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ARTÍCULOS DE REVISIÓN

The history in DNA: A proposal to generate a change of vision of science in school

La historia en la enseñanza del ADN: Una propuesta para generar un cambio de visión de ciencia en la escuela

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Summary

Currently, in science teaching and in particular, natural science teaching there are concepts in the school that have a high level of abstraction. Concepts, such as atom, gene, mole and energy, among others are difficult to explain in an understanding manner to students. This situation requires the teacher to design alternative strategies to promote meaningful learning. Give priority to teaching concepts in science promotes the conception of science as a finished, infallible construct outside the context and does not evolve; turning science learning into something monotonous and uninteresting for students. According to some researches in the line of history and epistemology of sciences, its importance and advantages are recognized to promote not only a conceptual and formal education, but also to broaden the spectrum of possibilities that allow the students to transform conceptions of science into a more dynamic and participatory paradigm. Recognizing the benefits of the use of history in science teaching, a proposal is made for the DNA structure teaching in secondary school students within the framework of the Master in Teaching of Sciences of the Fundación Universidad Autónoma de Colombia, under this perspective.
Keywords: History of science, DNA, science teaching.

Resumen

Actualmente, en la enseñanza de las ciencias, y en el caso particular de las ciencias naturales, hay conceptos a nivel escolar que presentan un elevado nivel de abstracción. Conceptos tales como átomo, gen, mol y energía, entre otros, se dificulta llevarlos al aula de una manera accesible y comprensible para los estudiantes. Esta situación requiere que el docente diseñe estrategias alternativas que favorezcan aprendizajes significativos. Dar prioridad a la enseñanza de conceptos en ciencias promueve la concepción de ciencia como un constructo terminado, infalible, ajeno al contexto y que no evoluciona, tornando el aprendizaje de las ciencias como algo monótono y poco interesante para los estudiantes. De acuerdo con algunas investigaciones realizadas en la línea de historia y epistemología de las ciencias, se reconoce la pertinencia y las ventajas que tiene su inclusión para promover no solo una formación conceptual y académica, sino también para ampliar el espectro de posibilidades que permitan al estudiante transformar las concepciones de ciencia hacia un paradigma más dinámico y participativo. Reconociendo las bondades del uso de la historia en la enseñanza de las ciencias, en este texto se describe una propuesta para la enseñanza de la estructura del ADN en estudiantes de educación media en el marco de la Maestría en Didáctica de las Ciencias de la Fundación Universidad Autónoma de Colombia bajo esta perspectiva.

Palabras clave: Historia de las ciencias, ADN, enseñanza de las ciencias.

Introduction

Scientific work, beyond being considered as a possible way of understanding the surrounding world, is a human activity influenced by the social, political, economic and academic context where it develops. Knowing about how scientific knowledge is produced, its activity and its players, allows for generating critical-reflective postures of the people involved therein (Matthews, 1994; Solbes & Traver, 1996). Teaching from a historical approach not only requires broad knowledge about the course by the professor, but also needs a solid epistemological foundation and the use of a specific language that, beyond including dates and specific events, involves strategies to respond to historical situations and to be able to understand the past in a diachronic manner (Carrasco, Molina & Puche 2014). Therefore, including science history into the teaching processes of different education levels increasingly becomes more significant, where the professor should assume a critical and analytical position that, through an organized and structured work, achieves to articulate the curriculum with scientific thinking development.

On the other hand, scientific events were characterized as they are permeated by power, discrimination and interest conflict relations, among others. Consequently, introducing in the classroom historical elements of these events, facts and occurrences enables a change in the paradigm of science conceived by students towards something more adapted to reality, context and society

From the teaching experience in basic and middle education, and as reported by some authors (Sáiz Serrano, 2013; Prieto, Carrasco & Martínez, 2013; Betancur, 2008; Bugallo, 1995; Gil Pérez, 1993), it is necessary to introduce in the classroom didactical strategies other from the traditional ones, particularly for teaching some biological concepts with high abstraction level; for instance DNA structure. In this order of ideas, a part of

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work described herein was developed within the research project currently conducted with 11th grade students (secondary) and purported to approach DNA structure from a historical approach in order to favor a change in the science nature paradigm.

Importance on Science Teaching History.

For the last decades, the number of publications related to educational and didactical advantages of the use of history in science teaching has increased, and with the creation of courses such as science didactics, science history was consolidated as a line of research to qualify teaching and learning processes in this field. From this perspective, science history in teaching processes favors the determination of epistemological obstacles, the definition of teaching contents and the possibility to open reflection spaces in the classroom on knowledge production appropriation and control at individual and social level (Carrasco, 2014; Martínez, Valls & Pineda, 2009; Sáiz Serrano, 2013; Gagliardi, 1988; Gil Pérez, 1993).

The historical approach also offers the possibility to view future-projected scientific facts, thus showing science is a constantly changing process and permeated by social, political and economic factors, subject to stress, crisis and recessions inherent to human activity. The current historical times depend on the decisions made through history and, to this extent; the future is determined by the current provisions. This type of reasoning not only has to be taken to the classroom, but also has to make up teachers' training processes regardless of the specific discipline of knowledge, providing elements of judgment enriching teaching activity and enabling to introduce an innovative didactics (Izquierdo, 1996). Considering the use of history in science, teaching also favors the change in the predominantly positivist paradigm towards one that reports human, ethical and social nature of scientific work that gives analysis and reflection spaces (Solbes & Traver, 2001). Figure 1 specifies other significant contributions to the use of history in teaching science.

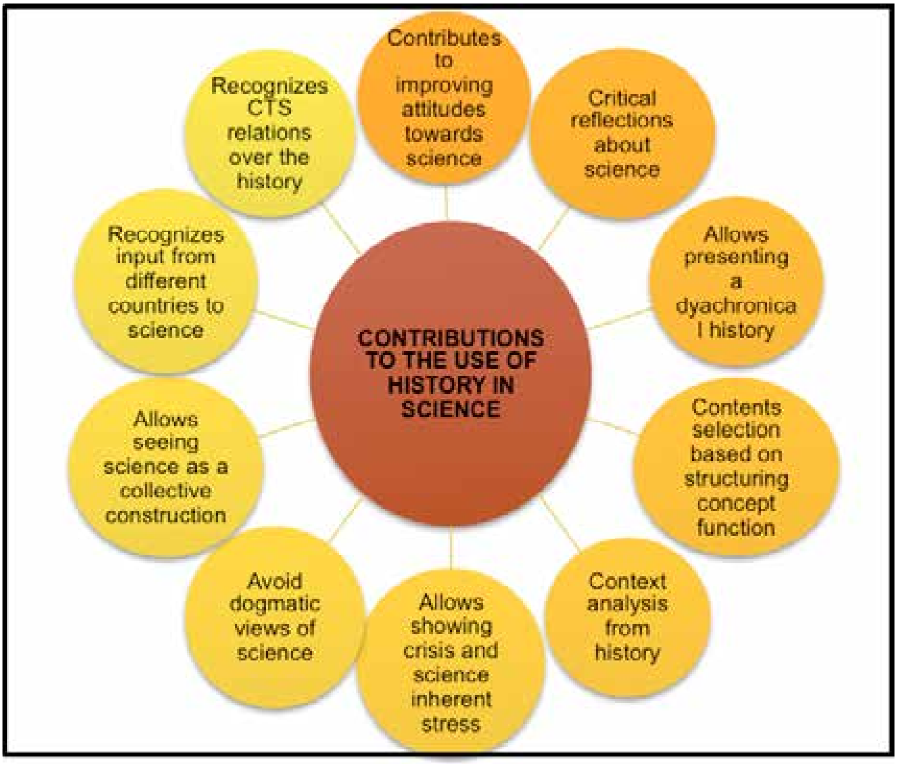

Figure 1. Contribution of use of history in teaching science.

Science Paradigms.

One of the aspects to be contrasted at the beginning and end of the research is what students think about science, identifying on which paradigm they orientate their thoughts, forms of expression and actions. This obeys to the need to promote a change in the paradigm on science nature in school in order to establish a relation between the scientific fact and its impact on the society that, according to some referrals, must not exceed 50 years, but the evidence shows that, in some cases, this period has increased beyond the expectations (Merlano, 2013). Based on the foregoing, there was a need to epistemologically ground paradigms on the nature of science to be adapted to the Colombian educational model tendency in order to orientate pedagogic practices towards that model that, from a historical perspective, will approach more to promote elements necessary for promoting critical and reflective thinking of students in a certain context and, thus, be able to extend conceptions about science. For this reason, the classification of science paradigms by Vázquez, Manassero & Acevedo in 2001, was treated as an epistemological referral where four paradigms characterizing scientific work are proposed.

- Positivist paradigm: science is assumed as a set of truths obtained from experimentation and the use of scientific method as a linear, single and universal method, which takes into account magnitudes and measurements, to create a set of rules defining and controlling the world.
- Pragmatist paradigm: it covers science as a search of true theories through reason, showing their falsifiability and looking for the truth on the existing theories.
- Realistic paradigm: science is seen as a tool purported to produce theories capable of overcoming empirical obstacles, which make them more reliable.
- Relativist paradigm: it considers science as a social, human, flexible and dynamic process where the scientist interacts not only with reason but with the social, political and economic environment influencing work and action.

Taking into account these characterizations on the nature of science, this research looks for, besides using history in teaching DNA structure, approaching students to the relativist paradigm retaking some events where times of stress and crisis inherent to human activity around DNA structure deduction are evident, as this paradigm enables to present scientists as people permeated by emotions, society and historical moments where research are conducted.

Didactical Strategy Proposal.

Some forms of introducing history of science in teaching as a didactical strategy are, frequently, timelines, biographies and biographical data, among others, where many times a linear and aseptic description of successful discoveries and absolute truths are provided (Valcárcel, González & Llavador, 2006; Gagliardi & Giordan, 1986). The use of sections and historical account is not very recurrent in natural science teaching due to the complexity and exigency for the earch of primary sources and since, in one way or another, they get apart from anecdotic and conceptual nature with which the historical events are presented to address scientific concepts, if they are effectively taken into account. One historical introduction alternative are historical accounts that, beyond chronologically locating scientific events or narrating biographic aspects, enable to contextualize a scientific importance event involving social, political and economic elements that extend the science view constructed in a dynamic, non-linear and more human manner, and that, articulated with another type of activities, favor constructing concepts and changing the science nature paradigm.

Below we can see a fragment of historical account, an axle of the didactical strategy of this proposal, designed and prepared by the authors, wherein both primary and secondary sources were reviewed and used, which path takes into account players of DNA structure deduction, not only the ones recognized by history but also the ones significantly contributing to this research and that, at the time, had no acknowledgements for their work. Likewise, some personal and social stressed situations are mentioned, which shaped and gave sense not only to a scientific but a social and human process to an event that divided biology history into two parts.

DNA Double Helix.

Rosalind Elsie Franklin (1920-1958), remembered as “The dark lady of DNA”, was born in Notting Hill, London, on July 25, 1920. She followed

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university studies in Physics, Chemistry and Mathematics at Newnham College, the women's college of Cambridge University. During this time, Cambridge women students were not granted a *Licenciate* degree; they were not considered as a part of the cloister and there was a restriction to a number of 10% doctoral students at most. Before working with DNA, Rosalind studied coal crystals and, upon obtaining her doctoral degree, she specialized in the X ray defraction technique in Paris. She returned to London to work at King's College, leaded by Sir John T. Randall (1905-1984), where she obtained the famous photograph 51. With her, Maurice Wilkins was conducting a research on coal crystals (1916-2004), he is a New Zealander physician and X ray studies specialist. The relationships between these two scientists were characterized by being so distant and marked by stress at personal and work level, a situation that led Rosalind to maintain progress on research apart from her colleague and laboratory they worked at.

Due to the difficult relationships between Franklin and Wilkins at King's College, and with the aim of freeing stress, Randall asked Rosalind, through a rude and authoritarian notice, to assign her work to Maurice Wilkins and leave the laboratory with her entire research.

Simultaneously to the studies conducted at King's College, James Watson (1928), a biologist and doctor in US Zoology, and Francis Crick (1916-2004), a physician, molecular biologist and British neuroscientist, developed studies – a little timid– regarding DNA structure in Cavendish laboratory, in Cambridge, under the direction of Sir William Lawrence Bragg (1890-1971). Watson was obsessed with his conational, biochemist Linus Carl Pauling, born in Portland (Oregon), in order to decipher the DNA structure (Vicente, 2008). This situation leads Watson and Crick to conduct a sudden research on DNA, proposing a three helix structure with sugar and phosphate sequence inside the molecule and composing nitrogenous bases outside joined by magnesium ions. This structure was informally shown to Rosalind, Wilkins and Raymond Gosling (1926-2015), a student researcher assigned to Rosalind, who in November 1951 had sufficient data to propose that DNA was a helicoidally structure composed of sugar and a phosphate group outside the molecule, and nitrogenous bases should appear inside. This was a part of the critical sources they would particularly receive from Franklin.

Upon becoming aware of this disaster, Lawrence Bragg ordered Watson and Crick to assign the DNA research to the members of the research group of King's College and return to their specific tasks: nucleic acid tobacco mosaic virus structure (ARN) and hemoglobin structure, respectively (Guevara Pardo, 2004).

In January 1953, and without the knowledge of Rosalind Franklin, Wilkins imprudently showed James Watson photograph 51, obtained from the X ray defraction of DNA crystals, under special hydration conditions which evidence that DNA structure obeyed to a double helix, a situation which was not considered before and used by James Watson and Francis Crick as a key to propose the final DNA molecule structure.

On February 28, 1953, Watson and Crick had deciphered the DNA structure, so they went to their regular entertainment point, The Eagle pub, which they attended after long workdays, and in a gesture of victory, Crick says the famous phrase *"...we have discovered the secret of life..."*. After having an academic reconciliation with Rosalind Franklin, biologists Watson and Crick sent a manuscript from their research to *Nature* magazine and on April 25 of the same year this research was published under the title *"Molecular Structure of Nucleic Acids"* in an 900-word article. The same magazine and publication contain an article from Wilkins with two of his cooperators, entitled *"Molecular Structure of Desoxypentose Nucleic Acids"*, and another from Rosalind Franklin and Gosling, entitled *"Molecular Configuration in Sodium Thymonucleate"*, all of them about DNA molecular

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structure, confirming that the same conclusions had been reached (Ortiz Hidalgo, 2003).

These publications did not get the expected success during the first years within the scientific community, and only when an explanation was given regarding DNA duplication –during the 60's–, as an acknowledgment to research works conducted, the Nobel Prize in Physiology and Medicine was awarded in 1962 upon Watson, Crick and Wilkins. Rosalind Franklin died when she was 37 years-old, due to an ovarian cancer, so that she was not awarded with the prize together with her colleagues.

Below we can see a didactical proposal for science history introduction on DNA structure teaching with secondary students of the capital district of Bogotá (Colombia). This project is aimed to contribute transforming traditional teaching practices, wherein a conceptual and transmitting teaching predominates, into the ones allowing students to access flexible, contextualized, human and conscious science knowledge, in order to improve ideas, perceptions, conceptions and notions of students about the world, thus making their understanding and actions to promote scientific literacy and training of future scientists easier (Roca, Sanmartí & Márquez, 2013; Deulofeu, Márquez & Sanmartí, 2010; Sanmartí, 2000).

Table 1.

Description of the proposal's development stages.

Stages	Description
Historical reconstruction	▪ Theoretical bibliographic review of primary and secondary sources of 50 years before Watson & Crick work. ▪ Selection of the most relevant sources for the developing world. ▪ Generation of source analysis and reading categories. 1. DNA biological aspects. 2. Relations among science, technology and society. Social stressed situations of players. 3. DNA studies projection. ▪ Drafting of the reconstruction document.
Epistemological and didactical foundations	▪ Description of conditions whereby knowledge was produced around DNA structure, specifying scientific and social aspects. ▪ Review of some conceptual supports which systematically marked knowledge generation and construction that guide teaching labor. ▪ Recognition of conceptual bases for the establishment of science didactics as a consolidated scientific course purported to study and intervene the teaching and learning processes of a specific area of knowledge.
Didactical strategy design	▪ Design, preparation, validation and implementation of diagnostic instruments: 1. Likert scale-type instrument, for collecting conceptions of students about science. (See appendix A). 2. Open-question questionnaire, based on a reading on current issues, to identify alternative conceptions of students about DNA and its structure. (See appendixes B and C). ▪ Unit structure. ▪ Contents selection: 1. Historical reconstruction: journey in time. 2. DNA structure: decipher DNA puzzle. 3. Projection: *"The Chemistry of Life":* implications on DNA structure at biological level. ▪ Selection of activities and sequencing. ▪ Generation of monitoring and assessment criteria.
Didactical structure implementation	▪ This didactical strategy is designed to be implemented with secondary students, taking into account basic genetics and organic chemistry concepts they should have been acquired in previous educational levels.
Results and result analysis	▪ Presentation of monitoring and assessment criteria. ▪ Applied instrument analysis ▪ Result analysis and triangulation. ▪ Didactical strategy assessment.

Final Considerations

Making use of science history for teaching concepts such as DNA structure becomes a didactical strategy which not only allows for understanding and learning science-related concepts, but also making changes in conceptions of students about science and how it progressed over the time, so that they

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approach to a more human science permeated by times of stress and crisis from a certain place, time and context which determine and demarcate how scientific research works are developed and conducted. Even today science recognizes that, within a cooperative and collaborative framework, the trace for deciphering the puzzle of life structure was achieved in a short time with similar results and where players had different recognition.

Science history introduction into the teaching of DNA structure is a strategy that not only favors and minimizes conceptual fracture for heritage understanding at macroscopic and microscopic level, but enables the analysis of players and social, political and economic situations determining at the time of DNA structure deduction. In this way we can highlight the significance of scientific input that, beyond describing a chemical molecular structure, furnished information to understand heritage and hereditary feature transmission bases, which enabled to arise out scientific courses such as molecular genetics and biotechnology, with multiple contributions to science and that, taken to the classroom, favors the generation of scientific processes and promotes the analysis and reflective spaces on scientific and ethical implications.

Establishing epistemological and didactical foundations strengthens research processes oriented towards generating fundamental transformations in teaching practice from the proposals for a viable, contextualized intervention in response to the current educational needs. The foregoing was possible taking authors Carraco (2014), Borgui (2010), Matthews (1994), Solbes and Traver (1996) as referrals, who developed strategies from the use of science history in teaching different scientific courses including biology, chemistry and physics, among others, and furnishing theoretical elements according to the students' needs in our educational context, favoring a view of flexible, human, crisis-subject science and social, economic and scientific stressed situations.

The design and preparation of a didactical strategy are indispensable elements for organizing and introducing alternative proposals for science teaching and learning, allowing for thinking of what to teach, how to teach, what for, what resources may be used, how to assess and what should be assessed. These questions, among others, are a guide to articulate a didactical unit proposal (Hernández, 2011) which will generate transformations in alterative conceptions about science between research students and which shall significantly contribute to didactical transposition processes necessary for taking science to the classroom which will enable, from the school dynamics, to promote processes of future scientist education.

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Appendix A.

FUNDACIÓN UNIVERSITARIA AUTÓNOMA DE COLOMBIA
PROYECTO DE INVESTIGACIÓN:
"LA ENSEÑANZA DEL ADN DESDE UN ENFOQUE HISTÓRICO CON ESTUDIANTES DE EDUCACIÓN BÁSICA SECUNDARIA Y MEDIA VINCULADOS AL SECTOR PÚBLICO"

Este instrumento tiene como objetivo identificar cuál es tu opinión frente a las siguientes afirmaciones. Marca con una X la opción que consideres se acerca más a tu punto de vista de acuerdo con la siguiente tabla:

Muy de acuerdo	De acuerdo	En desacuerdo	Muy en desacuerdo
1	2	3	4

ÍTEM	1	2	3	4
1. Los resultados de la investigación científica no se ponen en duda, ya que son el resultado de un proceso riguroso que les da validez.				
2. Los procesos realizados en la investigación científica tienen más importancia que los resultados obtenidos.				
3. Las verdades en la ciencia son producto de un proceso lógico que dan cuenta de la realidad del mundo que nos rodea.				
4. Los avances en la ciencia son el resultado de un proceso científico, histórico y social.				
5. El trabajo científico se lleva a cabo en el laboratorio, y es allí donde se produce el conocimiento en la ciencia.				
6. El conocimiento científico es verdadero porque los científicos explican los hechos del mundo.				
7. Las teorías científicas son el resultado de estudiar y analizar hechos sorprendentes.				
8. La ciencia es una actividad humana que permite conocer el mundo natural y social.				
9. El éxito de la ciencia radica en la aplicación del método científico, que es ordenado, riguroso y garantiza llegar a la verdad.				
10. Uno de los objetivos de la ciencia es explicar los fenómenos naturales para poder controlar lo que nos rodea.				
11. La explicación científica de un fenómeno natural obedece a un exclusivo punto de vista.				
12. Los conocimientos que se tienen sobre un fenómeno siempre son observables.				
13. Los instrumentos y materiales de laboratorio son recursos indispensables para la generación de conocimiento científico.				
14. La ciencia puede predecir con exactitud el funcionamiento del mundo natural.				
15. Las investigaciones científicas se ven influenciadas por creencias religiosas, intereses económicos, políticos y sociales.				
16. Para generar conocimiento científico es necesario relacionar la ciencia, la tecnología y la sociedad.				

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Appendix B.

OSOS POLARES, LOS REYES DEL HIELO

Aíslan por primera vez ADN de oso polar de una huella en la nieve

Un equipo de científicos franceses, en colaboración con WWF (Fondo Mundial para la Naturaleza), ha conseguido aislar por primera vez ADN de oso polar de una huella en la nieve. Los científicos analizaron dos muestras de agua tomadas de las pisadas del plantígrado, recogidas a principios de este año durante la expedición de WWF-Canon y del Instituto Polar Noruego al archipiélago de Svalbard. Según Eva Bellemain, líder del equipo investigador, "no solo encontramos el ADN del oso, sino también el de una foca y una gaviota. El equipo de WWF que recogió las muestras pudo ver al oso cazando a la foca y, después, cómo varias gaviotas aparecían en el lugar para intentar participar en el festín, así que una sola huella da fe de toda la historia".

En un entorno tan lejano, aislado e inmenso como el Océano Ártico, que además está cambiando a gran velocidad, supone un gran reto mantener información actualizada y precisa sobre las poblaciones de oso polar. En abril de este año, un equipo de WWF-Canon se embarcó con el Instituto Polar Noruego en una expedición científica por el archipiélago de Svalbard (Noruega), para investigar cómo está afectando el cambio climático a esta región del mundo.

"Este método sería una herramienta muy útil para la biología de la conservación", dice Arnaud Lyet, de WWF. "En la actualidad, los científicos usan técnicas muy caras e invasivas para estudiar el estado de las poblaciones salvajes de especies como el oso polar. Tomando ADN de huellas, podríamos reducir notablemente el presupuesto necesario para investigar, con lo que sería más accesible estudiar las poblaciones de fauna". El equipo espera perfeccionar el análisis del ADN de oso polar para obtener más información sobre el animal. También se trata de descubrir si el método puede aplicarse a otras especies tan esquivas y difíciles de alcanzar como los osos polares.

Recuperado de: http://www.muyinteresante.es/naturaleza/articulo/aislan-por-primera-vez-adn-de-oso-polar-de-una-huella-en-la-nieve-601409668243

ACTIVIDAD

De acuerdo con la información anterior, responda las siguientes preguntas:

1. Teniendo en cuenta la lectura, ¿a qué se hace referencia cuando se habla de ADN?
2. ¿Qué encontraron los científicos en las huellas del oso?
3. ¿Por qué los científicos se interesaron en el ADN del oso?
4. Haga un dibujo que represente la idea que tiene usted de ADN.

Propósitos y Representaciones
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http://dx.doi.org/10.20511/pyr2016.v4n1.91

Appendix C.

OSOS POLARES, LOS REYES DEL HIELO

Aíslan por primera vez ADN de oso polar de una huella en la nieve

Un equipo de científicos franceses, en colaboración con WWF (Fondo Mundial para la Naturaleza), ha conseguido aislar por primera vez ADN de oso polar de una huella en la nieve. Los científicos analizaron dos muestras de agua tomadas de las pisadas del plantígrado, recogidas a principios de este año durante la expedición de WWF-Canon y del Instituto Polar Noruego al archipiélago de Svalbard. Según Eva Bellemain, líder del equipo investigador, "no solo encontramos el ADN del oso, sino también el de una foca y una gaviota. El equipo de WWF que recogió las muestras pudo ver al oso cazando a la foca y, después, cómo varias gaviotas aparecían en el lugar para intentar participar en el festín, así que una sola huella da fe de toda la historia".

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ACTIVIDAD

De acuerdo con la información anterior, responda las siguientes preguntas:

1. Describa, según el artículo, cuál fue el proceso que siguieron los científicos para extraer el ADN a partir de la huella del oso.
2. ¿Qué importancia tiene conocer la información genética de estos organismos?
3. Según lo presentado en el artículo y sus conocimientos, haga un esquema que represente la molécula del ADN y sus componentes.

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