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Article

The Idea of Science of Brazilian Physiologist Miguel Ozório de Almeida (1890-1953)

Letícia Pumar[1]

Abstract:

Epistemological considerations of philosophers and scientists from the late nineteenth century to the mid-twentieth century guided Brazilian physiologist Miguel Ozório de Almeida (1890-1953) in formulating his researches and participating in national and international scientific debates. With his siblings, Álvaro Ozório de Almeida and Branca de Almeida Fialho, he participated in debates on Brazilian educational and scientific system's reform and in international organizations. The family's residence in Rio de Janeiro housed a laboratory that became a reference in experimental physiology researches in Brazil. This article aims to present Miguel Ozório de Almeida's conception of science, constructed mainly within the private laboratory's sociability, providing new aspects of scientific work production in Brazil in the early twentieth century. I argue that Ozório de Almeida's stand as an internationalist physiologist in national and international contexts was related to his reading of texts by Ernest Mach, Pierre Duhem, Henri Poincaré and William James.

Keywords:

Miguel Ozório de Almeida; Experimental Physiology; History of Science in Brazil; Historiography of Science in Brazil; Epistemology; Internationalism

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A Scientist and his Bets

Scientists have doubts about their scientific practice; they also have certainties, or it would be better to say: bets.

Notes, drafts, articles and books written by Brazilian physiologist Miguel Ozório de Almeida (1890-1953) contain fundamental questions of a scientist who reflects on his practice: What is science? How is scientific knowledge produced? Why? By whom? These are epistemological and moral questions that followed the physiologist throughout his life. And they reverberate up to the present.

[1] Letícia Pumar is a Postdoctoral researcher at Federal Rural University of Rio de Janeiro – UFRRJ. Address: Program in History – Federal Rural University of Rio de Janeiro – Institute of Human and Social Sciences – PPG (prédio anexo) Br 465 – Km 7 Campus Seropédica – RJ Brazil – CEP 23.897-000. Email: leticiapumar@gmail.com

Along with these questions of a general character there are specific ones: How to make use of the reflections on physics and mathematics for the understanding of the biological world? How can one explain physiological phenomena such as breath, muscular movement, or nervous influx? What relation may be established between a differential equation and a complex physiological phenomenon such as the excitation of the nervous system? Faced with these questions, Miguel Ozório de Almeida rejected and reaffirmed positions and practices. He receded and reacted in disputes and controversies. He made bets.

Born in 1890, Miguel Ozório de Almeida graduated in medical studies in the early 20th century but worked as an experimental physiologist during his entire life. He taught physiology of domestic animals at *Escola Superior de Agricultura e Medicina Veterinária* (School of Higher Education in Agriculture and Veterinary Medicine); he was a member and president of *Academia Brasileira de Ciências* (Brazilian Academy of Sciences); member of *Academia Brasileira de Letras* (Brazilian Academy of Letters); and researcher (from 1927 to 1953) at *Instituto Oswaldo Cruz* (Oswaldo Cruz Institute).

Together with his siblings Álvaro Ozório de Almeida (who was a professor at the Faculty of Medicine of Rio de Janeiro) and Branca de Almeida Fialho, he actively participated in the debates on the reform of the country's scientific and educational system conducted by *Academia Brasileira de Educação* (Brazilian Academy of Education) and the Brazilian Academy of Sciences. They kept a private laboratory, set up with the support of a Maecenas, at their parents' home in Rio de Janeiro. The residence was a place of production of knowledge, training and meeting of the city's intelligentsia (Sanglard 2008). In the national context, they were engaged in the debate on the enhancement of the country's scientific research. They also sought to establish direct contact with scientists in other countries (especially France) and ensure the recognition by their peers abroad of the scientific knowledge produced in Brazilian laboratories. In their private laboratory, the Almeidas received French researchers Eugène Gley, Henri Piéron and Louis Lapicque for short stays, which resulted in scientific articles, some in co-authorship, and in extensive scientific debates between the Brazilians and the French (Pumar 2018, in print). In this laboratory, Álvaro Ozório de Almeida conducted his study on basal metabolism, which is cited by Georges Canguilhem in *Le normal et le pathologique* (*On the Normal and the Pathological*) as "one of the best examples" of the understanding of "basal metabolism in its relation to climate and race" (Canguilhem 2011, 111).

Miguel Ozório de Almeida was very active at *Instituto Franco-Brasileiro de Alta Cultura* (French-Brazilian Institute of High Culture) (created in 1923), and was indicated to give lectures under its auspices at the Sorbonne. He participated in several intellectual and scientific societies in Brazil and abroad; in 1933 he was granted the Einstein Prize by the Brazilian Academy of Sciences, and in 1936 he received the Sicard Prize from the *Faculté de Medicine de Paris* (Faculty of Medicine of Paris) for his work on the theory of excitation. He took part in the League of Nations' international project of intellectual cooperation in the interwar period (Pumar 2015); he participated in the creation of Unesco in 1946 and was one of the Brazilian candidates for the position of the Natural Sciences section's officer and director-general of the organization. He published three books of essays: *Homens e coisas de sciencia,*[2] 1925 (*Men and Issues of Science*), *A vulgarização do saber*, 1931 (*The Vulgarization of Knowledge*), and *Ensaios, críticas e perfi*s, 1938 (*Essays, Critics and Profiles*); one novel named *Almas sem abrigo*, 1933 (*Souls without Shelter*); the book of memories *Ambiente de Guerra na Europa*, 1943 (*War Environment in Europe*); and a physiology treaty (1937), besides several articles published in scientific and cultural journals, both national and international. The scientist was a great mathematician and a voracious philosophy reader, particularly of

[2] Translator's Note: Free translation of all titles of publications and excerpts from the writings of Miguel Ozório de Almeida, which use the Brazilian-Portuguese syntax and spelling of the early twentieth century.

epistemology issues. These characteristics marked the way he took part in the national and international scientific debates.

Experimental researches in phisiology in the nineteenth century were marked by the use of measuring instruments and data register. The so-called graphical method consisted of a technique of lines and curves production using sophisticated mechanical instruments that provided visual representation of phenomena in nature (Chadarevian 1993). The technique was considered a way to generate knowledge that was impersonal, not subjective and therefore more exact, mathematical, neutral. Apparatuses as the galvanometer (used to measure electrical current intensity) and the kymograph (used to measure muscle contraction time) became essential instruments in physiology studies, especially electrophysiology. These instruments enabled the visual representation of the phenomenon and the comparison with data collected by scientists elsewhere. Furthermore, experimental physiology in the first half of the nineteenth century sought to establish stable laws of life phenomena. The incorporation of the biological world to physics as a discipline was on the base of the considerations that the functioning of biological systems was determined by physicochemical processes. Therefore, the laws of physics (like thermodynamics, the law of gases etc.) could be on the base of the understanding of biological phenomena, providing suggestions for the definition of laws on biology.

Considering this context of appropriation of physics and mathematics by physiology, it is possible to frame Ozório de Almeida's approach within what Lorraine Daston and Peter Galison named "structural objectivity" (Daston; Galison 2007). Ozório de Almeida used mathematical models to think his researches on physiology, especially on the nervous system functioning. Experimental physiology became closer to physics and mathematics; at that moment, these disciplines were also undergoing changes that made them more attractive to physiology. Therefore, the new epistemological questions related to the production of mathematics and physics knowledge could and should also be thought to produce biological/physiological knowledge. This was one of physiologist Ozório de Almeida's bets (Pumar 2018, in print).

Epistemological formulations were part of his bets as a scientist, especially as a Brazilian scientist. I believe that Ozório de Almeida's readings of texts by Ernest Mach, Pierre Duhem, Henri Poincaré, and William James was related to his stand as an internationalist physiologist in the national and international context. Thus, I draw on the perspective that one can enhance the reflections of historiography of sciences in Brazil by thinking about what images of science are handled by the scientists under study and what are the impacts of these images on their scientific studies and institutional stands.

An Experimental Physiologist and his Epistemological Concerns

For a competition for the chair of medical physics at the Faculty of Medicine of Rio de Janeiro, in 1916, Ozório de Almeida prepared a presentation of his scientific works and the thesis *A lei de conservação de energia e a teoria energética do trabalho muscular* (The law of energy conservation and the energetic theory of muscle work) for the examining board's evaluation. The material presented a physiology research agenda that enhanced researches on "pure sciences" and sought to take the advances on physics and mathematics to biology by approaching authors like mathematician Henri Poincaré and physicists Pierre Duhem and Ernst Mach.

According to Ozório de Almeida, the aim of the presentation of his works was to show the contribution that since 1910 he had brought to the domain of science "either in the form of new facts or as original ideas" ("quer sob a forma de factos novos, quer sob a forma de ideias originaes") (Almeida 1916, 5). Curiously, the first section was "On the role of theory in biology" (*Sobre o papel da teoria em Biologia*).

Ozório de Almeida reported having been led to think about the role of theory in biology and physiology when presenting the nervous system basic functioning theories in a lecture at *Sociedade Brasileira de Neurologia* (Brazilian Society of Neurology), in 1914 (Almeida 1914). The uncertainties about this phenomenon and the various existing theories to explain it encouraged the reflection about what would a theory be and its role in scientific research.

The physiologist was critical about the existing notion in biological sciences that the objective of a theory was to provide an "explanation" showing what would be the intimate and real cause of the phenomena under study, i.e., evidencing reality. Drawing on studies by physicist Pierre Duhem and mathematician Henri Poincaré, Ozório de Almeida presented the idea of theory as a "representation". Considering the differences between biology, physics and mathematics, the physiologist affirmed that the fundamental core of this idea and its consequences could also be transported to biological sciences (Almeida 1916).

According to Ozório de Almeida, when theory was understood as an explanation of reality, it would be tied to metaphysics, i.e., to the individuals' phylosophical idea of reality and the exact conditions that would constitute the determinism of phenomena. He exemplified with Walther Nernst's theory of excitation, in which an equation (mathematical model) was formulated drawing on the idea that the phenomenon of excitation consisted essentially of changes in the concentration of certain ions in contact with membranes. If this theory (and this equation) would be taken as an explanation, i.e., that it presented what happened in reality, we would attest that our ideas about the vital phenomena were nothing but pure and simple physicochemical phenomena. However, a vitalist or a follower of Bergson's philosophy might accept Nernst's formula as merely representative of the laws of excitation but would not admit that excitation was solely the result of an ionic concentration, and would seek another explanation to represent reality according to his/her way of thinking (Almeida 1914).

With this example Ozório de Almeida demonstrated the flexibility of attempts to explain natural phenomena and stressed that most theories of biological sciences, in particular, had short life. According to him, the concept of theory in physiology no longer had the immobility of a pure explanation because unconsciously physiologists did not give theories the absolute value of certainty, but rather a relative character, one of probabilities. Since Claude Bernard, physiologists saw theories as relative truths destined to be modified over time and with the progress of science. Skeptical persons who proclaimed the failure of science were, therefore, based on the idea of theory as explanation (Almeida 1914).

Citing Henri Poincaré and Pierre Duhem, Ozório de Almeida stated that theoretical physics had been opposing this idea of theory as "explanation" to the idea of theory as "representation". Theory would be a system of mathematical propositions deduced from a small number of principles with the aim to merely "represent" a set of experimental laws. Therefore, theory would have the aspect of a classification: "Physical theory classifies experimental laws, i.e., it gathers the relations that exist between phenomena, revealed by experiments, in a set of propositions that condense them, ordering them in a harmoniously and natural manner" ("A theoria physica classifica as leis experimentais, isto é, reúne as relações existentes entre os fenômenos e reveladas pela experiência, em um conjunto de proposições que as condensam, ordenando-as de modo harmonico e natural") (Almeida 1914, 148). By assuming a "more modest role" to classify and represent a given set of experimental laws, without aspiring to attain reality, theory acquired freedom and autonomy, thus becoming independent from philosophy and metaphysics.

Ozório de Almeida thought that although physiologists realized the representative character of theory, they would not have deduced (as theoretical physicists had done) one of the most significant and useful consequences to the development of scientific research: the right to adopt more than one theory at the same time for the same set of phenomena, as far as those theories did not contradict the experiment. According to him:

> Theory is a simple image we make of a given group of phenomena; thus, nothing prevents us from, according to our spirit, our tendencies or even our commodity, addopting either that theoretical image or, according to the needs of the moment, using one or another theory, that are apparently incompatible. (Almeida 1914, 152)[3]

Theory would be a research method, a working instrument applicable to the discovery of new experimental laws, i.e., it would be an instrument of inspiration for new ideas:

> What is the utility of a theory when we deny its explanation value to consider it only as a representation? This utility consists of, on one hand, bringing the greatest possible economy of thought to the study, and on the other hand enabling to deduce new ideas susceptible of experimental verification. The economic role of theory was signaled and very well studied by Ernst Mach. In fact, theory enables coordinated exposure and methodical classification of a large number of facts and experimental laws, which if not related to one another by a logical link would greatly exceed the limits of intelligence and memory. The economic utility of theory is realized at its most when it establishes, as it often occurs, the proximity of facts and phenomena that would otherwise remain eternally apart, subjecting them to an identical representation. (Almeida 1914, 14)[4]

By becoming affiliated to the studies of French epistemology in the early twentieth century and to the studies of Austrian Ernst Mach, Miguel Ozório de Almeida deduced from their principles new practices for his work as a physiologist. It is noteworthy that he was a Brazilian physiologist, hence a scientist placed at a marginal position regarding the international physiology debate and a researcher who strived to gain space for his discipline within the national context. This perspective is made evident in the scientific works produced by Miguel Ozório de Almeida.

Soon after his presentation of theory's role in biology, Ozório de Almeida delivered his article on the theories of the nervous system basic functioning, which had set out his advocacy of Poincaré's and Duhem's conventionalist ideas application to general biology and especially to physiology. The aim of his article was to examine those theories and verify if they were legitimate (if there was no well-established experimental fact that would contradict them) and sufficient (if they represented all facts known then) (Almeida 1914).

The way the scientist presented French physiologist Louis Lapicque's theory of the nervous system functioning and its potential to stimulate new researches demonstrates his early interest in the subject, which later became a project to formulate a theory of excitation that was carried out until the end of his life. The relation between theory and experiment and the role of theory in knowledge production based Ozório de Almeida's way of conducting this project, in a period when Lapicque's theory started to be criticized, because of a

[3] "A theoria é uma simples imagem que nós nos fazemos de um determinado grupo de fenômenos; nada nos impede, pois, que segundo nossa forma de espirito, nossas tendências ou mesmo nossa comodidade, adoptemos ou aquella imagem theorica, ou ainda que segundo as necessidades de momento lancemos mão de uma ou de outra theoria, na sua apparência incompatíveis" (Almeida 1914, 152).

[4] "Qual é a utilidade da theoria desde que lhe negamos o valor de uma explicação para consideral-a apenas como uma representação? Essa utilidade consiste de um lado em trazer para o estudo a maior economia possível de pensamento, de outro em permitir a dedução de ideias novas suceptiveis de verificação experimental. O papel econômico da theoria foi assignalado e muito bem estudado por Ernst Mach. Com efeito, a theoria permite a exposição coordenada e a classificação methodica de grande numero de factos e leis experimentais, que se não fossem ligados uns aos outros por um laço logico, de muito excederiam os limites da inteligência e da memoria. A utilidade econômica da theoria se faz sentir ao máximo, quando, como frequentes vezes se dá, ella estabelece a aproximação de factos e fenômenos, que de outro modo ficariam eternamente afastados, sujeitando-os a uma representação idêntica" (Almeida 1914, 14).

movement of changes in the understanding of the nervous system by studies on the chemical transmission of nerve impulses and of the constant specialization of biology.

Another aspect highlighted in the material handed by Ozório de Almeida for the competition was the value of mathematics to biology studies. His thesis "The law of energy conservation and the energetic theory of muscle work" constituted an attempt to apply the principles of thermodynamics in physiology. His aim was to establish a theory of muscle work with the definition of equations that sought to represent the phenomenon and that could "agitate and indicate new problems that will require new researches" ("agitar e indicar novos problemas que exigirão novas pesquisas") (Almeida 1916b, 96). This behavior towards a research theme demonstrates the practical implications of incorporating the epistemological principles that he assumed.

Miguel Ozório de Almeida used mathematical models as a research instrument, with the purpose of finding new facts and relations between phenomena that had not yet been thought about. He also presented equations as models that could be used in different hypothesis to explain a complex phenomenon, such as the functioning of muscle work, which did not have, yet, a precise and well-defined theory to explain it.

The material presented by Ozório de Almeida to the examining board was dense and its character could lead us to consider it as the scientist's "research agenda" for his work as researcher/professor at that institution. However, his research agenda – perhaps, precisely for being formulated the way it was – did not enable him to win the competition. The chosen one was Francisco Lafayette Pereira, who had presented the memory *Fenômenos de ressonância* (Resonance phenomena). Contrary to Ozório de Almeida, in his presentation Lafayette stressed that he had sought to describe those phenomena with the least possible use of mathematics, since "with some development, it has little use in a work of MEDICAL PHYSICS" ("ella, com certo desenvolvimento, pouca cabida tem em um trabalho de PHYSICA MEDICA") (Pereira 1916,1). And he completed: "In general, we always follow the explanations of the masters on the subject, giving our humble personal opinion in one or another case" ("Em geral, seguimos sempre as explicações dos mestres no assumpto, dando para um ou outro caso a nossa humilde opinião pessoal") (Pereira 1916,2).

The two candidates had quite different stands and this probably weighed in the final decision of the selection. Most likely, being rejected was a great personal failure, but his "agenda for biology" was aligned with the ideals of scientists who demanded new spaces for science in Brazil and that, in that same year, created the *Sociedade Brasileira de Ciências* (Brazilian Society of Sciences), later named *Academia Brasileira de Ciências* (Brazilian Academy of Sciences), and participated in the *Associação Brasileira de Educação* (Brazilian Association of Education).

Having been classified in second place in the competition, in that year of 1916 Miguel Ozório de Almeida became associate professor in biological physics. One year later he became a member of the Brazilian Society of Sciences and was invited to be a professor of domestic animals' physiology at *Escola Superior de Agricultura e Medicina Veterinária* (School of Higher Education in Agriculture and Veterinary Medicine). In 1927, he assumed on a regular basis (after a short period in the institution in the early 1920s) the laboratory of physiology at *Instituto Oswaldo Cruz* (Oswaldo Cruz Institute – IOC); he worked in this institution until the end of his life.

Since the nineteenth century, both in Europe and in Brazil, confidence in science and its "civilizing mission" increased. In this context, the creation of scientific institutions in Brazil was marked by the defense of science as knowledge useful to the nation's material and moral progress. The positivist ethos propagated the belief in science's capability to present effective solutions to Brazilian problems, thus engendering the material and cultural progress of the country (Ferreira 2008). Several studies demonstrate how scientists appropriated themselves of the role of intellectuals and started to think of solutions for the nation (Lima; Hochman 1996 and 2004, Kropf 2009). In the turn of the nineteenth to the

twentieth century, scientists also advocated the differentiation of their activities in relation to literary and encyclopedic practice, which had prevailed in the country's intellectual activities up to that time. This generation strengthened the idea that the country had no original science up to then because of the bookish character averse to science that was typical of the prevailing Portuguese heritage (Sá 2006).

Scientific activities, especially biomedical, in the first decades of the twentieth century achieved recognition due to the capability to resolve Brazilian society's specific problems. This "pragmatic" sense of science was one of the pillars of the institution in which Miguel Ozório de Almeida developed his career as a researcher: Oswaldo Cruz Institute, created in 1900 to produce serum and vaccine against a bubonic plague epidemic. According to Nancy Stepan, however, the efforts to create the conditions to develop science associating its "applied" objectives to the perspective of actively contributing to the advancement of knowledge, in alignment with the international scientific agenda, were crucial for the survival of the Institute and its significance as a landmark in the institutionalization process of Brazilian science (Stepan 1976; Kropf; Hochman 2011). It is with the creation of the Brazilian Academy of Sciences (1916) and the Brazilian Academy of Education (1924) that occurs the strengthening of arguments in favor of a "disinterested" scientific production and the cultivation of "high culture" and "pure science" in the country.

In general, historiography has demonstrated that Brazilian scientists have not passively appropriated methods, theories and techniques from international science, but rather produced new knowledge on local issues, such as the so-called national or tropical diseases, or the use of local flora. The originality of the production achieved in the country was highlighted by contemporary scientists as a strategy for the legitimization and enhancement, in the national and international contexts, of the scientific knowledge they produced. When producing knowledge on local themes that had public utility, scientists received support and acknowledgment within the national context. On the other hand, when publishing in international journals their knowledge of local issues, that very singularity reached the international sphere. Besides works that sought solutions to local problems, many researches were significant for the international agenda because they provided advances to a given field of knowledge. In the case of tropical medicine, scientists like Adolpho Lutz and Carlos Chagas are examples of researchers who succeeded in enhancing national and international dimensions in their scientific work produced in the country (Benchimol 2007, Kropf 2009).

Miguel Ozório de Almeida's trajectory presents another formulation about the ways of thinking local production internationalization: the production of new knowledge in the country not only provided the possibility of progress in a field of knowledge internationally established, but also led to the re-signification of certain laws and experimental hypotheses of international science that could generate new hypotheses and new theories. Drawing on the conception of theory as representation (and not explanation) and the use of mathematical models, Ozório de Almeida made a point of questioning the canons of the field of knowledge he was studying. In his own words, he sought to produce "original ideas" in the field of experimental physiology, rather than only new facts. This stand, marked by his epistemology readings, had great significance at a moment of debates about the country's scientific production. It was an attempt to internationalize knowledge produced in the country not for its singularity ("new facts"), but for its universalizability ("original ideas").

An Image of Science

In the scientific diffusion texts published by Ozório de Almeida throughout his life, he currently used E. Mach's "economy of thought" concept. He identified science's objective as the creation of an economic representation of what was factual and not as the explanation of the mechanisms of a given reality per se. The use of mathematical models by Ozório de

Almeida in his physiology practice was related to his idea that these would be useful instruments for the concise formulation of observations and could save energy during scientific activity. As mentioned before, Ozório de Almeida was also a follower of French Poincaré's and Duhem's epistemology. It is noteworthy that these authors rejected the classical idea of science, condemned the inductive method and the idea of "crucial experiment" that would explain a phenomenon. They criticized Auguste Comte's positivism, but instead of totally rejecting it, they sought to "renew" it. And they defended the need to formulate theoretical definitions and to provide a good use to hypotheses, seen as a mix of empirical and rational elements (Brenner 2003).

Highlighting the role of decision (or "convention", to use Poincaré's term), these French authors pointed to a reflection about scientists' freedom and responsibilities during experimental researches. The fact that scientific laws were seen as conventions did not mean that they were arbitrary. They questioned the raw fact of empiricism drawing on an approach according to which empirical facts existed due to research hypotheses with a conventional character, i.e., resulting from a collective decision mediated by a common language, thus arising from given rational and empirical elements. Every experiment would promote a generalization that would enable prediction and the establishment of laws. Generalization was made through a common, conventional language whose criterion was to be the most "comfortable". Thus, only the relation, expressed in a conventional language, between empirical facts counted. Truth and objectivity criteria were questioned and seen in a more dynamic way because there would no longer be a comparison between theories and so-called "exterior" facts, nor was there a belief that truth was occult in the facts. Therefore, there was a non-definitive conception of laws and experiments in relation to reality (Gattinara 1998). From positivism they kept the criticism of the search for ontological (metaphysical) questions and the explanatory character of science. They defended the idea that science was the knowledge only of laws and not of causes of phenomena. Science would thus analyze phenomena to discover effective laws, constant relations and not to know their intimate nature. Instead of explaining the phenomenon, the scientist should make a description and a deduction of a law that would represent it. Science would be a system of relations that did not intend to know the true nature of things, but rather their relations. And it would be only in these relations that scientific objectivity (and a certain invariability) should be sought (Poincaré 1995, 165).

In the preface of his first book, published in 1925, Ozório de Almeida warned his readers:

> Apart from some repetition, it would not be difficult to find in these pages, with some patience, more than one contradiction. I did not go through the work of eliminating them, cleansing the book of something that alarms many people. [...] But the contradictions to be found are more apparent than real. They are not from the realm of basic contradictions that at short intervals assert antagonist and incompatible things. They merely denote a thought in movement, in evolution, and arises from the need to fix it at a certain moment in an unstable and transitory position. (Almeida 1925, 7)[5]

[5]"Alem de algumas repetições, não seria difficil, com um pouco de paciencia, encontrar nestas paginas mais de uma pequena contradicção. Não quis dar-me ao trabalho de eliminal-as, expurgando o livro de uma coisa que assusta muita gente. [...] Mas as contradições a serem levantadas são mais aparentes que reaes. Ellas não são da ordem das contradições básicas, consistindo em asseverar a pequeno intervalo coisas antagônicas e incompatíveis. Ellas denotam tão somente um pensamento em movimento, em evolução, e provêm da necessidade de fixal-o em um dado momento em uma posição instavel e transitória" (Almeida 1925,7).

The author's warning demonstrates the difficulty in trying to define his position regarding significant epistemological questions. However, it is possible to highlight some themes and tendencies that constantly appear in his texts and that mark the author's concerns, studies and writings about the functioning of science and the scientist's activities.

In an article later edited as one of the 1925 book's chapters, Ozório de Almeida stated something that became one of his greatest concerns as a man of science:

> The true man of science often becomes more interested in the way to achieve knowledge than in knowledge itself. William James has already shown this point: for him, the professional of a science is the one who cultivates its methods; the amateur is the one who cares for results only. (Almeida 1925, 92)[6]

Therefore, the definition of what would science be, how do men of science act and what is their role are frequent questions in his articles.

The idea of a genius in science appeared in several of Ozório de Almeida's writings as, for example, an article about Louis Pasteur. According to the author, Pasteur based his discussions on facts and his adversaries sustained ideas imposed by tradition. Hence Pasteur incarnated the ideal of a genius with his moral qualities:

> His belief in the value of science, of which he never doubted, his assured intuition of the experimental method, his courage and self-confidence in facing problems that would arise, and the unshakeable will, the energy in fulfilling his duty, the submission to self-imposed discipline never abandoned him. (Almeida 1925,32)[7]

The qualities that Ozório de Almeida explained in detail in his text became associated to the very ideal of scientist, of a good scientist. This issue appeared in many other articles, for example, *O sábio* (The scholar). According to the scientist, scholars had qualities and imperfections; however, they had a characteristic of "great respect for truth and absolute honesty" ("grande respeito pela verdade e uma honestidade absoluta") (Almeida 1925,68). Honesty was crucial in the day to day of research at the laboratory:

> Errors may arise from technique failure, to be sooner or later discovered; they may appear and unfortunately they do appear very often in interpretations, but they are never the expression of a conscient and intentional will to alter the truth. Oh! This inexorable truth! What sacrifices it imposes to vanity, to self-confidence! What humiliation it makes one suffer! (Almeida 1925, 68)[8]

Another scientist whom the physiologist called a genius was Claude Bernard. Based on his thoughts, Ozório de Almeida criticized the attempt to build any kind of system that would comprehend the scientific practice. For Bernard, experimental medicine was not a new

[6] "O verdadeiro homem de sciencia acaba quase sempre mais interessado pelo modo de chegar ao conhecimento do que pelo conhecimento propriamente dito. William James já mostrou esse ponto; para ele o profissional de uma sciencia é o que cultiva os seus methodos; o amador é o que só quer saber dos resultados" (Almeida 1925, 92).

[7] "A sua crença no valor da sciencia, da qual nunca duvidou, a sua intuição segura do methodo experimental, a coragem e a confiança em si para enfrentar os problemas que se lhe deparassem, e a vontade inabalável, a energia no cumprimento do dever, a submissão à disciplina por ele mesmo estabelecida nunca o abandonaram" (Almeida 1925, 32).

[8] "Os erros podem provir de defeitos de technica, cedo ou tarde descobertos; podem aparecer e infelizmente aparecem com grande frequência nas interpretações, mas nunca são a expressão de uma consciente e intencional vontade de alterar a verdade. Ah! Essa inexorável verdade! Que sacrifícios ella impõe á vaidade, ao amor próprio! Que humilhações ella faz sofrer!" (Almeida 1925, 68)

system of medicine, but, on the contrary, the negation of all systems. Drawing on this citation, Ozório de Almeida criticized positivism for repealing the philosophical systems, but, ultimately, creating another system. According to Ozório de Almeida:

> He (C. Bernard) could thus establish not a system, not a rigid set of principles, but rather an example of extreme purity of reciprocal reactions of these two sorts of things: human intelligence on the one hand, and nature on the other. His effort was to distance as much as possible all obstacles that separate these two worlds and facilitate reciprocal and increasingly intimate penetration. And this might be the fundamental character of C. Bernard's work, which renders it the gift of perenniality. Undoubtedly, science's path has taken research to unsuspected fields in C. Bernard's time. These fields are very complex and the principles established half a century ago need retouching in many points or even a vast broadening. These changes, though, do not alter the fundamental character of C. Bernard's work. (Almeida 1925, 147-148)[9]

In several articles the physiologist attempts to define science as what would seek to study the phenomena, "establishing, as thoroughly as possible, the conditions in which they happen and determining the relations between them" ("estabelecendo tão rigorosamente quanto possível, as condições em que eles se passam e determinando as suas relações entre si") (Almeida 1925, 115). Science would not seek to research the reality behind the phenomena. Scientific theory, thus, would not be destined to give a real explanation of the phenomena, but would only intend to create an image that would represent them more clearly:

> It is a simple construction, which corresponds to the needs of our spirit, but does not intend to present itself as an expression of reality. Thus understood, scientific theory did not lose its value at all. The loss for having been an object of belief was largely compensated by the gain achieved as a working instrument. (Almeida 1925, 115)[10]

According to Ozório de Almeida, criticism to science came from those who did not know it and sought in it the solution to all problems, expecting revelations that would satisfy different aspirations; and by not finding what they sought, they accused it from being narrow, uncertain, or of being in a crisis. However, he stressed that: "science cannot do all and does not reach everything. It cannot comprise everything within its limits. And if many people think these are narrow, it is a matter of personal viewpoint, it is related solely to the each one's spirit" ("a ciência não pode tudo e não se estende a tudo. Nem tudo cabe nos seus limites. E se muitos acham que estes são acanhados, isto é questão de ponto de vista pessoal, tem que vêr unicamente com a forma de espirito de cada um") (Almeida 1925, 116).

Furthermore, Ozório de Almeida often wrote about the limits of exacerbated nationalisms in science. In the article "A sciencia e a língua portugueza" (Science and the

[9] "Elle (C. Bernard) poude estabelecer assim não um systema, não um conjunto rígido de princípios, mas um exemplo de extrema pureza das reações reciprocas dessas duas ordens de coisas: a intelligencia humana de um lado, a natureza de outro. O seu esforço foi o de afastar o mais possível todos os empecilhos que separam esses dois mundos e facilitar a sua penetração reciproca e cada vez mais intima. E talvez seja esse o caracter fundamental da obra de Cl. Bernard, o que lhe empresta o dom de pereninade. Sem duvida, a marcha da sciencia tem levado a pesquiza para campos não suspeitados no tempo de Cl. Bernard. Esses campos são muito complexos, e os principios estabelecidos há meio seculo atraz necessitam em muitos pontos de retoque ou mesmo de ampliação vasta. Essas modificações não alteram , porém, o caracter fundamental da obra de Cl. Bernard" (Almeida 1925, 147-148).

[10] "Ella é uma simples construção, que corresponde a necessidades de nosso espírito, mas não pretende se apresentar como expressão da própria realidade. Assim compreendida, a teoria scientífica em nada perdeu de seu valor. O prejuízo por ella tido como objeto de crença foi largamente compensado pelo lucro alcançado como instrumento de trabalho" (Almeida 1925, 115).

Portuguese Language) the scientist highlights the fact that one of the consequences of war would have been the spread of nationality feelings:

> Science is universal, according to a largely repeated sentence. Knowledge of natural phenomena interests not only a given group of individuals living in this or that country; in principle, it should be of interest to all. In practice, however, things happen in a very different way. Each country endeavors to have its own science, clearly characterized and separated from the science of neighbor countries. [...] Science is made by scholars and if it knows no country, they do have it, as Pasteur said. As it is the result of human work, science cannot, fortunately or unfortunately, keep away from human passions' reach. (Almeida 1925, 174-175)[11]

Despite this statement, he affirmed that "the loss for the general development of science, the delay in knowledge diffusion, are clear enough to have to insist on this issue" ("o prejuízo para o desenvolvimento geral da sciencia, o atrazo na diffusão dos conhecimentos, é bastante claro para que seja necessario insistir sobre isso") (Almeida 1925, 174-177).

For a better understanding of the dynamics of scientific activity, Ozório de Almeida stressed the value of the historical method. According to him, the history of science would offer a great moral lesson: the understanding of scientific transformation through time and the acceptance of a certain modest posture of the scientist regarding the value of the truths he/she produces. He wrote: "It [the history of sciences] teaches us to be modest, convincing us that our truths are merely approximate, will have a shorter or longer life, and will be substituted by more precise and lasting truths; the result of our work is thus ephemerous, at least partially" ("Ella [a historia das ciências] nos ensina a ser modestos, convencendo-nos que as nossas verdades são simplesmente approximadas, terão uma vida mais ou menos curta e serão substituídas por outras mais exactas e duradouras, o resultado de nosso trabalho, sendo assim efêmero, pelo menos em parte"(Almeida 1931, 191). Furthermore, he affirmed that another significant verification of the history of sciences is the collective character of science, i.e., "the freely recognized or tacitly occult collaboration of all workers, even the most isolated from one another" ("a colaboração livremente reconhecida ou tacitamente oculta de todos os trabalhadores, mesmo os mais isolados, uns dos outros") (Almeida 1931, 191).

Ozório de Almeida constantly referred to the importance of scientists, especially biologists and physiologists, to think about their own research practices. For this purpose, he advocated greater proximity to philosophy because, ultimately, it had started the development of modern science. He affirmed, though, that regarding the "contemporary movement of ideas" ("movimento de idéas contemporâneo"), philosophy of science would hardly be well conducted by a pure philosopher; it would be necessary, first, to make science, and then, by a "very difficult and arduous analysis, see how it is made" ("analyse muito difícil e muito árdua, vêr como é que se faz") (Almeida 1925, 122).

To give examples of thinkers who undertook this task, Ozório de Almeida mentioned Pierre Duhem, Henri Poincaré, Ernest Mach, Wilhelm Ostwald, and Abel Rey; they examined the relation between physics and mathematics, discussing especially basic epistemology

[11] "A sciencia é, segundo uma phrase muito repetida, universal. O conhecimento dos phenomenos naturaes não interessa sómente a um certo grupo de individuos habitando este ou aquelle paiz; em principio deve interessar a todos. Na pratica, entretanto, as coisas se passam de modo muito differente. Cada paiz esforça-se por possuir a sua sciencia própria, nitidamente caracterisada e bem separada da sciencia dos paizes visinhos. [...] A sciencia é feita pelos sabios e, se ella não tem patria, estes a têm, como disse Pasteur. Sendo obra humana, a sciencia não pode, infelizmente ou felizmente, ficar de todo fora do alcance das paixões humanas" (Almeida 1925, 174-175).

issues. However, he stated that other disciplines were also useful for this philosophical analysis about the act of knowledge production. In his 1925 book, Ozório de Almeida commented French chemist Georges Urbain's book, *Les disciplines d'une Science* (*The Disciplines of a Science*):

> The determinism that lies on the base of all experimental sciences may not, according to Urbain, be seen in an absolute way. […] The greater or lesser perfect knowledge of the phenomena's conditions give us the right to predict with greater or lesser probability of being correct. For Urbain, prediction is the ultimate purpose of Science. Adaptation to environmental circumstances may only be achieved through the previous knowledge of future phenomena.
> The role of Science may be considered accomplished when we reach this point. It does not seek to 'explain'. Explanations are mostly limited to establishing simple analogies between something that is still little known and that we seek to understand, and something that has already been studied, which we are familiar with. Scientific theory, on the other hand, cannot be taken as an explanation essay. It merely classifies and organizes experimental laws, establishing between them a logical link, hence forming a system that is easy to preserve, thus saving our efforts. At this point, Urbain meets E. Mach. Science always seeks to attain the ideal of maximal economy of thoughts in the understanding of facts. (Almeida 1925, 124-125)[12]

Ozório de Almeida, now through Urbain's book, resumed the idea of theory as representation and economy of thought. This conception, according to the physiologist, would provide great elasticity and, therefore, great fecundity to scientific theories; it was at the base of modern science and distanced itself from old ideas that saw reality in theory. For defenders of the latter conception, "Science is chaos, a monstrous heap of contradictions" ("*a Sciencia é um chaos, é um monstruoso amontoado de contradicções*") (Almeida 1925, 125). But adepts of a modern view of science realized that they could use it as a guideline and, hence, they would not get lost:

> Recognizing that a theory is false is no delusion; at the most, this can cause the pain one feels when losing a good working instrument. The criterion of falsity or legitimacy of a theory is the experimental criterion. In fact, as pointed by Urbain, theories are neither true nor false. (Almeida 1925, 126)[13]

[12] "O determinismo que se encontra na base de todas as sciencias experimentais, não póde, segundo Urbain, ser encarado de um modo absoluto [...] O conhecimento mais ou menos perfeito das condições dos phenomenos nos dá o direito de prever com mais ou menos probabilidade de acertar. A previsão é, para Urbain, o fim real da Sciencia. A adaptação ás circumstancias ambientes só póde ser realizada pelo conhecimento prévio dos phenomenos vindouros.

O papel da Sciencia póde ser considerado como terminado quando chegarmos a esse ponto. Ella não procura nunca "explicar". As explicações limitam-se o mais das vezes a estabelecer simples analogias entre aquillo que ainda é pouco conhecido e que procuramos comprehender e alguma coisa já estudada, com a qual já estejamos familiarizados. A theoria scientifica, por seu lado, não póde ser tomada como um ensaio de explicação. Ella apenas classifica e ordena as leis experimentaes, estabelecendo entre ellas uma ligação logica e formando assim um systema facil de conservar, que poupa os nossos esforços. Urbain se encontra neste ponto com E. Mach. A sciencia procura sempre attingir ao ideal da máxima economia de pensamento na comprehensão dos fatos" (Almeida 1925, 124-125).

[13] "Reconhecer que uma theoria é falsa não é uma desillusão; quando muito isso póde causar a pena que se tem ao perder um bom instrumento de trabalho. O critério de falsidade ou de legitimidade de uma theoria é o critério experimental. Em rigor, como o nota Urbain, as theorias não são nem verdadeiras nem falsas" (Almeida 1925, 126).

These considerations about science and scientists are greatly valuable for the understanding of his practice as a physiologist. Drawing on the conception of theory as representation (and not explanation) and economy of thought, Ozório de Almeida saw theories as working instruments. Thus, he believed that it was possible to adopt more than one theory for the same set of phenomena, as long as they were legitimate, i.e., would not be in contradiction with the experiments.

As an example of this attitude, one can mention his project to write a general theory of nerves and muscles excitation. Ozório de Almeida conducted researches on several themes in physiology, but the theory of excitation represented one of the greatest research projects of the scientist's career. One can say that this theory became an obsession for the scientist, who until the end of his life worked on perfectionating the mathematic equation he formulated (Pumar 2018, in print).

Time was a crucial measure for researches that sought to understand phenomena that were little known and hard to treat experimentally, as were the cases of nervous transmission, mental process, or sensations (Daston; Galison 2007). The measuring of time enabled to collect data in laboratory researches and to relate abstract numbers to objective phenomena.

Chronaxie, established by French physiologist Louis Lapicque, was one of those measures that had large application in studies on the nervous system. A 'hot' theme in the early twentieth century, researches on the nervous system with *chronaxie* soon interested Ozório de Almeida. But it was in the 1920s – when his connections with the French academic community became stronger – that the scientist sought to develop a theory of excitation, in which the measuring of time and intensity of electric currents necessary to excite nervous and muscle fibers based the formulation of an equation that could represent the phenomenon.

Since the nineteenth century, the demonstration of muscle excitation of frog paws from electrical current became the classical experimental model in neurophysiology. An electrical current was used as a tissue excitation agent and, depending on the intensity and time span of the current, nerve and muscle excitation would occur. Many researchers studied these factors seeking to understand the minimum values of intensity and time of current for the excitation to occur. In the beginning of the century, the first mathematic curves representing the intensity of the electric current time span were made. With the establishment of chronaxie, Louis Lapicque became the central figure in debates on neurophysiology in the first half of the twentieth century (Harvey 1994).

Chronaxie became the base for a great nervous system theory that guided researches in France and Europe for several years. In the mid-1930, the influence of Lapicque and his nervous system theory decreased in Anglo-American circles due to consecutive attacks from English physiologists such as A. V. Hill, Henry H. Dale, and especially from Dale's pupil W. Rushton (Harvey 1994; Barbara 2010).

Criticism to Lapicque arose, mainly, due to theoretical interpretations that the French physiologist sought to generalize drawing on the use of chronaxie, especially with his definition of the law of isochronism. This physiologist drew on the conception that the nervous influx transmission during nerves and muscle excitation was essentially an electric phenomenon and that chemical transmission played a small role in this phenomenon. According to Lapicque's law of isochronism, the direction of the nervous influx in the tissues was related to their chronaxie, because only tissues with the same chronaxie could excite one another. However, Lapicque's explanation was formulated at the same time as physiologists at Cambridge University developed researches on the chemical transmission of nervous influxes and defined the concept of chemical receptor. Therefore, one can notice the existence, at that moment, of different hypotheses on the same phenomenon. This was a polemic debate in the early twentieth century. Considering that mathematical models fitted into different hypotheses and in view of uncertainties regarding the phenomenon of nerves

and muscles excitation, Ozório de Almeida sought to formulate a mathematical model, before the definition of a physicochemical theory of this phenomenon, from the assimilation of research data originating from local scientists and various theoretical guidelines. For the physiologist, scientific cooperation and the transformation of empirical data into more general theories by means of mathematics was a natural path of sciences, but a path full of obstacles and changes (Pumar 2018, in print). Therefore, the Brazilian physiologist Ozório de Almeida's posture in this debate was strongly related to his epistemological studies.

At the end of his life, during a debate at the *Centre International de Synthèse* (International Center of Synthesis), directed by Henri Berr, following a lecture by Julien Benda, Ozório de Almeida advocated that there existed no Synthesis in science, but rather syntheses. He stated that he was skeptical about the attempt to make a great synthesis, i.e., to try to reduce the world and its infinities of phenomena (of which we have very little knowledge) to a general formula. It was necessary to maintain the idea of partial syntheses, instead of seeking to make one great definitive synthesis. According to him, mathematicians and physicists expressed different phenomena through identical formulas: "How many phenomena are expressed by an equation or a simple function! But this does not oblige us to make one synthesis of analogy of the nature of these phenomena, which are different" ("Quantos fenômenos são expressos por uma equação ou uma simples função! Mas isso não nos obriga a fazer uma síntese de analogia da natureza desses fenômenos, que são diferentes") (Benda 1950, 209).

According to Ozório de Almeida, the evolution of science was made of small syntheses. When one achieved to express facts of experiments that had something in common in a law, with words, or, in a more precise way, by mathematical relations, it was a synthesis. And when one made a theory, it was no more than an effort of synthesis that gathered a certain number of laws; there could be, however, different theories for the same phenomenon. The scientist opposed, thus, large generalizations or one large synthesis. According to him: "Only the pure could be an object of generalizations" ("Apenas o puro poderia ser objeto de generalizações") (Benda 1950, 210).

Furthermore, in a debate at the same Center, soon after the lecture given by A. Koyré (Koyré, 1950), Ozório de Almeida criticized the divisions in the history of scientific thought. For him, different scientific mentalities overlapped at that time. He stated that he was not pessimistic regarding science's future or its current state; but he stressed that it was interesting to observe that, perhaps because of the extreme sub-division of researches, there was still a quite restrictive mentality (nearer to the Renaissance mentality described by Koyré) that was not in accordance with the principles established by what was called current science, under the spirit of the idea of synthesis (Koyré 1950).

To use his terms, for him the mentality of analysis (production of new facts) was not sufficient, it was also necessary to seek that of synthesis. However, his idea that modern science was formed by syntheses and not by the Synthesis, in a certain way was opposed to the idea of one sole and structuring science. According to Ozório de Almeida: "In face of the great and numerous discoveries of science, it is necessary to maintain the idea of partial syntheses, but not seek to make the definitive synthesis" ("Diante das grandes e numerosas descobertas da ciência, é necessário manter a ideia de sínteses parciais, mas não tentar fazer a síntese definitiva") (Benda 1950, 210).

Concluding Remarks

When analyzing Ozório de Almeida's life and work it is possible to notice that in a period marked, on one hand, by Karl Popper's principle of falsifiability and the "scientific conception of the world" of logical positivism and, on the other hand, by Bergson's valorization of intuition, Ozório de Almeida tended to a stand that sought to be in balance between a

unitarian and dogmatic vision of science, seen by him as simplistic and responsible for the distrust directed to science, and a more critical position towards scientific activity.

One can observe in Ozório de Almeida's texts that he sought to be distant from what he called an "average man of science" ("homem médio de sciencia"). In every research theme, he sought to produce new facts, but his ultimate purpose was to present original ideas, i.e., to debate the canons of physiology themes and propose new theories and hypotheses. One can also verify his interest in issues related to scientific practice and his concern with more fundamental philosophical questions. His engagement in national and international debates was guided by the understanding of science and its dynamics engendered by his readings in epistemology.

As seen earlier, authors like Poincaré, Duhem and Mach refused a total rule for science. They suspected of all objective fundament of reality and strived to make a sort of "psychology" of scientific behavior, stressing the convention system that supported scientific activity, a response to the need to adapt the variety of phenomenal experiment to the unitarian request of human spirit (Canguilhem; Planet 2011 [1939]). On the other hand, the North-American pragmatism had also a different point of view of the traditional image of science and knowledge, especially with William James, an author highly admired by Ozório de Almeida. The criticism of Henri Bergson to science went relatively in the same direction. As a reader of Bergson, Dewey, James, Duhem and Poincaré, Ozório de Almeida seemed to have a distinct understanding of the scientific activity, distant from a more traditional viewpoint influenced by Comte's positivism that animated other contemporary Brazilian scientists.

The idea preconized by Ozório de Almeida – that modern science had demonstrated the mutable and flexible character of scientific theories – provided a moral aspect to the scientist's work, who should not be tied to traditions and to seeking immutable truths about the natural world or even about the social world (political/moral). The use of theory (especially mathematic formulations) as a research instrument that may (and should) be discarded, when necessary, demonstrated the scientist's freedom and autonomy toward any kind of authority: intellectual or political, national or international. This understanding of the scientific activity from a perspective that enhances the individual's moral freedom had consequences in the way Miguel Ozório de Almeida dealt with Brazilian society's changes, especially concerning the educational and scientific system and international scientific relations.

Note

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