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Título 1 Genetics of fingerprints and their use in forensic identification of individuals

Título 2 Genética de las huellas dactilares y su uso en identificación forense de individuos

Título 3 Xenética das pegadas dactilares e o seu uso na identificación forense de individuos

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Abstract

Fingerprints are one of the most reliable biometric identifiers, their characteristics and genetics are often unknown by the general public. By conducting a scientific dissemination workshop, we want to introduce the genetics and embryogenesis of fingerprints, along with their use in forensic science, to a general audience. A brief introduction about where do fingerprints come from, the different types we can find, and the definition of some genes that take part in the process, will be followed by a practical activity in forensic science. The workshop will include two different posters that will be use as a visual aid for a better understanding of the concepts exposed, with a practical activity of fingerprint sample taking for an interactive experience.

Keywords: Fingerprints, scientific disclosure, forensic science, magnetic graphite powder, magnetic graphite applicator, loops, whorls, arches.

Resumen

Las huellas dactilares son uno de los datos biométricos más utilizado, sus características y su genética son normalmente desconocidas para la población general. Mediante la realización de un trabajo de divulgación científica, buscamos introducir la genética y embriogénesis de las huellas dactilares, junto con su uso en ciencias forenses, a este público. Una pequeña introducción sobre el origen de las huellas dactilares, los distintos tipos que podemos encontrar, y la definición de algunos genes implicados en el proceso, será seguido por una actividad práctica en ciencias forenses. El taller incluirá dos posters diferentes que servirán como apoyo visual para un mayor entendimiento de los conceptos expuestos, junto con una actividad práctica de revelado de huellas dactilares para una experiencia más interactiva.

Palabras clave: Huellas dactilares, divulgación científica, ciencia forense, polvo magnético de grafito, aplicador de polvo magnético de grafito, bucles, verticilos, arcos.

Resumo

As pegadas dactilares son un dos datos biométricos máis utilizado, as súas características e a súa xenética son normalmente descoñecidas para a poboación xeral. Mediante a realización dun traballo de divulgación científica, buscamos introducir a xenética e embrioxénesis das pegadas dactilares, xunto co seu uso en ciencias forenses, a este público. Unha pequena introdución sobre a orixe das pegadas dactilares, os distintos tipos que podemos encontrar, e a definición dalgúns xenes implicados no proceso, será seguido por unha actividade práctica en ciencias forenses. O taller incluirá dous pósters diferentes que servirán como apoio visual para un maior entendemento dos conceptos expostos, xunto con unha actividade práctica de revelado de pegadas dactilares para unha experiencia máis interactiva.

Palabras crave: Pegadas dactilares, divulgación científica, ciencia forense, polvo magnético de grafito, aplicador de polvo magnético de grafito, bucles, verticilos, arcos.

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1. Introduction

1.1 Scientific disclosure in Spain

The definition given to the term disclosure by the Cambridge Academic Content Dictionary is the following, "something that was not previously known, or the act of giving such information to the public". In the Scientific world this is used to bring people closer to the latest discoveries and to keep them inform in a way that everybody understands.

Scientific disclosure has as its purpose the exposition and diffusion of the knowledge, culture, and technical and scientific thinking. This was one of the first definition of the term given by F. De Lionnais in a debate that took place in 1958 in France. This definition has been changing through the years and different authors have been complementing this statement. Raichvarg and Jacques published "Savant et Ignorants. Une historie de la vulgarization des sciences (1991:95-237)", where they divide the scientific disclosure into four groups: divulgation by writing, including magazines, diaries, encyclopedias… divulgation by speech, through courses, conferences, or radiophonic programs, withing others. Divulgation by images, with drawings, schemes, photographs, or scientific cinema. Lastly, they described divulgation by three dimensions, through exhibitions, scientific museums, and scientific laboratories, among others (Belenguer, 2003)

To understand the better way to introduce scientific topics into the population, we look into a study (survey) carried out by the Spanish government in 2020 about the social perception of science. It shows that the interest in scientific topics is far behind other subjects like health, economics, culture, or environmental sciences (Figure 1)

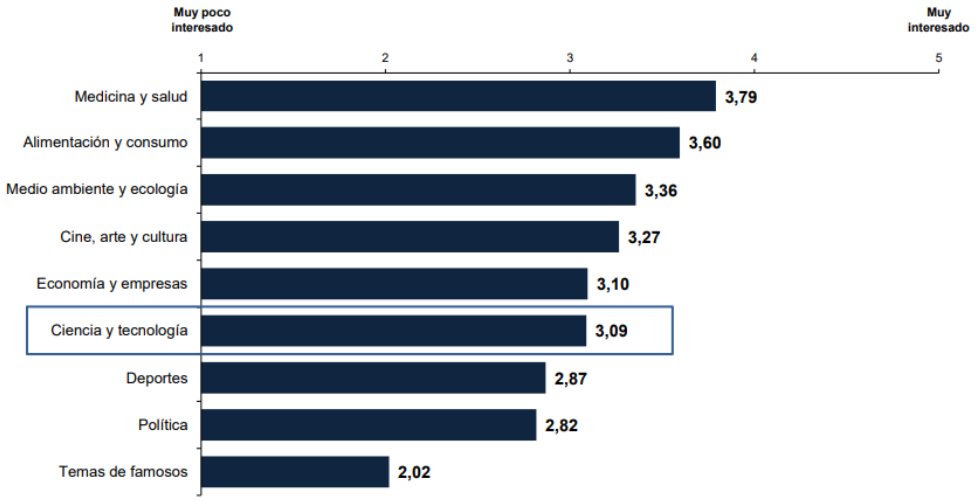


Figure 1. Degree of interest on different topics in spanish surveyed population (sample size of 7953 people) Taken from the X PSCT 2020 report , Fecyt.

In average, Spanish population is not very keen on any type of topic relating this field. Therefore, it is important to understand the areas where scientific disclosure has a bigger impact in society. When asked about the media they used to inform themselves about science and technology topics, the answers were the following (Figure 2):

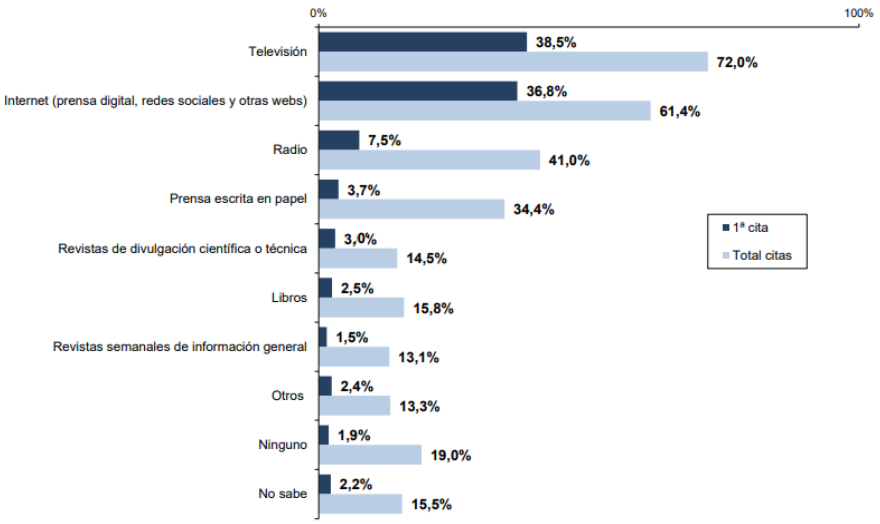


Figure 2. Media used by the spanish surveyed population to inform themselves about scientific and technological issues (sample size of 2019 people). Taken from the X PSCT 2020 report , Fecyt.

Television, internet, or radio have a significant greater impact on people than any other form of media. Within those who answer internet, social media is the main resource they use, followed by online newspapers, YouTube videos and Wikipedia. From this we can learn that scientific disclosure has adapted to the new era, and that the learning process is changing in the new generations. It is shown that the more specific and complex the scenarios are, such as conferences, seminars, congresses, or scientific papers, the more focus on a small percentage of people are. To widen up this spectrum it is important to develop multimedia material that reaches as many individuals as possible, and that makes them interested in the expose topics.

In this final project it is represented a scientific disclosure paper in the topic of genetics of the fingerprints, their development and use in forensic identification. Through the development of a scientific workshop, we expect to introduce the general public to the topic exposed.

1.2 Genetic of the fingerprints

Fingerprints represent a mean of individualization; each individual has a unique pattern. Every possible morphology comes from a genetic pattern, along with environmental factors. The ratio at which each one of these values acts is still not fully understood, but the underlying genetic pattern remains stable throughout a person´s life (Barnes, 2017).

The genetic pattern can form three different kinds of fingerprints patterns: arches, loops and whorls that can also have combinations between them (Barnes, 2017). Arches form a wave-like design, with ridges entering from one side of the fingerprint and exiting from the other. Loops are the most common type, making up to 60-70% of all the fingerprints. Ridges enter from one side, curve, and the exit from the same side. Lastly, whorls make a circular or spiral pattern (O´Brien & Murphy, 2020). With only these three patterns and their

combinations, there are several billion different designs that allow the differentiation and identification of individuals.

DNA is crucial for the formation of these designs, but it is also limited by the environment. The best example of the interaction between both factors is seen in monozygotic twins. In this case, both of them have the exact same genetic information, and the environment and characteristics inside the uterus are practically identical. Nonetheless, their fingerprints patterns, although similar, differ from each other (Barnes, 2017).

The main genetic force that acts on fingerprint regulation is still not fully known, but a recent study shows that "their pattern is produced by a Turing reaction-diffusion system operating in several spreading waves and triggered at distinct initiation sites" (Glover et al., 2023). In 1952, Alan Turing published a research paper in the field of mathematical biology where he first described the role of morphogens and the reaction-diffusion system. Morphogens were defined as signaling molecules that arise from random sources in the tissue and move away from the source. The addition of diffusion of morphogens at specific time points lead to the development of different patterns within the system (Turing patterns, 70 years later, 2002).

The complete set of genes implicated in the formation of dermatoglyphics is still unknown. However, different studies show genes with important roles in embryonic limb development as the principal determinants of heritable fingerprint variation (Li et al., 2022). Ectodysplasin A receptor (EDAR) is one gene that signals directly in the ectoderm surface, so it is likely that it influences the different patterns. The lack of function of this gene has shown abnormal fingerprints by a rare condition called hypohidrotic ectodermal dysplasia. In the earliest stages of development, ecotropic virus integration site 1 protein homolog (EVI1) promotes cell proliferation, and it may modulate the shape and size of volar pads (specialized regions of thickened skin found on the palms) by altering cell production (Li et al., 2002).

Another gene with an important role is a disintegrin and metalloproteinase with thrombospondin motifs 9 (ADAMTS9-AS2), a long noncoding RNA (lncRNA), which is widely expressed in fetal tissues. Emerging evidence points towards the potential involvement of this gene in the formation of whorls in human fingerprints (Walsh et al., 2016). In figure 3 we can see a table with a short description of these three genes.

Genes that show implication in the development of fingerprints and their pattern	
EDAR	Important during embryonic development. Takes part in signaling pathways between ectoderm and mesoderm
EVI1	Takes part in tissue development and promotes cell proliferation. Modulates shape and size of volar pads
ADAMTS9-AS2	Long noncoding RNA expressed in fetal tissues. It may take a big role in the formation of whorls in human fingerprints

Figure 3. Table showing three genes that are suspected to have a role in fingerprint formation and their different patterns.

1.3 Embryogenesis of the fingerprints

Fingerprints are formed during the fetal development through the process of embryogenesis, which is regulated by both genetic and environmental factors. During this time, a unique pattern of ridges is formed in an individual, at it will last throughout its life (Adamu & Taura, 2017)

Between the 4 to 8 week of embryological development the limbs start to form and at the end of the second month arms and fingers can be seen. It is not until the 10 weeks of estimated gestational age when friction ridges start to appear. As the embryo enters the second trimester, these ridges continue to mature under different extrinsic and intrinsic conditions. After this point, the development of the embryo is mostly finished, and any further changes are attributed to fetal growth rather than embryotic development (Barnes, 2017)

The unique arrangement of fingerprints is determined by the way the epidermis (outermost layer of skin) and dermis (layer of connective tissue beneath the epidermis) grow together. At 10^{th} week, the skin on our fingerprints consists of the layered epidermis on top of the more amorphous fibrous dermis (Adamu & Taura, 2017). By the 11^{th} week, the basal layer of epidermis begins to fold into de dermis, forming primary ridges that outline the future pattern of fingerprints and that will become well pronounced at the 16^{th} week. Over this time, the fingerprint pattern is fully formed and remains unchanged. (Adamu & Taura, 2017)

1.4 Use of Fingerprints in forensic identification

Biometric identification (automated recognition of individuals based on their biological and behavioral characteristics) is an essential component of forensic science, and fingerprints are one of the most reliable biometric identifiers used for this purpose (Jain & Ross, 2015). The unique fingerprint pattern of each individual makes an ideal tool for identification. By collecting and analyzing fingerprints, forensic experts can compare them to databases of known fingerprints and use them for the identification of an individual. (Jain & Ross, 2015).

Forensic science uses scientific methods to examine evidence found at a crime scene with the aim of reconstructing and describing past events within a legal context (Jain & Ross, 2015). Although there are several sources of evidence in this science, such as tyre marks, shoe marks, handwriting and many other, fingerprints are considered to be one of the most reliable ones. Fingerprints can either identify the suspect with high accuracy or exclude a potential suspect if there is no match between fingerprints (Jain & Ross, 2015).

However, this method is not infallible, human errors, poor quality fingerprints or intentional manipulations can occur. Furthermore, databases are only as accurate as the information they contain, and they might have some limitations (Jain & Ross, 2015).

Before the decade of 1960, fingerprint record collection was classified manually. This collection was used for individual identification, but it was time consuming and required high human resources. That is why it was necessary the automation of the system, a faster and more accurate way of identification (Barnes, 2017). For this, three main tasks were necessary. First, de development of a scanner that could capture de fingerprint image. Then, some kind of detector should identify exactly the different ridge characteristics and patterns in fingerprints. Lastly, a method for comparison between prints should be developed. This is how the Automated Fingerprint Identification Systems (AFIS) were born (Barnes, 2017).

2. Objetives

The objective of this paper is to introduce the general public to the fundamentals around the genetics and embryogenesis of fingerprints, as well as their use in forensic studies and identifications. The later will be exposed visually using different posters and through a workshop for a more interactive representation. This workshop will be adapted to the possible different age groups.

3. Material and Methods

To carry out this disclosure project, we propose the utilization of different materials and methodologies that will provide visual and practical support to accomplish the objectives outlined in the paper.

3.1. Scientific Workshop:

3.1.1. Posters: we will use two posters as visuals aids for a brief presentation about the generalities of fingerprints and their use in forensic identification. The first poster provides an overview of the three main properties of fingerprints that makes them indispensable in the field of forensic identification. Also, it outlines the three distinct systems observed in fingerprints, and points out the primary database utilized by the police for individual identification is Spain. The second poster describes the three main types of dactylograms and shows a table with seven main ridge characteristics, that will be used in the fingerprint development activity.

3.1.2. Fingerprint sample taking: Once we finish the initial explanation, we will continue with a practical activity of fingerprint sample taking. Each individual will develop their own fingerprint using the following materials:

3.1.2.1. Magnetic graphite powder: It will be use by each participant to allow the visual representation of their own fingerprint by developing an artificial dactylogram.

3.1.2.2. Magnetic powder applicator: Along with the magnetic graphite powder it will be use by each individual to allow visual representation of their own fingerprint.

3.1.2.3. Magnifying glass: As the main objective of the scientific workshop is for the public to differentiate between the basic ridge characteristics of their own fingerprint, a magnifying glass is required for a better visualization and understanding.

Figure 3. Materials use in the workshop. a) magnetic graphite powder, b) magnetic graphite applicator, c) magnifying glass

3.1.3. Worksheet: We will distribute a worksheet with some questions at the end of the workshop to see the implication of participants in the workshop.

4. Development

The structure and format of the scientific workshop would be as described in the following sections:

4.1. Posters

4.1.1 Poster 1: Main characteristics and properties of fingerprints.

The first part of the scientific workshop will consist of a brief introduction to the subject matter. We will begin discussing the main characteristics of fingerprints and how they take big part in forensic studies. For this purpose, we will use Figure 4 as a visual aid. Additionally, we will provide a brief overview of the genetics of fingerprints to understand the perpetuity property, follow by an explanation of the other two main properties: immutability and shape diversity.

Furthermore, we will see how a fingerprint is divided in three systems, marginal, nuclear, and basilar. Lastly, we will provide an introductory overview on the Automated Fingerprint Identification Systems (AFIS) program, the database use by the police in Spain for forensic studies. Throughout the discourse, everything will be disclosed in an accessible tone, ensuring that all participants can understand and participate in the scientific workshop.

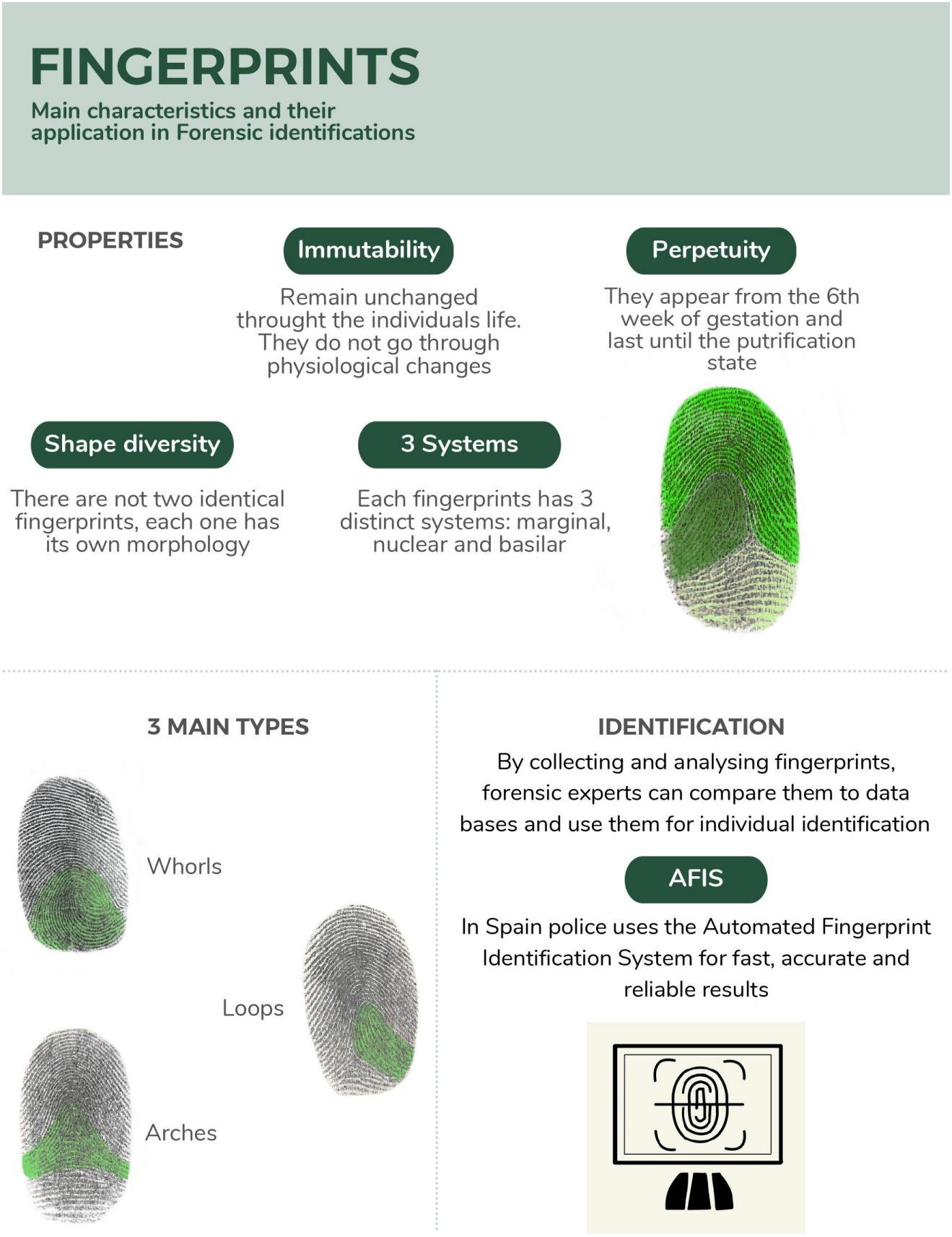


Figure 4. Introductive poster to fingerprints and their use in forensic studies.

4.1.2. Poster 2: Dactylogram

Once we make a brief introduction with poster 1 about fingerprints and their main characteristics, we will continue to talk about what is a dactylogram and the different types that exist, along with ridge characteristics. A dactylogram is originally described as the impression formed by the capillary ridges of fingertips of the hand, but there can be three different types: Natural, artificial, or latent. In this part we describe the three types, specially emphasizing in the artificial dactylogram, that is the one that we will perform during the workshop.

Then, we will show the table with the main ridge characteristics. We will briefly explain each one of them so they can search for them in their own fingerprint in the next activity. We will ask them to search for as many characteristics they can find with the help of a magnifying lens.

DACTYLOGRAM

Impression formed by the capillary ridges of the fingertips of the hands

3 TYPES

NATURAL Pattern form by capillary ridges in fingertips. We observe it directly

ARTIFICIAL Pattern achieved through the graphic reproduction of the natural, by impregnating the fingers in ink and putting them in contact with any surface

LATENT Pattern reflected through the impression made by the fingertips when contacted with a smooth surface

RIDGE CHARACTERISTICS

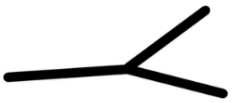
Bifurcation	Line that divides in two, forming and acute angle	
Island	Line between two parallel lines	
Bridge	Line that connects to parallel lines	
Dot	It is the minimal expression of a papillary ridge.	
Interruption	Line that is inturrupted once or more times along its path	
Enclosure	Eliptic space between two bifurcation lines that end up converging	
Deviation	Two lines from opposite sides go in different directions, leaving a blank space between them	

Figure 5. Second poster describing the types of dactylogram and seven main ridge characteristics.

4.2. Practical activity

After finishing the oral presentation, we will proceed with the second segment of the workshop, which is divided in two parts. Firstly, each participant will have the opportunity to develop their own fingerprint using the materials specified in section 3.1.2 of the scientific disclosure. Secondly, once they obtain a clear image of their fingerprint, they will identify the distinct ridge characteristic points of each fingerprint that make them unique from the rest, using Figure 5 to look for similarities. This will highlight why the fingerprints are such reliable indicators in the field of forensic science.

4.2.1. Fingerprint sample taking

For the procedure of fingerprint development, we will use the following materials: magnetic graphite powder and magnetic graphite applicator that will be used over a white sheet.

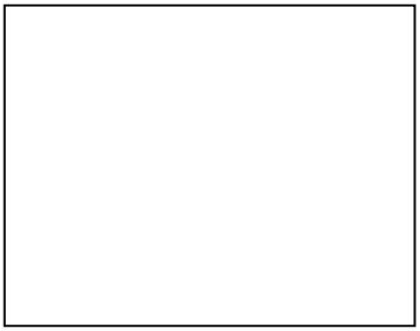
First, each participant will mark the space where they will place their fingerprint in the white sheet. Once they have this space, they will put the fingertip gently over the sheet, making a latent fingerprint. Next, they will take the magnetic graphite applicator and put it in the magnetic graphite powder container. This powder will magnetically join the applicator leaving a brush form. With this “brush” we will paint over where the fingerprint was placed before, allowing the development of the fingerprint, and making an artificial fingerprint. We can repeat this procedure as many times as we want until we obtain a clear image that will allow a later identification of the significant ridge points in fingerprints. Lastly, we will return the powder to its container by pulling up the upper part of the applicator.

4.3. Worksheet

Finally, after the oral presentation and the fingerprint sample taking, we will distribute a worksheet among the participants as the last activity. This worksheet contains seven questions about what was explained during the activity. This can show us the implication of the participants in the workshop and indicate us if there are some aspects to improve during future workshops.

FINGERPRINT DEVELOPMENT WORKSHOP

NAME: ……



Make an artificial dactylogram of your own fingerprint.

1. What are the main factors that interfere in the formation of fingerprints?

2. What are the three properties that make fingerprints good for individual identification?

3. What are the three types of dactylograms?

4. What can you identify in your fingerprint: Loops, whorls, or arches?

5. List the materials we use for the development of the artificial dactylogram.

6. When are fingerprints form?

- ☐ When we are born
- ☐ At around 10 weeks of gestational age
- ☐ At around 3 years old
- ☐ When we turn 18 years old

7. What ridge characteristics did you find in your own fingerprint? (Bridge, bifurcation, island, dot…)

Figure 6. Worksheet with different questions about the workshop and the oral presentation, that will be completed by the participants at the end of the activity.

5. Expected results

As we mentioned in the objectives, this paper wants to show to the general public some brief aspects about fingerprints and their use in a daily basis in a more entertaining way and accessible for all public. Our initial observation is that the majority of individuals do not have a clear idea of where fingerprints come from, or how they are useful in forensic studies. By the realization of a scientific workshop adapted for different age ranges, we expect to bring closer these terms to the group of participants.

The workshop was carried out in a group of 30 students and 5 adult individuals from the course of Clinical and Biomedical Laboratory, delivered by Cruz Roja. The workshop has a duration of approximately 30 minutes. We saw a high implication of the students throughout the duration of the activity, actively taking part in all the activities and asking questions related to the theme. By talking with them, we recall that they enjoyed the fingerprint sample taking the most, as it was something they had never seen or done before, and that they were able to take home with them. As for the worksheet, it was shown that it was a good moment for assimilation and accommodation of the ideas presented before, as most of them were able to respond to all seven questions just by listening to the initial presentation.

By the realization of this paper and this workshop we hoped to introduce the general public to the basis of fingerprints, their characteristics and their use in forensic studies. The results show a positive reception of the workshop by the participants, and an interactive way of carrying out this purpose. We would say that the purpose was accomplished and that the workshop could be carry out again, hoping for similar results.

Resultados esperados

Como mencionamos previamente en los objetivos, este trabajo pretende enseñar a un público general algunos aspectos sobre las huellas dactilares y su uso en el día a día, de una forma más interactiva y accesible al público de distintas edades. Nuestra observación inicial es que la mayoría de los individuos no tienen una idea clara acerca de dónde proceden las huellas dactilares, ni de su uso en ciencias forenses. Mediante la realización de este taller científico pretendemos acercar estos términos a la población general.

El taller se llevó a cabo con un grupo de 30 estudiantes y 5 individuos adultos del curso de formación de Laboratorio Clínico y Biomédico, impartido por la Cruz Roja. Este taller tuvo una duración aproximada de 30 minutos. Observamos una gran implicación de los estudiantes durante toda la duración de la actividad, activamente formando parte de las actividades propuestas y realizando preguntas relacionadas con el tema. Hablando con ellos pudimos observar que la parte que más disfrutaron fue la de revelado de huellas dactilares, ya que se trataba de una actividad que nunca habían realizado. En cuanto a la ficha final, pudimos ver que se trataba de un buen momento de asimilación y acomodación de las ideas previamente expuestas, ya que la mayoría de los participantes pudieron responder sin

problema las siete preguntas.

Mediante la realización de este trabajo y taller científico esperamos introducir al público general a las bases de las huellas dactilares, sus características y su uso en estudios forenses. Los resultados muestran una buena recepción de la actividad por parte de los participantes, así como una forma interactiva de llegar al objetico propuesto. Diríamos que el objetico se ha cumplido y que el taller se podría volver a llevar a cabo, esperando resultados similares.

Resultados esperados

Como mencionamos previamente nos obxectivos, este traballo pretende ensinar ao público xeral algúns aspectos sobre as pegadas dactilares e o seu uso no día a día, dunha forma máis interactiva e accesible ao público de distintas idades. A nosa observación inicial é que a maioría dos individuos non ten unha idea clara acerca de onde proceden as pegadas dactilares, nin do seu uso en ciencias forenses. Mediante a realización deste taller científico pretendemos acercar estes termos á poboación xeral.

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Mediante a realización deste traballo e taller científico esperamos introducir ao público xeral ás bases das pegadas dactilares, as súas características e o seu uso en estudos forenses. Os resultados mostran unha boa recepción da actividade por parte dos participantes, así como unha forma interactiva de chegar ao obxectivo proposto. Diríamos que o obxectivo cumpriuse e que o taller poderíase volver a levar a cabo, esperando resultados similares.

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