SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

Helminthology according to the philosophy of science of Imre Lakatos

La helmintología según la filosofía de la ciencia de Imre Lakatos

Martín Orensanz[1], Guillermo Denegri[2]

[1]Undergraduate Degree in Philosophy. Doctoral fellow, National Scientific and Technical Research Council, based in the Laboratory of Parasitic Zoonoses, Faculty of Exact and Natural Sciences, Universidad Nacional de Mar del Plata, Argentina.

[2]PhD Degree in Natural Sciences. Principal researcher, National Scientific and Technical Research Council, based in the Laboratory of Parasitic Zoonoses, Faculty of Exact and Natural Sciences, Universidad Nacional de Mar del Plata, Argentina.

ABSTRACT Lakatos's philosophy of science has been used for different branches of biology, however this has not been true for helminthology. Therefore, this article examines the possibility of using his methodology of scientific research programmes (SRP) for reconstructing the history of the discipline of helminthology. It is upheld that the first SRP in biology was inaugurated by Aristotle, and its protective belt included a small group of auxiliary hypotheses referring to helminths. This programme continued up until the 17th century, when two rival programmes in helminthology arose: the internalist and the externalist. After the second half of the 19th century the internalist SRP was abandoned, while the externalist considerably broadened its protective belt during the 20th century. The internalist programme was abandoned due to the crucial experiments of Küchenmeister, which permitted the consolidation of the externalist SRP.
KEY WORDS Philosophy; Helminthology; History.

RESUMEN A pesar de que en distintas ramas de la biología se ha utilizado la filosofía de la ciencia de Lakatos, no se ha hecho esto con la helmintología. Aquí utilizamos su metodología de programas de investigación científica (PIC) para reconstruir la historia de la disciplina en cuestión. Sostenemos que el primer PIC de la biología lo inauguró Aristóteles, y en su cinturón protector hay un pequeño grupo de hipótesis auxiliares que se refieren a los helmintos. Ese programa se mantuvo vigente hasta el siglo XVII, época en la que surgen dos PIC rivales en helmintología: el internalista y el externalista. A partir de la segunda mitad del siglo XIX, el PIC internalista fue abandonado, mientras que el externalista amplió considerablemente su cinturón protector durante el siglo XX. El abandono del PIC internalista se debió a los experimentos cruciales de Küchenmeister, que permitieron la consolidación del PIC externalista.
PALABRAS CLAVES Filosofía; Helmintología; Historia.

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

INTRODUCTION

This article is part of a larger research entitled *"La práctica individual y su relación con la práctica consensuada: el análisis del cambio conceptual en la helmintología"* ["Individual practice and its relationship with the consensual practice: analysis of the conceptual change in Helminthology"], which is focused on the epistemological aspects of helminthology. This is also the subject that Martín Orensanz, one of the authors of this article, chose for his doctoral dissertation in Philosophy at Universidad de La Plata.

Lakatos' philosophy of science[1] has been used for different branches of biology, such as population genetics,[2] historical biogeography,[3] ecology,[4] the cell theory,[5] nematology,[6] the theory of evolution,[7,8] the study of prions,[9] parasitology,[10,11] the synthetic theory of evolution,[12] the study of sea phytoplankton,[13] the study of the facial component in mammals,[14] the history of tropical medicine[15] and the analysis of the history of agriculture policies.[16] Although the mentioned works on parasitology, nematology and tropical medicine applied Lakatos' philosophy for reconstructing some aspects of the history of those disciplines, no studies — at least in a schematic manner — attempted to reconstruct the most outstanding moments in the history of helminthology from ancient times to the present.

Several studies about the history of general parasitology have been conducted and they address subjects related to helminthology.[17,18,19,20,21,22,23] However, Lakatos' methodology of scientific research programs (SRP) has not been applied in any of them. Therefore, this article offers a rational — although schematic — reconstruction of this discipline.

LAKATOS' PHILOSOPHY OF SCIENCE AND ITS APPLICATION IN DIFFERENT BRANCHES OF BIOLOGY

Michod[2] uses Lakatos' philosophy to rationally reconstruct the history of population genetics. He states that the hard core of SRP in this subfield of genetics is the assertion that evolution is equal to gene frequency changes in a population. The protective belt consists of mathematical models of genes, which started to develop at the time of the synthetic theory of evolution in the first half of the 20th century, continuing up to the present time. Such development enabled the prediction of new facts that were later corroborated which, according to Michod, could be an indicator of the progressive nature of SRPs. These predictions particularly referred to the mechanisms in charge of gene frequency changes in a population, as for example, natural selection, migration and genetic divergence, among others.

Craw *et al*.[3] use Lakatos' philosophy for reconstructing two different SRPs in a discipline known as "historical biogeography": the SRP in "panbiogeography" and the SRP in "vicariance biogeography." Regarding the branch of biogeography known as "dispersalist" or related to the "centers of origin," Craw *et al*. remark that this SRP is not Lakatosian as it does not have the ability to make any novel theoretical predictions. The hard core of the SRP in vicariance biogeography is the assertion that biological cladograms are historically connected with each other and with the geological alterations that occurred over time. On the other hand, the hard core of the SRP in panbiogeography is the assertion that standardized or generalized routes (known as geographic distributions of taxa) delimit ancestral biotas. Craw *et al*. suggest that the most progressive of these two SRPs is the one pertaining to panbiogeography, as it could predict the transatlantic connection between South America and Africa as well as the existence of an ancient supercontinent (Gondwana) composed of Africa, Madagascar, Australia and India. Nonetheless, the authors remark that the success of the SRP in panbiogeography is not forever guaranteed, for it is possible, theoretically, to develop a more progressive version of the SRP in vicariance biogeography.

Peters,[4] in his study on some of the conceptual problems faced by the trophic

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

network theory in the context of ecology, analyzes some feasible solutions. He maintains that Lakatos' philosophy of science could be useful, at least initially, as a way of facing the flaws of this discipline. More specifically, he proposes setting those flaws aside until the SRP can solve them in the future. Nevertheless, it would also be useful to maintain said SRP if it offers novel predictions. However, Peters then rejects the possibility of using Lakatos' theory in that way and declares that he agrees with Karl Popper when he says that hypotheses and theories should be rigorously tested, and that appealing to the productive capacity of such hypotheses or theories should not serve as an excuse to uphold them when they are deeply flawed.

González Recio[5] uses Lakatos' philosophy to reconstruct the cell theory as an SRP. He starts by presenting the historical context, which begins with the discovery of the cell by Robert Hooke in the 17th century. He then describes the most important milestones in the study of cells during the 18th century up to the 19th century with the cell theory proposed by Schleiden and Schwann. After describing the limitations of Popper and Kuhn's philosophies for the analysis of the emergence of cytology or cell theory, González Recio provides an interpretation based on Lakatos' philosophy. The hard core of Schleiden and Schwann's SRP is the assertion that cells are the smallest biological units of animal and vegetal organisms. The protective belt was developed in subsequent years as well as various researchers such as Leydig, Schultze and Overton contributed to its development. Their supplementary hypothesis addresses the cell division process, the cell composition (which includes the nucleus, the membrane, the cytoplasm, etc.) and the process through which cells form different types of tissue.

Schomaker and Been[6] use Lakatos' philosophy to reconstruct an SRP in nematology, stating that Seinhorst's work on this discipline can be interpreted as a progressive SRP. Although they use Lakatos' philosophy, they remark that Seinhorst developed his own empirical philosophy — which ascribes particular features to his SRP — and that such features cannot be reducible to the Lakatosian approach. The main purpose of Seinhorst's SRP is to search for methods to improve crop yield, based on the study of pests and diseases affecting them, particularly focusing on plant-parasitic nematodes. Through his positive heuristics it was possible to develop a series of mathematical models to understand the interaction between nematodes and crops. He used, for instance, several equations to measure growth reduction in crops over time because of the number of nematode parasites of specific species. Schomaker and Been conclude their work by asserting that Seinhorst's SRP could be broadened to include the study of fungi and insects affecting crops.

Dressino *et al*.[14] apply Lakatos' philosophy to analyze the study of the facial component in mammals by revisiting previous research in which some concepts of the Lakatosian philosophy had been modified. One of them is the concept of "hard core," which was replaced by the concept of "conservative core." The difference between these two concepts lies in that the conservative core can be modified — as a maneuver of last resort — if the flaws cannot be solved inside the protective belt. The conservative core of the SRP for the study of the facial component in mammals affirms that "the morphology of the facial component in mammals is the one resulting from the interaction of the different functional facial components in terms of the nutritional state and the adaptation to the type of diet" that includes herbivores, carnivores, insectivores and their variants. Denegri[10] reviewed the results of that work and states that the protective belt is composed of four supplementary hypotheses: "A) the hypothesis of the effects of hereditary factors on the ontogeny of the facial component, B) the hypothesis of the effect of nutrition on genic expression, C) the hypothesis of morphological changes during growth, and D) the hypothesis of the effects of malnutrition on facial ontogeny." One of the most significant conclusions of this SRP is the statement that certain phylogenetic trees would require

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

a reformulation including genetic and morphological criteria and also the effects of malnutrition on morphology.

Silva[7] questions the propositions of Popper, Kuhn, Lakatos, Feyerabend and other authors to analyze the history of the theory of evolution. He states that dialectic materialism rather than the philosophy of science of the mentioned authors would be more appropriate to analyze the history of that theory. Silva also remarks that the way in which Lakatos addresses the separation between the internal and external history of science poses a problem: it cannot rationally explain the fact that a scientist may adhere to a regressive SRP for political and social reasons rather than for scientific reasons. Silva states that this question can be rationally explained by dialectic materialism, whereas Lakatos would relegate it to the external history of science.

Caponi[15] argues that tropical medicine can be considered a Lakatosian SRP which originated as a result of the contributions of microbiology and parasitology, eventually differentiating itself from said disciplines. He analyzes the creation of two of the most important institutes of tropical medicine of his time: the *Institut Pasteur* in France and the London School of Tropical Medicine in England. Caponi adds that the basic model of tropical medicine at that time was based on the parasite-vector relationship, malaria being a paradigmatic example of that model, although other parasites, such as filaroid nematodes, are included. Thus, tropical medicine is based on the idea of the possibility of exerting control over vectors that transmit tropical parasitic diseases. Malaria is the key point that differentiates tropical medicine from classical bacteriology, as this disease is caused by a protozoan transmitted by a vector insect and bacteriology is based on the model of bacteria transmitted through water or air. Positive heuristics was able to create a protective belt composed of multiple supplementary hypotheses related to the different types of tropical parasites but linked to the model of insect vector-transmission by vector insects.

Zobbe[16] affirms that Lakatos' philosophy of science is useful for the analysis of the history of agricultural research policies in the US. As a result of the farm crisis of the 1920s, two competing SRPs emerged with regard to agricultural policies: the first one argued in favor of governmental intervention in agricultural economics through subsidies and other funding mechanisms. The second one asserted that monetary support was not enough and proposed governmental intervention in general economics including the relationship of agriculture with other economic sectors. Both SRPs remained in force until the 1970s, when the former entered a regressive phase. The latter continued being progressive as it added predictive hypotheses regarding international relations policies for US agriculture.

Pidone[9] assesses different approaches of philosophy of science — including Popper's, Kuhn's and Lakatos' — for the analysis of the prion theory. First, he analyses the fact that diseases known as "transmissible spongiform encephalopathies" (TSE) affect both human beings and animals. Although various theories — such as the viral theory, the virino theory, the mixed molecules theory, the nemavirus theory and the prion theory — have attempted to explain the causes of these diseases, being the prion theory the most accepted one nowadays. According to Pidone, all these theories could be considered Lakatosian SRPs with their respective hard cores, protective belts of supplementary hypotheses and heuristics. He also adds that, although the prion theory is the most accepted explanation for TSE, in some cases making predictions through this theory is not appropriate. Hence, it is valid to make predictions through "more pragmatic" theories, such as specific hypotheses of classical virology.

Denegri[10] applies Lakatos' methodology to formulate an SRP in parasitology. His main purpose is not to find an SRP already existing in the history of this discipline, but to create one that can be useful to parasitologists in their daily work. The hard core of this SRP is the assertion that the endoparasitic fauna of the hosts allows researchers to know their eating habits and vice versa. The protective belt is composed of two hypotheses: the first one is related to the general patterns of the

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

biological cycles of parasitic cestodes, trematodes, acanthocephalans and nematodes in vertebrates. The second one refers to the development of parasitic communities and is based on four models: non-asymptotic, asymptotic balance, non-asymptotic balance and co-speciation.

Pievani[12] applies Lakatos' philosophy to rationally reconstruct the structure of the synthetic theory of evolution, also known as "modern synthesis" or "modern evolutive synthesis." First, he describes a "disclosed" or "vulgarized" version of this theory, and then provides a more "realistic" version. The "vulgarized" version of the synthetic theory of evolution can be reconstructed as an SRP as follows: its hard core is a neo-Darwinist version of natural selection, as it focuses on the change in gene frequency in the populations. The protective belt is composed of three main supplementary hypotheses: i) the hypothesis of phyletic gradualism, ii) the hypothesis that macroevolution processes can be explained in terms of the approach of microevolution processes, and iii) the hypothesis of the possibility of using both functionalism and adaptationism as explanations, as required by specific cases. In the rest of his article, Pievani exposes another possibility for reconstructing the synthetic theory of evolution as a Lakatosian SRP, although in a more sophisticated and "realistic" manner than that the SRP used for reconstructing the "vulgarized" version.

Several other works of this kind could be added to the list of abovementioned research studies, such as the one proposed by Alsina Calvés,[8] who analyzes natural selection in terms of different philosophies of science, including that by Lakatos; the work of Nunes-Neto *et al*.,[13] in which Lakatos' methodology is applied for the reconstruction of an SRP in the study of sea phytoplankton; Sosa's work[24] in which he holds that biologists find Lakatos' philosophy of science more useful than Kuhn's; and Scioscia *et al*.'s work,[11] which corroborates the SRP developed by Denegri through the analysis of endoparasites in the grey pampean fox.

This article does not intend to conduct an exhaustive review of the entire specialized bibliography in which Lakatos' philosophy was applied in different branches of biology, as that would totally exceed the scope of this research. Those studies have been mentioned with the purpose of offering a varied and representative sample. In the previous works that refer to parasitology, tropical medicine and nematology, we did not seek to offer a reconstruction of the history of helminthology from ancient times to the present. This is precisely the task that we will conduct in this work.

THE HISTORY OF HELMINTHOLOGY BASED ON LAKATOS' PHILOSOPHY OF SCIENCE

It could be stated that the first SRP of biology was proposed by Aristotle[25] in his research entitled *On the generation of animals*. However, Lakatos[1] and Kuhn[26] had ruled out that statement, as both of them agreed that the first SRPs *(or paradigms according to Kuhn)* emerged in the 19th century as a result of Darwin and Mendel's work. Nevertheless, Lakatos and Kuhn did not focus on the history of biology but on the history of astronomy, physics, chemistry and mathematics.

The hard core of Aristotle's SRP is, apparently, the assertion that in nature, all living things are organized in a hierarchical system based on a "scale of nature" which begins with the "inferior" organisms and ends up with the human species. Invertebrates, such as worms, mollusks, crustaceans and insects, occupy the lowest rungs. As complexity increases, fish, amphibians and reptiles, birds, mammals and, lastly, human beings follow.

The protective belt is composed of many supplementary hypotheses: several of which refer to all animal species and others to a specific group. Among the supplementary hypotheses of the Aristotelian SRP, a small set that refers to helminths stands out. The first supplementary hypothesis is morphological in nature: it states that worms are generally apoda, they have soft bodies and lack eyes, mouth and skeleton. The second hypothesis,

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

referring to helminths, is of a taxonomic or classifying nature and states that there are three kinds of helminths: long and flat (beef tapeworms), round and short (nematodes) and ascarid (which nowadays are known as a subgroup within the nematodes). It is yet unknown why Aristotle made a distinction between ascarids and nematodes. The third and last supplementary hypothesis regarding this group of animals has a generative nature: it states that worms emerge by spontaneous generation from putrefying matter, such as rotten meat or decomposed food in the intestine.

During the Middle Ages, the Aristotelian SRP did not undergo significant modifications, yet it was slightly expanded by incorporating some of the latest findings of the time. Regarding helminths, trematodes — which were apparently unknown to ancient Greek and Roman scholars — were discovered in 1379 by Jean de Brie. Their incorporation into Aristotle's SRP was not controversial, as trematodes were regarded simply as a group of parasitic worms unknown until then; however, its incorporation only implied the modification of the taxonomic supplementary hypothesis to include them.

In the 17th century, two competing SRPs were developed. Farley[27] remarked that the debate in the helminthologist communities divided them into two separate groups: "internalists" and "externalists." The former group held that helminths originated spontaneously within the host's organism. For instance, it was believed that beef tapeworms generated spontaneously within the intestine as a result of maldigestion. William Ramsay,[28] who proposed the term "helminthology" in 1668 to characterize the scientific discipline that studies helminths, supported the internalist theory. Likewise, Francesco Redi,[29] who refuted for the first time the hypothesis of the spontaneous generation of insects, had an internalist stance about parasitic worms. Through a series of experiments, the author proved that maggots and flies swarming around rotten meat do not generate spontaneously but emerge from the eggs that progenitor flies deposit. Regarding intestinal helminths such as beef tapeworms, however, Redi adhered to the internalist theory as he believed that worms generated spontaneously within the intestine. It should be noted that Redi's experiments were conducted 200 years before Pasteur's experiments that refuted the theory of spontaneous generation. As a naturalist, Redi suspected that spontaneous generation was not the origin of new organisms, at least not in the case of insects such as the flies commonly observed on rotten meat.

Externalists, on the other hand, refuted the hypothesis of spontaneous generation by upholding that helminths enter the host from the external environment. Edward Tyson[30] and Antony van Leeuwenhoek[31] supported the externalist theory. Tyson dissected several specimens of nematodes and proved that they have reproductive organs, which suggested that they reproduce sexually within the host's intestine, after entering from the external environment. In turn, Leeuwenhoek also remarked that all helminths live in the external environment but as miniature beings which, he believed, after entering the host in whatever way, such as through the airways, grow until they become worms that can be easily seen with the naked eye.

The distinction made by Farley[27] of these two groups of researchers can be interpreted, based on Lakatos' philosophy of science, as the difference between two competing SRPs. The hard core of the internalist SRP is the assertion that helminths generate spontaneously. There is a significant difference in this case with the SRP in biology developed by Aristotle, which involves all animal species, and whose hard core is based on the "scale of nature." In regards to helminths, the protective belt includes a small group of supplementary hypotheses in which the spontaneous generation hypothesis can be found. In the internalist SRP, on the contrary, spontaneous generation is no longer a supplementary hypothesis of the protective belt but is now part of the SRP's hard core. The protective belt is composed of a considerable number of supplementary hypotheses which are described in detail and extensively in William Ramsay's work. In his book entitled *Elminthologia*,

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

Ramsay provides a series of hypotheses to explain how the diverse humoral imbalances, in addition to the type of food ingested, the host's "good" or "bad" digestion and even the influence of climatic factors, such as heat and cold, may generate different kinds of helminths. All these and many other factors had been very useful for the internalist SRP to provide an explanation regarding the spontaneous generation of helminths.

The hard core of the externalist SRP is the assertion that helminths enter the host from the external environment. The protective belt is composed of several supplementary hypotheses that mention the possible entry routes for helminths, such as through the airways, water and food; and even the pores of the skin could be a way of accessing the host, if it is considered, as Leeuwenhoek did, that the size of helminths in the external environment is microscopic.

The discrepancies between these two SRPs continued until the second half of the 19th century, when Friedrich Küchenmeister conducted his famous but also controversial experiment consisting in the administration of cestode larvae (specifically *Taenia solium* cysterca) to a group of death row inmates. After the prisoners were executed, Küchenmeister dissected their corpses and found adult cestodes inside. Despite the flood of ethical controversies raised because of his experiment, the results obtained were considered a definite refutation of the thesis of the spontaneous generation of helminths. However, the interpretation of these results did not occur immediately but took several years to be widely accepted.

The controversial considerations in Lakatos' philosophy of science regarding this type of "crucial experiments" encourage certain reflections on the subject. Lakatos states that "crucial experiments" will never be immediately interpreted as such in the historical moment in which they are conducted but it will take several years before it is acknowledged as "crucial" by the historians who reconstruct the most important moments of the scientific discipline that they study. If that were the case, Küchenmeister's experiments would not have been recognized as crucial until long after of being conducted, although this fact may be debatable. It can be stated, however and avoiding further deliberation, that by accepting this theory, the flood of ethical controversies raised as a result of the experiments conducted by Küchenmeister would indicate that the internalist SRP was still supported by a group of helminthologists.

This is not an attempt to suggest that the analyzed example refutes Lakatos' conception, but rather the opposite. In fact, Küchenmeister's case supports Lakatos' approach, precisely because various helminthologists continued to adhere to the internalist SRP. Küchenmeister did not conduct an "isolated crucial experiment," but his work helped the externalist SRP to consolidate. This consolidation was not exclusively a matter of time, as the externalist SRP could increase its empirical foundations by proving that *T. solium* entered the host from the external environment. From a historiographic perspective, it can be stated that this became a flaw for the internalist SRP.

If Lakatos' thesis regarding crucial experiments was correct, this would mean that it was not until the 20th century that the assessment of Küchenmeister's experiment was finally known. Nevertheless, it should be determined whether such assessment was conducted within an externalist SRP, which would probably remain valid to this day, or within the context of a new and different SRP. A new research should be conducted to provide a proper answer to that question. Nonetheless, it can be concluded, at least as a historiographical hypothesis, that no new SRPs were developed in the 20th century and that the externalist SRP developed in the Modern Age was expanded and refined instead. Apparently, the hard core was kept intact but significant changes were made to its protective belt of supplementary hypotheses. First, it is believed that the supplementary hypothesis that helminths can enter the host through the airways was dismissed. Moreover, the hypothesis that helminths are present in the external environment as miniature beings was also dismissed. Rather, the elucidation of the

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

biological cycle of cestodes, trematodes and nematodes in the 19th century and the early 20th century might have helped replace the hypothesis of "miniature helminths" with another hypothesis based on a complete description of the successive larval stages of their life cycles.

CONCLUSION

Lakatos' methodology is useful for rationally reconstructing the history of helminthology based on the identification of consecutive SRPs. Nevertheless, it is necessary to modify his theory. It seems more logical to state that the first SRPs of biology were inaugurated by Aristotle rather than by Darwin and Mendel in the 19th century. The protective belt of Aristotle's SRP is composed of many supplementary hypotheses referring to all animal species but it is believed that it also contains a small set of hypotheses referring to helminths. The supplementary hypothesis referring to the spontaneous generation of helminths should be highlighted.

The distinction between "internalist" and "externalist" helminthologists proposed by Farley during the Modern Age can be interpreted as the difference between two competing SRPs. It has been already mentioned in this article that the internalist SRP differs from Aristotle's SRP in that the theory of spontaneous generation is no longer a supplementary hypothesis of the protective belt of the former SRP, but is the hard core of a new SRP specifically related to helminthology and not to biology or zoology in general.

Finally, Lakatos' theory regarding crucial experiments encourages reflection on the significance of the experiments conducted by Küchenmeister in the second half of the 19th century. If Lakatos' theory was correct, then Küchenmeister would not have delivered the final blow to the internalist SRP and it would have been active for some time. This would also explain why several helminthologists continued to support the explanation based on the spontaneous generation theory at that time. In other words, while the externalist SRP was consolidated as a result of Küchenmeister's works by increasing its empirical foundations, the internalist SRP struggled to explain the success of its rival.

In this article, only the general aspects of the history of helminthology based on Lakatos' philosophy of science have been covered. For future studies, it will be necessary to conduct a deeper analysis and to provide detailed information about the various aspects of this rational reconstruction. This will require, for instance, to analyze the impact of Linnaeus' taxonomy on the helminthology of the 18th century, the influence of Lamarck and Darwin on helminthology during the 19th century and which aspects of the synthetic theory of evolution, genetics, ecology and molecular biology, among other disciplines, influenced the body of knowledge of helminthology throughout the 20th century and the early 21th century.

ACKNOWLEDGMENTS

This research was supported by the Internal Doctoral Scholarship granted by the National Scientific and Technical Research Council (CONICET for its Spanish initials) to Mr. Orensanz, holder of an undergraduate degree for the period 2015-2019, and the following subsidies granted by: the Universidad Nacional de Mar del Plata (EXA764/16) and the National Scientific and Technical Research Council (PIP No. 0029).

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

REFERENCES

1. Lakatos I. La metodología de los programas de investigación científica. Madrid: Alianza Editorial; 1983.

2. Michod R. Positive heuristics in evolutionary biology. The British Journal of Philosophy of Science. 1981;32(1):1-36.

3. Craw RC, Weston P. Panbiogeography: A progressive research program? Systematic Biology. 1984;33(1):1-13.

4. Peters RH. Some general problems for ecology illustrated by food web theory. Ecology. 1988;69(6):1673-1676.

5. González Recio JL. Elementos dinámicos de la teoría celular. Revista de Filosofía. 1990;3(4):83-109.

6. Schomaker CH, Been TH. The Seinhorst Research Program. Fundamental and Applied Nematology. 1998;21(5):437-458.

7. Silva EP. A short history of evolutionary theory. História, Ciencias, Saúde – Manguinbos. 2001;III(3):671-687.

8. Alsina Calvés J. Modelos de cambio científico a partir de la selección natural: análisis y propuestas. ILUIL. 2006;29(64):221-257.

9. Pidone CL. La teoría del prión. Analecta Veterinaria. 2005;25(2):62-72.

10. Denegri G. Fundamentación epistemológica de la parasitología. Mar del Plata: EUDEM; 2008.

11. Scioscia N, Beldoménico P, Denegri G. Contrastación de un programa de investigación científica progresivo en parasitología: los endoparásitos del zorro gris pampeano Lycalopex gymnocercus. Filosofia e História da Biología. 2016;11(1):107-120.

12. Pievani T. An evolving research programme: The structure of evolutionary theory from a Lakatosian perspective. In: Fascolo A, (ed.). The theory of evolution and its impact. Berlin: Srpinger-Verlag; 2011. p. 211-228.

13. Nunes-Neto NF, Santos do Carmo R, El-Hani CN. The relationships between marine phytoplankton, dimethylsuphide and the global climate: The CLAW hypothesis as a Lakatosian progressive problemshift. In: Kersey WT, Munger SP, (eds.). Marine phytoplankton. New York: Nova Science Publishers; 2009.

14. Dressino V, Denegri G., Lamas SG. ¿Es posible una propuesta lakatosiana para el estudio del componente facial en mamíferos? Episteme. 1998;3(5):73-87.

15. Caponi S. Coordenadas epistemológicas de la medicina tropical. História, Ciencias, Saúde – Manguinhos. 2003;10(1):113-149.

16. Zobbe H. On the foundation of agricultural policy research in the United States. Acta Agriculturae Scandinavica Section C – Food Economy. 2004;1(1):34-45.

17. Amici RR. The history of Italian parasitology. Veterinary Parasitology. 2001;98(1): 3-30.

18. Cordero Del Campillo M. The history of veterinary parasitology in Spain. Veterinary Parasitology. 1989;33(1):93-116.

19. Cox FE. History of human parasitology. Clinical Microbiology Reviews. 2002;15(4):595-612.

20. Enigk K, Habil HC. History of veterinary parasitology in Germany and Scandinavia. Veterinary Parasitology. 1989;33(1):65-91.

21. Grove DI. A history of human helminthology. Wallingford: CAB International; 1990.

22. Hoeppli R. The knowledge of parasites and parasitic infections from ancient times to the 17th century. Experimental Parasitology. 1956;5(4):398-419.

23. Touratier L. History of veterinary parasitology in France. Veterinary Parasitology. 1989;33(1):45-63.

24. Sosa R. ¿Por qué a los biólogos les sirve más Lakatos que Kuhn? Centro de Estudios Filosóficos de Salta: Temas de Filosofía. 2012;15:175-184.

25. Aristóteles. Investigación sobre los animales. Madrid: Editorial Gredos; 1992.

26. Kuhn TS. The structure of scientific revolutions. 2nd ed. Chicago: University of Chicago Press; 1970.

27. Farley J. The spontaneous generation controversy (1700-1860): The origin of parasitic worms. Journal of the History of Biology. 1972;5(1):95-125.

28. Ramsay W. Elminthologia, or some physical considerations of the matter, origination, and several species of wormes macerating and direfully cruciating every part of the bodies of mankind. London: John Streater; 1668.

SALUD COLECTIVA. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134

29. Redi F. Experiments on the generation of insects (Translated from the Italian Edition of 1688 by M. Bigelow). Chicago: The Open Court Publishing Company; 1909.

30. Tyson E. Lumbricus Latus, or a discourse read before the Royal Society of the Joynted Worm. Philosophical Transactions of the Royal Society. 1683;13:113-144.

31. Leeuwenhoek A. The select works of Anthony van Leeuwenhoek: containing his microscopical discoveries in many of the works of nature (vol 1). London: Black Horse Court, Fleet Street; 1800.

CITATION
Orensanz M, Denegri G. Helminthology according to the philosophy of science of Imre Lakatos. Salud Colectiva. 2017;13(1):139-148. doi: 10.18294/sc.2017.1134.

Recieved: 11 Sep 2016 | Modified: 5 Dic 2016 | Approved: 29 Dic 2016

https://doi.org/10.18294/sc.2017.1134

The translation of this article is part of an inter-departmental and inter-institutional collaboration including the Undergraduate Program in Sworn Translation Studies (English < > Spanish) and the Institute of Collective Health at the Universidad Nacional de Lanús and the Health Disparities Research Laboratory at the University of Denver. This article was translated by Tais Abril Adonis and Rocío Ferraro Torres under the guidance of María Victoria Illas, reviewed by Anne Neuweiler under the guidance of Julia Roncoroni, and prepared for publication by Candelaria Alonso under the guidance of Vanessa Di Cecco. The final version was approved by the article author(s).