ready answer". However, he does not mention here the propagation of torpedo's power, which might have illustrated a "qualitative transmission".

In a parallel way, the same question was asked in the field of toxicology, which was important to physicians. The enigma of the power and propagation of poison or animal venom in the body fascinated society, political circles, and Roman medicine, which ignored blood circulation. Physicians were searching an explanation for the gap between a small local cause and a large immediate pathogenic effect. Galen envisaged two hypotheses: the release of venom from the animal, or the simple contact, with a propagation of the alteration. The sting of scorpion, or of any other animal, illustrates the first, torpedo the second. "I think that those who regard as unlikely a small quantity of humour contained in a part as a cause, when considerable symptoms occur in the whole body, do not keep in mind what is each day observed. After a bite from any venomous spider, the whole body is altered although a very small quantity of the venom entered by way of a very small aperture. The effect produced by the scorpion is even more surprising, since most violent symptoms suddenly occur: however, what is released when it bites is either very small, or even nothing, the sting does not seem piercing... Some physicians think that simple contact of some substances can, by the sole power of their quality, alter touched bodies." An example is the torpedo: "Such nature is encountered in torpedo fish; they possess so great a power that the alteration is transmitted through his trident to the fisherman's hand, which becomes rapidly numbed" [18]. After that, Galen reminds once again the power of the magnet. The hypothesis of noxious propagation best explains for him obscure affections as hysteria or rabies, which suggests that an element from the body becomes pathogenic by alteration. It transmits progressively its deleterious power to the whole body. To come back to torpedo fish, it appears that physicians saw it as a particularly powerful poisonous animal, while considering its narcotic action as an 'intoxication'. A supplementary proof is given by the framework of hypotheses elaborated to explain asphyxia by toxic gasses with wood fires or lime in enclosed spaces. Galen, taking advantage of the theory of asphyxia, feels that the cause is the bad quality of air and its qualitative alteration, and not its too tenuous texture, according to ideas of Erasistratus. In an imaginary dialogue, Galen wishes to invoke torpedo to explain this theory to his adversaries who ask for it: "But, they say, if you find fault with Erasistratus' explanation, tell us another. I reply: If you will first tell me how it is to be explained that we are numbed when we touch the sea-animal, the numbing fish. If you are unable to say anything, perhaps you will agree to my saying so much, that the numbing power of the animal upon those that touch it is so strong that the effect easily passes right through the fisherman's trident implanted in the fish into his hands. Now will you agree that there are certain qualities and powers, of which brings numbness, another torpor, another chilling, another putrefaction, and others some other ill, and you will nevertheless deny that there is any such power in air? They answer: We cannot clearly show what this quality and this power are". This difficulty brings Galen to abandon, while he recognises: "it is wrong to argue for or against anything from things that are unclear" [19]. The 'qualitative' effect of torpedo fish is too obscure to explain anything else.

However, a possible explanation seems possible. For this purpose, we must come back to narcosis, the way it was analysed in the Hippocratic period. With the progress of knowledge on the nervous system in Roman times, symptoms of narcosis are defined as "mixed dysesthaesia and dyskinaesia". The affection affects nerves or more broadly "nervous bodies". Or, under some circumstances, "the nerve prevents the faculty sent from the principle (brain) to reach it". That is what happens in "cooling and compression [...] and also to those who touch marine torpedo" [20]. For these last ones, cooling is rather the cause. The reason is that the specific symptom of narcosis, numbness, would be due to cold. When discussing the nature of pain, Galen denies narcosis as a type of pain. According to him, "numbness is nothing but an extraordinary cooling which alters sensation and movement of affected bodies, the same way

full loss of movement and sensation result from complete cooling".

Galen refers to those who travel in great cold and whose feet are frozen. Numbness by compression exists too, but is close to numbness with cold. Here, Galen is close to the tradition seen in Theophrastus' texts on hibernation. Numbness due to torpedo is explained by cold. Galen makes us think torpedo's power is due to a cooling faculty that explains its pathogenic action. This justifies, as we saw it, its therapeutic usage.

But what about the modalities of transmission? Does the extreme power of torpedo explain it? Why does not Galen apply explicitly his model on light transmission that he discussed at length? We may give several reasons. The question of qualitative transmission is raised in the field of nervous transmission. A first reason is that no animal is invoked to understand the nervous phenomenon. The two favourite examples are those of sun and magnet. Was torpedo too low level an example to illustrate the hegemonic centre, the soul? This is what is implied by the use of torpedo in the field of toxicology, where it appears together with spider and scorpion. The second reason is precisely the interest devoted to venoms and poisons in ancient Rome, to the questions on substance and quality, to effects more spectacular than nervous transmission. The texts on narcosis favour this view. Lastly, one could think the answer was already known. The 'cooling faculty' acting on nerves and nervous bodies seems appropriate to explain the narcosis effect of torpedo, the same way as that of vegetal or mineral drugs enriching important pharmacological speculations in those times. Torpedo went on as a lasting enigma between the fields of physiology, pathology, toxicology and pharmacology, as it played the role of a model in qualitative transmission. But its power put it on the side of pharmacology. The obvious framework that we studied and the availability of specific answers on torpedo's power prevented further enquiries into the physiology of nervous transmission. However, these brilliant hypotheses were finally forgotten.

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