optics & photonics focus

# Forensic Optics: Transforming a Hair into a Travel Log

Solving crimes usually requires a lot of time and complicated investigations in order to find clear evidence. Now, it is possible to gather information about a suspect's travel history simply by analyzing their hair.

The unchanging difficulties of solving a crime: culprits rarely confess and dead people do not speak. Yet, somehow, the puzzle needs to be solved. Science has always been a key factor in the never-ending struggle for solving crimes. Researchers led by Rebeca Santamaria-Fernandez LGC in Teddington, London (United Kingdom), in collaboration with the University of Oviedo (Spain), has shown that isotope analysis of a hair sample can tell where a person has been traveling or recently changed diet, adding to the ever-growing scientific repertoire of a modern-day Sherlock Holmes.

Solving crimes often relies on associating unique features to people; a method that has been used in many ways by many civilizations throughout time. Around 4000 years ago the ancient Babylonians were using fingerprints to validate contracts. By the 13th century, fingerprints were used in many different cultures to authenticate documents. Throughout history, the uniqueness of fingerprints played an important role for proving authenticity and uncovering guilt. The Chinese have used them to convict criminals for over 1500 years and to this day, law enforcement and security personnel use this biometric feature to authorize access to secured facilities and to condemn murderers.

Criminal investigations always involve a multitude of aspects and typically identify a lot of evidence before a case is closed. Fingerprints can mistake a friend for the killer or, worse still, they can trap an innocent adversary into a complicated murder case. The truth is that fingerprints, like most clues, can be avoided, misinterpreted, or even faked. Circumstantial evidence, therefore, needs to be interpreted and backed up by collecting as much evidence as possible. Once this is done, the art is to identify where the evidence points to and, from this, to draw the right conclusions. The twentieth century has brought about many scientific and technological breakthroughs that are adding to the number and accuracy of circumstantial evidence. The most famous of them, DNA analysis, utilizes genetic information of an individual to prove match traces at a crime-scene with suspects. But sometimes, there are no DNA samples available or nobody to match them to. Criminal investigators, therefore, need a variety of techniques to solve their cases.

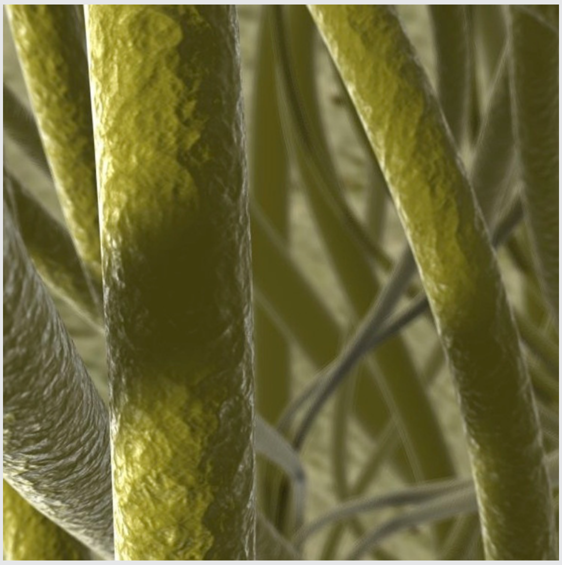

**Figure 1: Strains of hair.** A laser removes the outer parts and creates an aerosol of the inner, clean constituents of the hair. Isotope analysis of the constituting atoms then reveals if a subject has travelled recently or not.

"The human body is made of water, body fat, bones and proteins," Santamaria-Fernandez explains," and continuously produces cells, hair and fingernails." Our bodies take up the raw materials used for this lifelong production through our breath and diet — our lifestyle leaves traces. "Keratin, for example," she adds, "is an extremely strong protein which is a major component in skin, hair, nails and is made up of aminoacids containing Carbon, Nitrogen, Sulphur and Oxygen. It is therefore possible to study the isotope proportions of the constituting elements and extract information about food preferences or geographical origins. Since hair is produced continuously, we can potentially tell if somebody has, in fact, travelled recently!"

Isotope proportions are like a geographic fingerprint of an object. The chemical properties and the name of an atom are defined by the number of protons in its core. Therefore, when talking about Oxygen, Nitrogen, Sulphur, Carbon, and all other atoms we automatically know how many protons they contain - by definition. An atomic core, however, is not only made of protons but usually contains roughly the same number of neutrons also. Atoms of a certain type, for example Sulphur atoms, containing different numbers of neutrons are called isotopes. "The proportions of the isotopes that make up an element", Santamaria-Fernandez continues, "vary in nature due to fractionation processes. Therefore, measuring these variations, we can obtain information tracing the origins of foodstuffs, the authenticity of wines or pharmaceutical drugs."

Technically, the isotope analysis was achieved by coupling a laser ablation system to a mass spectrometer. A mass spectrometer is analyzing the atomic masses of a sample and can distinguish different isotopes because a larger number of neutrons in the core leads to a higher atomic mass. "The laser," Santamaria-Fernandez says, "makes contact with the selected fraction of the hair, eliminates surface contamination and generates an aerosol containing Sulfur (from the keratin), which is later ionized within a plasma mass spectrometer. This measurement provides the exact proportions of the Sulfur isotopes in the hair along the length, which may vary slightly from one individual to another and even within one hair strand."

The proof of concept experiment shows that isotope analysis ratio measurements can, indeed, give insight into the hair's travel log. For their study, hair samples of more than 4cm in length were collected from three volunteers. Two were permanent residents in the United Kingdom, and one had spent the previous six months living in Croatia, Austria, Australia, and the United Kingdom. Human hair grows between 0.5cm and 1.5cm per month. The collected 4cm segments therefore corresponded to 3-8 months of the subject's past. The experiment revealed that the traveler's hair did, indeed, show significant variations in the Sulphur isotopes over the length of the hair, while changes in the hair samples of the two people living in the United Kingdom were minimal, and similar in both cases. "Even if a more extensive study with hair samples from a significant number of volunteers should be performed," Santamaria-Fernandez is convinced, "the results shown in this work illustrate the ability of the method to measure longitudinal variations in human hair strands from different individuals and the potential correlation between geographical movements and variations in Sulphur isotopic composition."

The development of an effective method to measure longitudinal isotope variations in hair was the key to extracting geographical movements. "The next objective," Santamaria-Fernandez says, "is to demonstrate the global significance of these variations, and we are already working with hair samples from 150 volunteers with different diets and geographical origins in order to move forward in this area." In addition to Sulphur, her group is planning to measure isotopic variations of other Keratin constituents like carbon and nitrogen, hoping to observe a clear correlation between samples from different regions or even dietary preferences. All of this would tremendously improve the accuracy and impact of geographic studies using isotopes.

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Rebeca Santamaria-Fernandez, Justo Giner Martínez-Sierra, J. M. Marchante-Gayón, J. Ignacio García-Alonso & Ruth Hearn, **Measurement of longitudinal sulfur isotopic variations by laser ablation MC-ICP-MS in single human hair strands**, Analytical and Bioanalytical Chemistry (2009) **394**, 225–233.