



The trace in the technique: Forensic science and the Connoisseur's gaze

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ABSTRACT

Both scientific art investigations and forensic investigations rely on observation, inferential reasoning, and analytical techniques to answer questions concerning identification, source, and activity. The forensic scientist and the art connoisseur evaluate the whole—a crime scene or work of art, respectively—and draw meaning from the often-overlooked details, or traces, contained therein. This manuscript considers the correlations between art connoisseurship and forensic science, first by outlining the history of connoisseurship, focusing on the detection and evaluation of traces through patient observation, reasoning, and comparison based on methods established by Giovanni Morelli in the nineteenth century. This article then explores connoisseurship and forensic science within the historical sciences framework, based on the process in which observable traces can be ordered to provide a reconstruction of unobservable past events. Finally, this article asserts that art can be used to shape and refine the scientist's practiced eye, thereby improving trace detection and interpretation in investigations.

1. Introduction

There are myriad connections between fine art and the criminal justice system, from investigating art crimes (e.g. forgery, theft, looting, vandalism, destruction, illicit trade, smuggling and trafficking); to managing the physical security of museums and cultural heritage sites; to developing criminological and psychological profiles to understand the art thief or master forger. Art investigations can be criminal or non-criminal in nature, and may include addressing matters of repatriation, conservation, restoration and attribution. There exist clear similarities between the practices of museum sciences and forensic science (both in the laboratory and in the field), specifically with analytical techniques and methods employed—visual examinations, microscopic examinations, chemical analyses, and analytical instrumentation are common factors in the analysis of objects that are of importance to the laboratory scientist, whether the context is one of forensic or cultural heritage concern. Perhaps less obvious are the similarities between fine art and forensic science when considering methods of observation, reasoning and interpretation, specifically with respect to the development and evolution of art connoisseurship. The idea of connoisseurship as a scientific endeavor is aligned with the view that crime scene investigation is also an intellectual and scientific endeavor [1], built on those same observation and reasoning skills expected of the connoisseur. Viewing

the crime scene as a work of art, the forensic scientist becomes the connoisseur, evaluating the whole scene and drawing meaning from the often-overlooked details, or traces, therein [2].

The purpose of this manuscript is three-fold. First, to outline the (discrete) history of the systematic approach to connoisseurship and its relationship to the development of forensic science. This is done by focusing on observation, reasoning and traces. In essence, the crime scene, when viewed as a work of art by the educated and experienced forensic scientist, can be subject to trace detection philosophies that were critical to the development of connoisseurship and forensic science (historically under the discipline of criminalistics).¹ Second, this essay explores connoisseurship and forensic science within the historical sciences framework. This is done by demonstrating that observations and interpretation of relevant traces, established as facts, can contribute to an order of events in such a way to provide a narrative that lends itself to attribution and reconstruction. Last, by demonstrating associations between observation, reasoning and historical sciences in art connoisseurship and forensic science, this manuscript proposes an overarching epistemological framework for forensic science in order to effectively educate forensic scientists and apply forensic science in a meaningful way. By considering the evolution and foundations of art connoisseurship, this manuscript looks towards opening dialogue concerning how forensic scientists know what they know about past criminal events

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¹ Criminalistics [the German *Kriminalistik* as coined by Hans Gross [86] in 1893; the French *Criminalistique* used by Edmond Locard in the early twentieth century (c.1920); and the English version utilized by Paul Kirk in the mid-twentieth century, (c. 1947)] is the scientific discipline concerned with the detection, recognition, identification, individualization, and interpretation of (physical and digital) traces, and aims to aid criminal investigations through crime scene reconstructions.

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through the detection and interpretation of traces. Moreover, this manuscript highlights that within this framework, art serves an important role in the development of the forensic scientist's practiced eye. This manuscript begins by addressing terminology to situate the reader.

2. Terminology and framework

Presently, authenticity (or the process of authentication) and attribution (the process of identifying the artist) consists of connoisseurship, historical documentation (provenance), and analytical (scientific) testing. The approach presented here focuses on paintings of old masters (e.g. Botticelli, Rubens) in keeping with the subsequent section on the history of connoisseurship.

Connoisseurship is the endeavor to identify artworks by time, culture and authorship ([3]; p. 137). Brown [3] further adds that connoisseurship operates within an art historical context, identifying facts (who, when, where), and determining whether other circumstances of production including motive (why) may contribute evidence toward the essential goals of identification (p. 138).² Connoisseurship is historically based on visual inspection centered on well-developed observation skills and an intuitive impression of the work of art. In her tribute to art connoisseur Giovanni Morelli, Lady Eastlake [4] outlined the 'non-scientific' approaches to connoisseurship, explaining the pitfalls that can be encountered with attempting to assign attribution with these approaches (Table 1). Ultimately advocating for Morelli's 'scientific' approach to identifying the artist of a painting through systematic identification of details within the work of art, Eastlake asserted "For the picture is the only unimpeachable witness; all the rest is more or less circumstantial evidence" ([4]; p. 241). This echoed Morelli's claim that "the only true record is the work of art itself" ([5]; p. 26–27). Furthermore, it aligns with Kirk's [6] view of traces within the scene of the crime: "(Evidence) is not absent because human witnesses are. *It is factual evidence ... Only its interpretation can err. Only human failure to find it, study and understand it, can diminish its value*" (p. 4, emphasis in original).

For a long period of time, the intuitive general impression was the

Table 1

Eastlake's [4] ordered approaches to connoisseurship. Eastlake adds that connoisseurship is fallible, and that there are no guarantees in assigning attributions using these approaches, whether "singly or together" (p. 239–240).

Order	Approach	Comments
1	Intuition	Intuition/instinct/general impression; cannot distinguish an original from a copy or works between the scholar and the master
2	Knowledge of technical processes which the accredited works by the same master exhibit	Based on comparison; May identify a school, but not the specific artist
3	Signature of a painter by his own work	Can be misleading or wrongly interpreted; Forgeries are also possible, therefore signatures must first be authenticated [Also includes initials, monograms, cyphers, icons, inscriptions, abbreviations, dates]
4	Historical Record via books and documents	Authors can exaggerate, lie or be mistaken in their reports
5	Tradition	Literary accounts can be false

² This posing of questions has also been approached in the forensic science framework (Margot, P., Miranda, M., Crispino, F., Lucas, D., Roux, C., De Forest, P., Willis, S. The Questions of Forensic Science: Quintilianus Revisited, Panel Discussion, International Association of Forensic Sciences 21st Triennial Meeting, Toronto, CAN.).

primary means by which attributions were assigned to artwork. Over time, this approach was subjected to increased scrutiny amid questionable conclusions lacking any sort of support other than the connoisseur's trained eye and 'feeling;' and the discovery of new information (e.g. the unearthing of historical records and/or the results of modern scientific testing) that disclosed definitively incorrect attributions. Being viewed as non-scientific, the esoteric intuitive approach to attributions was supplanted first by efforts to find concrete support for attributions through more nuanced visual examination of the artwork—the identification of details that could be used to substantiate the connoisseur's assignments. Such systematic approaches became the cornerstone of describing a scientific approach to attributions—conclusions required observable evidence from the work of art and articulation of the means in which the connoisseur arrived at their conclusions (often through comparisons with other works). Essentially, the connoisseur needed to observe, generate hypotheses, and draw meaningful conclusions from those observations using analytical reasoning by relying on the work itself and its similarities and differences to other works of art. Moreover, the connoisseur had to be able to articulate to others the methodology used to arrive at their final conclusions. This ushered in the foundation of a scientific approach to attributions.

According to Brown [3]; "attributions on the basis of connoisseurship of the eye can enjoy a high degree of rational credibility only if documented by specifying the observable features that undergird the general impression and [when] reinforced by evidence of other kinds" (p. 147). These reinforcements include provenance and analytical testing. Provenance is concerned with the history of the object, chronologically, from its creation through transferred ownership, akin to evidentiary chain of custody records. Provenance is established through documents and records (e.g. production records, archived transactions, bills of sale). In some cases, the documents themselves may require authentication or skilled interpretation. "Written documents are only of value in the hands of a scientifically trained and competent critic" ([5]; p. 26). With advancements in technology, scientific testing has emerged as a powerful technique in art connoisseurship; techniques include imaging (e.g. macrophotography, infrared photography and reflectography, x-ray imaging, the utilization of alternate light sources [e.g. ultraviolet induced fluorescence]), chemistry, microscopy and instrumentation incorporating separations (e.g. chromatography) and spectroscopy (both atomic and molecular techniques). During his 2013 lecture entitled *Connoisseurship: The Rembrandt Paradigm*, David Bomford succinctly described modern-day connoisseurship as "old school connoisseurship [backed up with] technology" [7]. Utilizing examples of works attributed (or misattributed) to Rembrandt during his lecture, Bomford described a connoisseurship evolution occurring with the introduction of x-ray and infrared imaging to the interpretation of works of art, adding that this ushered in a new set of visual criteria by which style, technique and authorship was to be judged—going below the surface beyond the paint and brushstrokes on the top—which has become the focal point of technical art history [7]. Technical art history unites "conservation, scientific examination and art history" to generate new information about works of art ([8]; p. 51). This approach allows for reassessments of attributions through the introduction of data derived through technical and scientific tools and techniques. Moreover, technical art history allows for a comprehensive and informed reconstruction of events surrounding a work of art (see Ref. [9]; who directly equates the work of the technical art historian to forensic analysis). Much like forensic science, technical art history exists with the specter of uncertainty. Technical analysis "speaks in terms which must be interpreted and whose significance may be imperfectly misunderstood" ([10]; p. 11).

Authentications have the ongoing potential of being disproven on the basis of new information. This highlights the importance of pursuing lines of inquiry in connoisseurship, both cross-sectional and longitudinal examinations, as the discovery of new documents and works of art as well as advancements in technologies occurring with the passage of time

may bring to light new knowledge that could impact decisions about attributions. Connoisseurs and forensic scientists should be mindful of new evidence as it arises and of developments within their disciplines, as new findings can restructure and impact earlier investigations and interpretations. “Art historians, like police investigators, depend heavily on totally unexpected and unearned revelations to crack hard cases. Absent such serendipities, refractory cases usually are never solved, partly because the passage of time progressively destroys whatever hidden evidence there was earlier. On the other hand, a revelation is never strictly impossible even after all the known trails of evidence have proven unproductive” ([3]; p. 146).

This manuscript draws parallels between the art connoisseur and the forensic scientist, specifically the generalist forensic scientist.³ The generalist forensic scientist is an individual possessing a broad knowledge base grounded in science and knowledge of criminal investigations, criminology and behavioral sciences, forensic science, criminalistics, crime scene investigations, and traces.⁴ The generalist uses scientific methodology (defined here as iterations of observation, inferential reasoning [abduction, induction and deduction], hypothesis generation, testing) to guide their inquiries and decisions when applying this methodology to forensic investigations. In terms of traces, which are broadly defined as often overlooked details within a work of art or crime scene, the generalist forensic scientist goes beyond the knowledge of what traces are and how they can be analyzed in a laboratory to understanding the nature of traces and the environment in which they are found.⁵ This includes the creation of traces (deposition, retention); the discovery of traces (detection, recognition), and the interpretation of the traces to assign meaning (significance, relevance, and probative value).⁶ The discovery of traces at a scene (much like the discovery of traces in a work of art), requires exceptional observation skills and analytical reasoning skills in order to interpret traces to elicit meaning and significance. Such skills of observation and reasoning are the key to recognizing patterns and making meaningful comparisons to determine a common source in an effort to identify, classify and move towards individualization.⁷

The role of the generalist forensic scientist has much in common with

³ Throughout the remainder of this manuscript, references to forensic scientist are synonymous with the generalist as defined here. The converse to the generalist is the specialist, who is a scientist or technician specialized in one discipline or technique (e.g. DNA analyst; SEM operator). In general, ‘scientific investigator’ is used to include generalist forensic scientists and art connoisseurs.

⁴ The fundamental ideas behind criminology and the behavioral sciences can be applied to art attributions as well—consider the perpetrator’s or artist’s tools, techniques, styles and conventions (*modus operandi*; *oeuvre*).

⁵ Malcolm et al. [63] define the scene as a collection of objects or shapes; typically containing a large variety of items that are arranged in a meaningful manner containing a spatial layout that organizes the scene into foreground objects and background elements; observers act upon objects but act within scenes (p. 844).

⁶ Margot [48] described traces as the vestiges or mark of a presence, an existence or an action, having a sign whose signification may not be clear, yet it can be decoded to bring knowledge and meaning (p. 74). The trace represents any part of the whole (work of art, scene of a crime)—a brushstroke, underdrawings, a fabric impression or finger mark, a layered paint chip, an adhering fiber, etc. For a discussion of trace exchange, see Ref. [64]. For specific analytical approaches to some commonly encountered traces (hairs, fibers, tape, paint and glass), see Trejos et al. [65].

⁷ A foundational concept in forensic science (criminalistics), Kirk’s [66] view of identification and individualization (what is referred to as Kirk’s individuality principle) states that “a thing can be identical only with itself, never with any other object, since all objects in the universe are unique” (p. 236). Attempting to determine uniqueness (or assert that the trace will have a shared uniqueness with its source) is a process and not an end goal. Comparisons between a trace specimen (“questioned”) and a potential source (“known” or “standard”) are thus reported with some indication of uncertainty.

Table 2

Demonstrating the similarities between the general analytical processes utilized in technical art history and forensic science investigations towards goals of identification (attribution) and reconstruction. As the forensic scientist and technical art historian work through their analytical schemes, they reframe their hypotheses, develop additional questions, and consider the context of the traces within the broader framework of the investigation (and even broader matters within their disciplines). Note: Lists are general and not exhaustive. Specific analytical methods and standard operating procedures will vary depending on the trace material being examined (paint chips, fibers, fingerprints, gunshot residue, etc.) and the questions being asked in the context of the investigation (*What is it? Does it have a common source to another object/trace/material, etc.?*).

Technical Art History	Forensic Science
<i>Visual Examination</i> (work of art) Collection of material traces	<i>Visual Examination</i> (crime scene; object) Collection of physical traces
<i>Visualization Techniques</i> e.g. raking light; infrared photography & reflectography; x-radiography, microscopy (SM, PLM, SEM)	<i>Visualization Techniques</i> e.g. oblique illumination; infrared photography & reflectography; luminescence (UV fluorescence), microscopy (SM, PLM, SEM)
<i>Chemical Analysis</i> e.g. solubility, ion detection, enhancement	<i>Chemical Analysis</i> e.g. solubility, ion detection, enhancement
<i>Instrumental Analysis</i> e.g. IR, Raman, XRD, XRF, GC-MS, etc.	<i>Instrumental Analysis</i> e.g. IR, Raman, XRD, XRF, GC-MS, etc.
<i>Other</i> Dating e.g. dendrochronology, radiocarbon Comparisons	<i>Other</i> Comparisons

the art connoisseur, who requires a broad knowledge base that includes art, history, artist’s materials and techniques, and scientific analyses (Table 2). According to Constable [11]; “The placing of a work of art calls for wide general knowledge” adding that “it is essential that the art historian should realize the extent of the ground he has to cover and should know where to turn for the information that he wants” (p. 40). Brown [3] asserts, “Education and training needed by the aspiring connoisseur includes general cultural knowledge, extensive knowledge of art history ... observation and hands on experience ... For connoisseurship as a whole, to this can be added the knowledge and skills serving the connoisseur’s purposes coming from other fields” (p. 172). The art connoisseur is expected to be skilled in observation and reasoning in order to uphold connoisseurship as a scientific endeavor. “The education of the professed critic in art is essentially the same as that of the student in the exact sciences. Nothing is left to feeling, predilection, or wish—his stand must be taken upon a slowly gathered accumulation of facts, each one resting securely on that beneath it. Works of art must be treated as organic remains, subservient to some prevailing law, which it is the critic’s task to find out and classify by a life of observation and comparison” ([12]; p. 467).

For the art connoisseur and the forensic scientist, comparisons between objects are essential to their attributions (the connoisseur looking to identify the artist and the forensic scientist seeking to identify the perpetrator). For the forensic scientist, an identification may be straightforward when biological traces point to a single perpetrator. Conversely, an identification may be more complex in light of multiple contributors, environmental factors and contamination concerns. For both the forensic scientist and art connoisseur, evaluation and interpretation of circumstantial clues from physical traces may render such conclusions even more complex—for example interpreting accidental markings on a footwear impression or specific details in underdrawings, respectively—thereby requiring additional information from outside sources to support conclusions (in the case of the forensic scientist, this may be the discovery of digital traces placing the perpetrator at the scene, while in the case of the art connoisseur, this may be the discovery and authentication of records detailing authorship). Exclusions to both

the art connoisseur and forensic scientist can be meaningful in an investigation. Both comparisons and exclusions rely on memory, observation, and knowledge (a combination of education, training and experience).⁸ In affirming the importance of a broad knowledge base and the power of exclusion, Brown [3] notes, “A connoisseur confronting a work brings a complex set of posits from common and technical knowledge from many areas, in and beyond art and art making. One result of this is that whole regions of possibilities of authorship, period, and culture are ruled out at a glance since there will be massive incompatibilities between features of work and large stretches of art history, both temporally and geographically” (p. 144).

3. Historical background

In a series of publications beginning in 1978, Carlo Ginzburg described an epistemological model based on the detection of often overlooked details, drawing in part on analogies between art connoisseurship and detective fiction ([84]; 1983; 1989). For the connoisseur trying to identify the artist, these details were hidden in the works of art; and for the detective searching for the perpetrator, the details were left behind at the scene of the crime. Both the connoisseur and the detective investigate using evidence (details, traces) that is imperceptible to others ([13]; p. 97). For the connoisseur, such easily overlooked details included the artist’s brushstrokes, the casting of shadows, or the folds in drapery. For the detective, these details included hairs left behind on an object, a faint drag mark on the floor, or a void where an object once stood.⁹ In order to draw meaningful conclusions from investigations, the scientific investigator, whether connoisseur or forensic scientist, must be equipped with the tools of observation and inferential reasoning.

3.1. Observation

The discovery of traces, whether in a work of art or in a crime scene, requires the power of observation. Historically, observation was the key component of naturalists and collectors, as observation led to knowledge. Naturalists and biologists strove to understand nature and did so by studying objects, both the whole and its parts. Attempting to classify flora and fauna meant focusing down to fine details of the specimen, comparing and contrasting with other specimens, both similar and dissimilar, and identifying patterns to assign taxonomic rank. Professor and naturalist Louis Agassiz (1807–1873) became known for his approach to gaining knowledge by looking. Agassiz’s teaching was based on the idea that the more one looks, the more one sees [14]. Continued observation

⁸ I would like to distinguish three types of training here. First is short-term training on a specific topic that can last from hours to a few weeks. These trainings may include a one-day instrument training course or a two-week training workshop on bloodstain pattern analysis; these are often marked as continuing professional development for the forensic scientist. Second is longer (6 months to 1–2 years) on-the-job training that may include a series of workshops, laboratory-specific exercises, and supervised casework prior to independent lab work. This training is often one-time at the start of a forensic scientist’s employment or introduction to a new discipline. With the third (and linked to the concept of practice described with art connoisseurship), training is an ongoing process of indeterminate time—the connoisseur is always training his/her eye, continuously studying works to refine their knowledge base. This latter ‘lifetime’ training may distinguish the scientist from the technician and the idea of forensic science as a professional career versus an occupation.

⁹ Utilizing visual enhancement techniques such as infrared photography and reflectography extends the capabilities of the connoisseur (technical art historian) and detective (forensic scientist). Such applications allow the technical art historian to resolve details such as artist’s underdrawings obscured by layers of paint and varnish; enable the forensic scientist to resolve gunshot residues (smoke, gunpowder) obscured by dark or patterned clothing; and aid the investigator in the resolution of tattoos in human remains obscured by decomposition or mummification.

of a specimen and comparison to others that had been similarly studied allowed one to detect and recall details and consider the relations between features and specimens, ultimately resulting in classifications and taxonomic assignments.

The idea that observation was important for acquiring knowledge was not exclusive to the scientist. In 1798, Johann W. von Goethe (1749–1832) remarked, “He whose vocation is to be an artist should pay vital and constant attention to everything around him, observe closely all objects and their parts, and by making practical use of what he has experienced, come to observe ever more sharply, first on his own behalf, but later for such information as he will gladly give to others” ([85]; p. 3). Goethe’s assertion extended beyond the artist simply being accountable for creating a work of art. Art required observation, interpretation and reflection, and to do so meant that one must draw on attention to detail. Moreover, Goethe’s artist must be able to communicate his observations and reflections to others.

The approach to assigning attributions goes back to the early 17th century, when Giulio Mancini (1559–1630) added a few remarks in his 1620 text *Considerazioni sulla pittura* about distinguishing original works from copies—such clues were apparent in the details of the hair, beard, eyes and folds of the garments ([15]; p. 191–192). Moreover, Mancini noted that it was possible to determine the period and age of the painting if the observer possessed experience and knowledge of “various kinds of painting from different times” ([15]; p. 190). Mancini laid the groundwork for the role of the art connoisseur and began the process of developing an epistemological framework—in order to effectively recognize important details and compare paintings of different artists and different time periods, the art connoisseur required a practiced eye and education, training and experience of a broad range to contemplate the meaning of his observations. In 1719, Jonathan Richardson’s (1665–1745) *Two Discourses* on art connoisseurship were published. Richardson viewed connoisseurship as a science based on critical thinking, reasoning, and methodology; he presented an organized, systematic approach to connoisseurship: Conceive, Distinguish, Methodize, Reason, (See Ref. [16]; p. 202). According to Richardson [16]; “The first thing then to be done in order to become a good connoisseur one’s self is to avoid prejudices and false reasoning” (p. 17), adding later on the importance of observation and attention to detail,

... to be able to distinguish betwixt too things of a different species (especially if those are very much unlike) is what the most stupid creature is capable of—as to say this is an oak and that a Willow—but to come into a forrest of a thousand oaks, and to know how to distinguish any one leaf of all those trees from any other whatsoever, and to form so clear an idea of that one and to retain it so clean (as if occasion be) to know it so long as its charactersisticks remain requires better faculties than every one is master of; and yet this may certainly be done ([16]; p. 201).

Richardson’s approach to the scientific connoisseur is directly aligned with Agassiz’s approach to prolonged study through looking as well as Kirk’s individuality principle (see footnote 7)—to distinguish a willow and oak is a relatively simple matter that does not require much effort; but to distinguish one leaf from another in a forest of oak trees requires practiced observation and memory. Much like Mancini, Richardson [16,17] further laid the groundwork for the role of the art connoisseur and contributed the process of developing an epistemological framework, this time highlighting attention to details, reasoning, conducting meaningful comparisons and the importance of memory.

The most notable figure in the development of a systematic approach to art connoisseurship is Giovanni Morelli (1816–1891). Morelli is credited with developing and disseminating his experimental method of assigning attributions to the works of old masters based on observation and comparison [5,18–20]. According to Morelli, “It is my object to make you notice everything in a work of art, and in time you will come to see that even details, in themselves insignificant, may lead us to truth

...” (1900, p. 47). Noting that his method was not infallible, Morelli asserted that it was better than the existing general impression approach, which was based on the observer’s initial wave of emotion when viewing the work—it was not enough to assert that a painting “felt” like a Botticelli (the problematic “*I know it when I see it*”).¹⁰ By applying Morelli’s method as an aid to connoisseurship, attributions could be much more robust. Much like Richardson, Morelli believed that there were two types of observers, the average physical observers (Richardson’s “stupid creatures”) and the mental observers that can detect those details that a physical observer would overlook or render meaningless.¹¹ According to Morelli, these observers were distinguished by intense, long term study, “The eye must be trained by long and constant practice” (1893, p. 3). Such practice was not meant to be confined to works of art, but should extend to all things and should persist throughout the connoisseur’s lifetime, as refining perception requires persistent effort ([3]; p. 167). There exists a clear distinction between the casual observer and the trained observer. “Anyone with well-ordered intelligence and a commitment to sifting out the facts can theorize, provided that enough evidence is at hand; the well-endowed investigator with relevant experience in the field can make plausible connections from results to causes. But only the master of observation can tell which bits of a disordered presentation are clues” ([21]; p. 47).¹²

Morelli believed that the development and refinement of the practiced eye coupled with comparison by observation and reflection was necessary to the scientific approach to connoisseurship. Moreover, constant observation and reflection strengthen imagination and reasoning through experience, and by continually looking and finding details, the viewer can effectively distinguish observations (facts) from interpretations, which may be ‘tainted’ by individual bias. Coupled with developing and refining observation skills, the scientific investigator must be aware of observer limitations and biases. Maginnis [22] addressed observer limitations in connoisseurship; what we do (or do not) see can be a function of vision, image formation, perception and associated cognitive processes (therefore generating cognitive biases). Additional matters to consider include attention, continuous development of observation skills (practice, training), memory (experience, education), pattern detection, inquiry, and communication and collaboration with others to exchange observations and interpretations. According to Maginnis, a modern approach to connoisseurship means understanding that what we see is influenced by our expectations and intentions and that visual discernment can be improved with practice (1990, p. 113). According to Goethe,

But who will not admit that unprejudiced observations are rare than is generally believed? We are so ready to interject our own fancies, opinions, judgements into what comes to our notice, that we do not long remain quiet observers, but begin to reflect. But we should lay no great weight on these reflections except insofar as we can rely on the nature of training our minds (1980, p. 4).

Considering the attention to observation in art studies and connoisseurship, have forensic scientists overlooked the importance of observation and the need to develop a practiced eye? In forensic science,

¹⁰ “The method of study which I have recommended must not ... be held responsible for the mistakes which I made ten years ago. On the contrary, in nearly every instance where I have been misled in forming a judgment upon a picture, I had either misapplied the method or had not made use of it all. Of course ... I do not pretend to say that it is infallible for in no branch of science is there any infallible method” [20].

¹¹ Morelli describes these as “hypercritical observations” (1900, p. 45).

¹² While this historical overview focuses on Morelli, it is worth mentioning the work of Mau van Dantzig (1903–1960), whose pictological approach to attributions was centered on the study of artistic and non-artistic depictions in paintings, both in the overall work and in its details in an attempt to determine authenticity and quality [67].

especially crime scene investigation, technical matters of searching and documenting (note-taking, sketching, photographing) have become part of a method broadly considered crime scene processing. Searching for traces and objects within a scene has become akin to an “Easter egg hunt” and not one that requires reflection and study based in observation and reasoning. It is here where forensic science can learn from the history of art connoisseurship and the method of Morelli. Crime scene investigation requires consideration of trace creation, and the detection and recognition of traces within the scene requires the development of a practiced eye. What renders Morelli’s method scientific in part is that it needed to be understood—it requires explanation on the front end to teach the fledgling connoisseur and it requires explanation on the back end when the connoisseur is articulating the reasons for assignment of attribution. This presents additional questions. Does the forensic scientist, or crime scene investigator, understand what makes them mental observers, or what guides their reasoning and decision-making at the scene when reflecting upon, interpreting and assigning relevance or meaning to traces?

Focused attention to observation and detail within forensic science has been somewhat fragmented, broad and multidisciplinary, with focus on the detection of traces on or within substrates ranging from the human body [23,24] to dust [25,26].¹³ Most notably, clinical attention to forensically-relevant details on the human body was explored by Alphonse Bertillon (1853–1914). In the 1896 English translation of *Bertillon’s Identification Anthropometrique-Instructions Signaletiques* focused on detecting and measuring human features, the American publisher preface reads,

A word must be said about the altogether special and indispensable value of this work to detectives, who by its use will cease to depend upon accidental clues and vague intuitions and surmises, and to be constantly led astray by general resemblances of physiognomy, but will be able to find and to recognize the objects of their search with almost mechanical accuracy. From this point of view the Bertillon system may justly be called the detectives art raised to the level of an exact science (p. x).

While many texts related to detection and investigation remarked on the need for the detective-investigator to have observation skills, the topic of observation and developing such skills was oftentimes not explored further.¹⁴ Some exceptions exist.

In his 1920 text, Locard weighed in on observing, addressing the importance of observations in the early stages of an investigation as well as the pitfalls of observations impacted by perception, memory and experience. Locard [27] asserts that one can learn to observe—by

¹³ These attributes were also a central component of nineteenth century detective fiction. The most well-known example is Arthur Conan Doyle’s fictional character Sherlock Holmes, which was based in part on Conan Doyle’s mentor, physician Joseph Bell. Holmes, who has become a cornerstone of forensic science despite being a fictional character, was not only able to detect subtle traces at a crime scene, but he was known for his ability to ‘read’ individuals based on physical details that were often overlooked by the casual observer (see Refs. [68,69]; see also [24] for a ‘real-world’ approach to identifying and interpreting observational markings). In mentioning Sherlock Holmes here, it is worth considering the role of detective fiction in forensic science, which begs the question: if a writer of detective fiction can explain methods of detection and reasoning, shouldn’t forensic scientists (or crime scene investigators) be able to articulate their day-to-day application of similar methods? In attempting to build an epistemological model of forensic science, studying detective fiction (specifically utilizing select detective fiction that highlights observation and reasoning) allows for approaching and understanding method.

¹⁴ Interestingly, in the 1934 English edition of Hans Gross’s *Handbook*, despite a section entitled “Differences in the Observing Powers Resulting from Differences in the Natural Qualities and Intellectual Culture of the Observer” (located in the chapter pertaining to the examination of witnesses), there is no further development of observation or its utilization outside of witnesses (p. 58).

looking and comparing features, the trained observer can learn how to distinguish between different objects (p. 85).¹⁵ William Dienst, professor of criminology, began his 1952 text with a chapter entitled ‘Observation and Description.’ According to Dienst (and in alignment with connoisseurship), observation includes seeing both the whole picture and the many details that make it whole, and “nothing will develop the power of observation more quickly than ... practice” ([83], p. 3). Not only does Dienst address how to observe, he also highlights “situational factors causing inaccuracy in observation” and perception (p. 5). These factors include the emotional state of the observer; the nature of the situation; the predispositions of the observer; focus of attention; past experiences; rushing to completion; and resultant errors including substitutions, transpositions, focused attention, transmission of information, incompleteness or simplification, and complete confidence. Considering these factors, it becomes apparent that each observer brings different dispositions and experiences to the scene (or a work of art). As such, each observer will select and prioritize different observations to frame their interpretations.¹⁶ Dienst cautioned the reader to avoid assumptions and jumping to conclusions, asserting that observation in investigative work means seeing accurately and completely. Training, practice, and the ability to describe one’s observations are critical to the investigator. In his 1970 text (originally published in 1956), NYPD detective Charles O’Hara also included a chapter entitled ‘Observation and Description.’ According to O’Hara, “The accuracy of [the investigator’s] observations will depend chiefly on his training and experience ... He must be trained to describe as well as observe” ([89]; p. 587). O’Hara describes the process of observation as including attention, perception and reporting, with perception subdivided into intelligence, educational background, experience and occupation (p. 588).

For the scientific investigator, careful study through observation and comparisons aids in the observer’s ability to distinguish meaningful (or relevant) traces from the background, or environment in which they may be found. Such power of discrimination between traces within an environment (whether a work of art or a crime scene), requires context and knowledge of the environment being observed. These concepts were explored by Morelli and are the basis for his methodology.

3.2. From Morelli’s method to technical art history

In the second edition of his first book focused on Italian Galleries, Morelli (who wrote under the pseudonym Ivan Lermolieff) included a ‘Principles and Methods’ section to explain and clarify his approach to attribution. Morelli believed that in order to gain knowledge, the connoisseur needed to be in the gallery to observe and experience works of art, rather than relying solely on books. To Morelli, continuous study—identifying, comparing and distinguishing—leads to the trained and cultivated eye. By cross comparing works of art, it is possible to distinguish different masters (artists), different schools (mentors, pupils, imitators/forgers/copiers, other masters), and different time periods. It should come as no surprise that Morelli studied under Agassiz and picked up his attention to looking and comparing in order to classify objects. Morelli took Agassiz’s study of nature (e.g. fish) and transposed it on the study of art. Agassiz’s influence is clear, as Morelli refers directly to Agassiz in a footnote, “... observation and comparison being ... the intellectual tools most indispensable to the naturalist ...” to which Morelli parenthetically adds, “... the art connoisseur too” (1900, p. 74).

¹⁵ “On peut apprendre à observer ... Ainsi l’observateur exercé saura discerner dans chaque objet, dans chaque fait ce qui importe au point de vue de l’enquête.”

¹⁶ Weber [70] describes the idea that in light of differing interests and points of view, what is “historically interesting” will differ for individuals (p. 173). This necessitates an approach to evaluating the concerns of actors within either a singular case or the broader criminal justice system (forensic scientists, police investigators, lawyers, policymakers, etc.).

Morelli asserted that the general impression of the connoisseur was misleading and untrustworthy, with intuitive impressions and judgments differing for each individual, resulting in variation in conclusions (1900, p. 29). To Morelli, one could not begin to be meaningfully intuitive if not carefully trained in the study and observation of works of art. Morelli did not completely write off the intuitive general impression, indicating that may lead to school (classification, or identification) and may lead to a sufficient guess as to the master, but there will still be doubt and uncertainty (moving toward individualization). Most importantly, attributions made solely by natural intuition (“la tournure de l’esprit”) did not allow for scientific certainty ([5]; p. 71). As an alternative to the general impression, Morelli believed that the way to scientifically assign attribution was to move from the overall painting down to the fine details, which served as subtle clues indicative of the artist, as “almost every painter has his own peculiarities which escape him without being aware of it” ([5]; p. 75). According to Morelli’s scientific connoisseurship, details aiding in distinguishing the works of a master from an imitator add substantive information to what would otherwise be a subjective assessment. These details (traces), were less likely to be carefully reproduced by the copier or forger (Fig. 1). For the connoisseur, this meant consideration of often overlooked details within works of art; knowing how to discover them and committing to studying a variety of works (by the master and other artists) to compare and contrast these subtle details seemingly hidden within the works. Table 3 outlines the observational methods of attribution as described by Morelli, with attribution assignments becoming more robust as one works their way down the table.

It is important to note that Morelli does make mention, albeit brief, of “technical qualities,” or laboratory analysis of paints and varnishes (1900, p. 32). It is not surprising to see laboratory analysis techniques largely absent from Morelli’s text (and [4] recapitulation) based on the time period in which these connoisseurs were writing relative to the technology available at the time, compared to the principles and practices of technical art history.¹⁷

In his second book focused on German Galleries and in light of criticisms in response to his earlier publications on method, Morelli asserted in a footnote at the start of the text, “It has been asserted in Germany that I profess to recognize a painter solely by the form of the hand, the fingernails, the ear, or the toes in his work. Whether this statement is due to malice or to ignorance I cannot say; it is scarcely necessary to observe that it is incorrect. What I maintain is that the forms in general ... aid us in distinguishing the works of a master from those of his imitators and control the judgment which subjective impressions might lead us to pronounce” ([20]; p. 2). It is not merely the traces that decide the attribution, it is the totality of all parts—including the whole work and the contextual considerations that function to shape attributions. There are limitations to Morelli’s approach to attributions, many of which Morelli noted in his texts. Limitations mentioned by Morelli that can also be extended to forensic science include decisions in assigning relative weight/importance of details and observation conditions (e.g. lighting).

The Berensons, Bernard (1865–1959; also written as Bernhard) and Mary (1964–1965; neé Smith, who also went by Costelloe and Logan) extended Morelli’s work, advocating for and advancing the idea of scientific connoisseurship. Bernard highlighted the importance of methodology [28,29] explaining that the procedure requires “good average powers of observation ... concentration and reasoning of the kind that the botanist or anatomist is supposed to have [and] training in the historical method, that method which teaches not only how to weigh evidence ... but how to recognize what is relevant when it appears, and how to look for it when it hides” (1927, p. vii). According to Berenson,

¹⁷ Much like advances in technology have impacted art attributions, so too has forensic science been impacted by technology (e.g. the evolution from ABO blood typing to DNA typing).

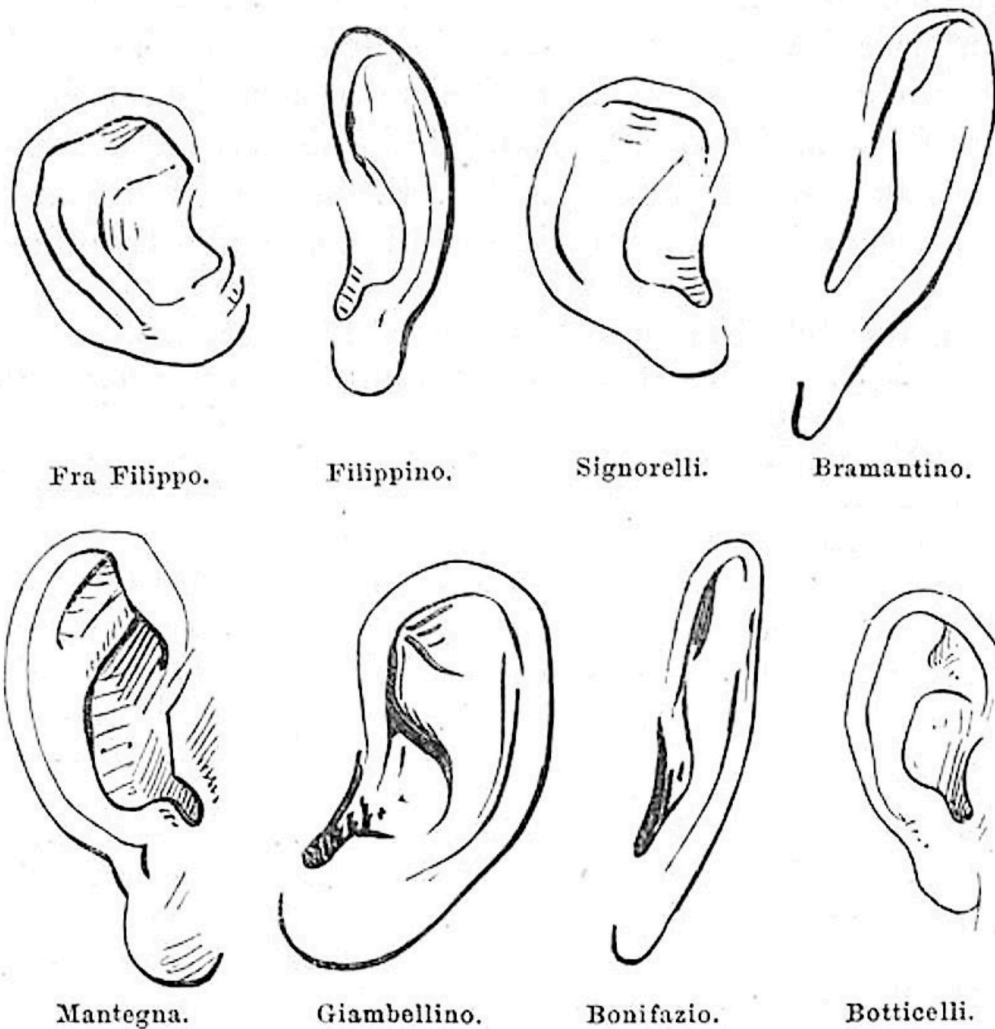


Fig. 1. Morelli's [Lermolieff's] sketches of ears characteristic of Italian painters. Close examination of the details of a work of art, such as the ear, would facilitate attribution, as the forger or copier was less likely to pay such attention to detail when reproducing the work of the master ([19]; p. 99). [Image: Public Domain].

connoisseurship was comprised of pre-scientific and post-scientific guessing, in which pre-scientific guessing believed in magic and relied on inspiration while post scientific calculates (1927, p. x).¹⁸ Like Morelli, Berenson believed that comparisons and the development of the practiced eye by observation were essential to assigning attribution (Table 4). Berenson advocated for the study of early drawings of the artist in addition to their works on view to further cultivate the practiced eye and detect those details that were unique to an artist. Moreover, he felt that understanding the historical context in which the artist worked was critical, as this could aid in distinguishing masters from their followers or competitors. Mary (writing as Logan) supplemented Morelli's approach and expanded on this inclusion of history within connoisseurship with what she described as 'The New Art Criticism.' Logan [30] believed that in order to understand and apply the new criticism, the connoisseur would need to consider the influences on the artist and where the artist stood in relation to those influences at the time the artwork was made. As such, to make such determinations under the new

art criticism, the student-connoisseur must have historical knowledge and recourse to sociological, political, literary, religious and philosophical information to determine what may have shaped the artist's way of seeing, expressing and executing the work [30]. This framework is interesting in that it ties to the 1911 work of forensic scientist and criminologist Rodolphe Reiss (1875–1929) [91] in applying a criminological approach to forensic science, as external forces may bear on criminal behavior and actions, impacting the traces left behind at a crime scene (see also [31]).

Critical of Morelli and the Berenson's approaches to connoisseurship, Max Friedländer (1867–1958) believed that first impression, based on intuition, was the determining factor in connoisseurship. Friedländer [32] felt that the connoisseur worked from an inner certainty acquired through an impression of the whole, with the decision based on feeling that could not be described adequately. "It is one's own impression of the entire picture which decides" authorship ([32]; p. 196). Friedländer conceded that scientific approaches are useful, but they were much more useful for conservation efforts than identifying the artist, as they could

¹⁸ References to science and magic (unexplainable phenomena) are connected to the idea that Sherlock Holmes had divinatory powers of detection. These can be linked to Peirce's ideas of reasoning (abduction) and imagination (see Ref. [69]).

Table 3

Morelli's [5] approach to assigning attribution as described in his *Principles and Methods*. Evaluating technique and form, or the study of individual parts, meant looking beyond the overall painting to gradually observing, comparing and thinking about the details within the work of art. Of these details, Morelli felt that the most expressive feature (and thus the most indicative of the artist) was the head (face) followed by the hands.

Approach	Comments
Assessment of the Overall Painting	General impression (includes intuition)
Characteristic Features	Whole character Composition Choice and conception of the subject matter Colors, shadows
Details	Overall appearance of subject (portrait), children, angels Human frame: Positioning (leg, arm); action, pose, expression, countenance, movement Drapery, landscape, architectural background, accessories Details in objects: book, magnifying glass, bell, clothing (fur, sleeve), carpet Hand, fingers, nails, nose, ear, head, mouth, arm, face, thumb, eyes, brow, lips

Table 4

Berenson's [28] approach to attribution as described in his essay *Rudiments of Connoisseurship*.

Approach	Comments
Documents, Signatures, Dates	Can be problematic (absent, forged)—subject to authenticity and accuracy; "The mere document cannot by itself perfectly determine the authenticity of a picture, because it can never be trusted" (1902, p. 115)
Tradition (Historical Writings)	Subject to the trustworthiness of the writer (and they often cannot be trusted)
The Work of Art	The best evidence and only source of reliable information Reliance on Aesthetics (instinct/intuition) "the feeling ... the spirit", as "it is impossible to put one's finger on certain morphological details" (1902, p. 125) Reliance on Quality "The sense of Quality is indubitably the most essential equipment of a would-be connoisseur" (1902, p. 147); Quality does not fall under the category of demonstrable things (1902, p. 148)

only facilitate attributions by limiting time and place of an artwork's creation.¹⁹

In general, there are occasions where attributions have been found to be incorrect, with changes in attributions resulting from newly discovered (or interpreted) historical records; the discovery of new paintings by a master that indicate a change in style; or through scientific analysis resulting from advancements in science and technology. The application of emerging scientific techniques to matters of attribution supported the introduction and evolution of what is presently referred to as technical art history [33–36]. Technical art history has allowed for an extension of observation methods by applying technology to look beyond the surface of a work of art. Specifically, non-invasive techniques utilizing x-rays and infrared radiation have extended the ability of the scientific

¹⁹ Within his 1942 text, Friedländer describes the connoisseur as a historian using archaeological methods and *a posteriori* deductions via an analyzing eye (p. 247); as a criminologist when detecting forgeries (p. 258); and as a cunning detective (p. 204). Bernard Berenson also referred to the historical application of connoisseurship as an archaeological method (1927, p. vii). For more information, refer to the historical sciences section of this manuscript.

investigator to observe beyond illumination techniques with white light sources (e.g. raking light, or oblique illumination). According to Faries [35]; in light of such advancements, "attribution is no longer so much a matter of individual pronouncement, as technical evidence lends itself to discussion and consensus building" (p. 80).²⁰ Moreover, as demonstrated by Bomford and his 2013 lecture on Rembrandt's works and Ainsworth's work with *Early Netherlandish Paintings* (2001, 2005b), technical art history has both enlightened and challenged connoisseurship and resultant attributions.

3.3. Traces in forensic science

The idea that Morelli's approach was connected to forensic science was not lost on members of the art community. In 1894, art critic Whibley stated "[Morelli's] method is the anthropometry ... of art criticism; he has applied the Bertillon system to pictures" ([95]; p.335) (Fig. 2). In 1913, art historian Tietze remarked, [Morelli] "wanted to create a Bertillonage style of criticism, not only concerned with obtaining the characteristic traits of the criminal in question, but indisputable individual marks as well ([93]; p. 335; translation by author).²¹ It is interesting that in this passage by Tietze, there is mention of both characteristics (identification) and individualization, linking to the principles that have become the cornerstone of forensic science as delineated by Kirk (1902–1970) in 1963 (see footnote 7). Direct correlations between Morelli's reliance on traces within artwork and the principles of traces within the forensic sciences as established by both Lord and Kirk are apparent (Table 5).

Much like a connoisseur viewing traces within the context of the work of art, the forensic scientist must consider traces in context to the crime scene. During a crime scene investigation, questioning (*who? what? where? when? and how?*) coupled with inferential reasoning methods can frame the prioritization or focus of trace analysis. For example, knowing the suspect and victim were domestic partners sharing a residence may render swabs taken from various locations at the scene for biological (DNA) analysis non-probative because of the relationship between the two individuals. What may be more probative is an examination and interpretation of the non-biological, physical traces found on objects within the scene or on the individuals themselves. Context becomes important when distinguishing the details from the background and the meaningful traces from those that have no significance. Margot [38] indicates that "the environment is full of traces from 'normal' uses and activities" that occur within the scene (p. 33). Moreover, Margot refers to the scene's historical record, which is a function of the background and traces that provide signs, or clues that need to be discovered. As a vestige, the trace is framed in a historical context, providing both source and activity information that can be

²⁰ It is worth noting that the shift to technical art history has not only addressed recent and long-standing matters of attribution, but has also helped to shape and redefine art in its historical framework by posing new questions about the production, treatment and value of art over time as well as artist's methods and influences (for additional information, refer to Refs. [35,36,71] and their respective references). What resonates for both technical art history and forensic science is Ainsworth's [71] statement, "... authorship, however, is not the conclusion of [the] investigation, but rather the beginning of research ..." (p. 113). In applying this sentiment to forensic science, identifying the perpetrator is only a part of the investigation—investigations include laboratory analyses of traces (in support or refutation of identity, presence and/or actions); the reconstruction of events from the aforementioned analyses and the larger criminal investigation; the communication of findings and interpretations in court; and any research endeavors that may arise from questions posed during the case (e.g. population studies), the latter of which may have bearing beyond forensic science into broader criminal justice matters.

²¹ "Er wollte ein Bertillonage der Stilkritik schaffen; und so we if dieses die charakteristischen Züge des betreffenden Verbrechers feststellt sondern nur ein indiskutables individuelles Erkennungszeichen erlangen will."

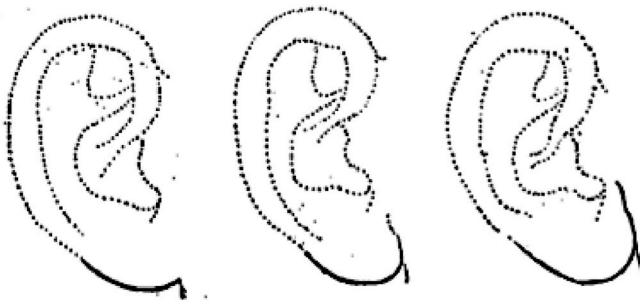


Fig. 14. — *Lobe à adhérence fondue, intermédiaire et séparée.*

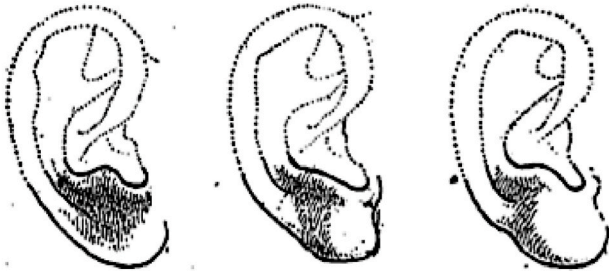


Fig. 15. — *Lobe à modelé traversé, intermédiaire (ou uni) et en éminence.*

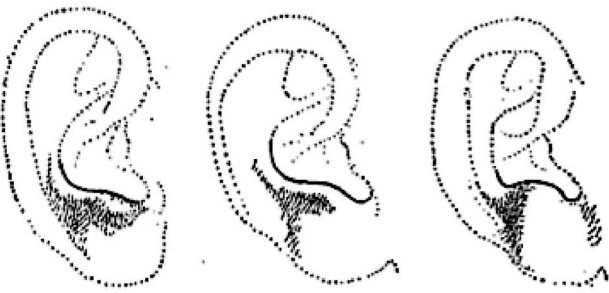


Fig. 16. — *ANTITRAGUS versé (en dehors), à renversement intermédiaire et droit.*

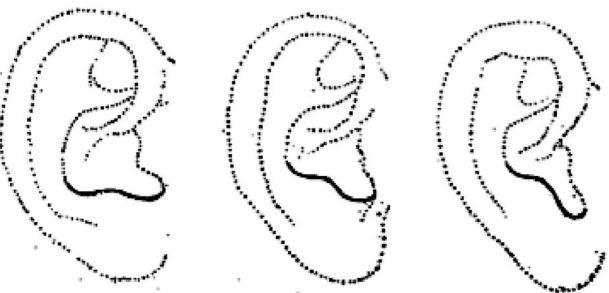


Fig. 17. — *ANTITRAGUS à inclinaison horizontale, intermédiaire et oblique.*

Fig. 2. Bertillon's sketches, descriptions and comparisons of ears, which were utilized to record the anthropometric features of criminals for identification purposes ([37]; p. LII). [Image: Public Domain].

elucidated if properly detected and interpreted. Constable [11] asserted, "more important and decisive is the way in which all the details of the work are brought together, the way the parts are related, and the weight given to the various elements" (p. 44), with Brown [3] enforcing 70 years later that no item is evidential of anything in the abstract, by itself, but only in the context of the total system of knowledge (p. 144).

Table 5

Trace principles.

Morelli [20]	"It is my object to make you notice everything in a work of art, and in time you will come to see that even details, in themselves insignificant, may lead us to truth ..." (p. 47)
Locard [27]	"The truth is that no one can act with the intensity required for criminal activity without leaving multiple signs of his passage [...] The clues I want to speak of here are of two kinds: Sometimes the criminal has left signs of his presence at the scene (by his actions); sometimes, alternatively, he picks up on his clothes or body signs of his presence or of his actions. Left or taken, these marks are of extremely different sorts" (p. 139; trans. from French)
Kirk [6]	"Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as silent evidence against him. Not only his fingerprints or his footprints, but his hair, the fibres from his clothes, the glass he breaks, the tool mark he leaves, the paint he scratches, the blood or semen he deposits or collects – all these and more bear mute witness against him. This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It is <i>factual evidence</i> . Physical evidence cannot be wrong; it cannot perjure itself; it cannot be wholly absent. Only its interpretation can err. Only human failure to find it, study and understand it, can diminish its value" (p. 4)

3.4. On intuition

The idea of assigning attribution based on the viewer's general overall impression of the artwork (intuition, hunch, or feeling; "I know it when I see it") is suggestive of divination or magical powers, and is rooted in conjecture [13,39]. Ginzburg expands on this, utilizing Voltaire's 1747 tale *Zadig* to articulate how what appeared to be magical powers of divination were actually based on the detection and interpretation of signs. Morelli's methods were critical to the larger framework of conjectural knowledge and semiotics. According to Ginzburg [39]; "Morelli's idea was to trace out within a culturally determined sign-system the conventions of painting, signs which like symptoms (and like most clues) were produced involuntarily ... in these involuntary signs, in the tiny details, Morelli located the most certain clue to artistic identity" (p. 104).²² In 1880, Huxley described this method, highlighting "incessant and patient" observation and reasoning backwards from effects to causes ([88]; p. 136). Despite the ability of authors of detective fiction to describe their methods, connoisseurs, forensic scientists and law enforcement investigators have had some challenges in articulating how they arrived at their hunches. Bernard Berenson described himself as having a sixth sense [40]; p.19), which did not sit well with critics in the court case concerning the

²² With regard to symptoms, Ginzburg [39] further draws connections between Morelli (details) and Holmes (clues) with medical diagnosis through the observation and interpretation of symptoms (Ginzburg refers to this as medical semiotics; see also Manetti [72]; who describes the history and fundamentals of judicial semiotics). For Ginzburg [13]; these connections are based on similar methods of seeking knowledge across disciplines [The idea that signs (whether in a work of art or in a crime scene), are subject to interpretation through conjecture is the overarching theme of the text edited by Eco and Sebeok [73]]. Beyond the details described in Morelli's methods of attributions, there are myriad signs, symbols, features and clues located in works of art that can lend themselves to assigning time period and attribution. These include signatures, emblems, heraldic symbols (a herald is in itself a sign), inscriptions, and specific iconography indicative of historical, political, religious, literary, allegorical, and societal matters. Reading paintings "involves making delicate discriminations and discerning subtle relationships, identifying symbol systems and characteristics within these systems and what these characters denote and exemplify, interpreting works ..." [74]. Goodman [74] adds that such actions involve experience and skill—when these 'grow,' so too does our understanding and reappraisal of symbols within the work. This approach, which connects directly to the importance of continuous study to develop the practiced eye and improve our knowledge based on training and experience, can be broadened to include all traces, extending beyond works of art to forensic science.



Fig. 3. Sidney Paget's sketch in the *Strand Magazine* of Sherlock Holmes examining the preserved, severed ears sent in a package in *The Cardboard Box* ([44]; p. 64). Ginzburg [39] points out that in this scene, Holmes is "Morellizing" when examining and comparing the details of the ears (p. 82). Holmes determines that the ears were similar to those of the woman who received the package, indicating familial relation between the victim and the recipient. [Image: Public Domain].

controversial attribution of the painting *La Belle Ferronnière*. Friedländer [32] described his process as "unconscious comparison with an ideal picture in my imagination" (p. 174), rooted in imagination derived from pleasure, contemplation and memory. "If someone tells me he owns a *Still Life* by Frans Hals ... I conjure up, without having seen a *Still Life* by Frans Hals, an idea which serves as a standard as to whether I accept or reject the picture when it is shown to me" ([32]; p. 176). While the crime scene investigator is not captivated by the beauty, or aesthetic elements of a crime scene, the investigator may develop an impression of the overall scene based on what it conveys to the viewer. This impression will be guided by knowledge, imagination and experience, potentially distinguishing the scientific investigator from the crime scene technician. While the latter follows prescribed iterations of documentation, collection, and packaging of obvious items, the former uses observation and reasoning to guide their detection of meaningful traces. As the connoisseur tries to assess the motivation of the artist, the scientific investigator considers criminal behavior and the resultant mechanisms of trace deposition as they move about the scene.

If we accept that there is an element of intuition that goes into investigations, then we must be prepared to understand and explain its origins, and follow up conclusions with facts—in other words, intuitive notions require firm epistemological grounding.²³ Kuhn describes aesthetics as a tool for scientist's attempts at problem solving, being utilized to choose between competing hypotheses—"a criterion of choice between theories which are in other respects comparable, or a guide to the imagination seeking a key to the solution of an intractable puzzle ..." ([41]; 405). Kind [42] asserted that crime investigation is based on intuition, and intuition leads to asking relevant questions (p.15). For

Brown [3]; the life of the conscientious connoisseur is a constant exercise in confirming and correction her intuitive perceptions at all levels; no *je ne sais quoi* should be accepted as the final word (p. 166–167).²⁴ As observed with the *Flora Wax Bust*, (see below) scientific analyses will continue to challenge attributions based on the connoisseur's intuitions and hunches.

4. Connoisseurship and forensic science as historical sciences

The forensic scientist, like the connoisseur, works within the framework of the historical sciences. This concept was explored by Ginzburg [39,43]; who described a historical process in which observable traces can be ordered to provide a narrative, or reconstruction, of unobservable past events. By inferring from remnants of past activity (traces), the historian, connoisseur, and forensic scientist interpret and explain utilizing scientific methodology. Historians have long equated traditional historical sciences with detection and investigation, and Ginzburg elaborated on the link between Morelli (searching for details in works of art) and Doyle's fictional detective Sherlock Holmes (searching for clues in investigations) (Fig. 3). Holmes's observation and inferential reasoning skills (abduction, induction and deduction) as applied to the intellectual endeavor of crime scene investigation made for direct correlations with forensic science and the call for scientists (generalist forensic scientists) at the scene of the crime [1]. Much like

²⁴ "Given that an individual connoisseur's intuitive perception is sufficiently stable and important to weigh heavily in her mind regarding an attribution, there is reason to expect that intensive, protracted, freely experimental, collegial effort by the connoisseur and others will develop a descriptive practice (aided by ostension) sufficient both to convey the property the connoisseur discerns and to reveal at least many of the local features on which it depends ..." [3].

²³ See, for example, [75].

the generalist forensic scientist, “It is indispensable that the historian possess at least a smattering of all the principle techniques of his trade, if only to learn the strength of his tools and the difficulties of handling them” [45]; p. 68). In recent years, the idea of forensic science as a historical science has been addressed by academics [46–49,92], often focusing on the work of Cleland [50–52],^{25,26}

Historical sciences are based on problem solving; asking questions about past events and answering them with selected facts arranged and adjusted to form of an explanatory model, which is then articulated in the form of a reasoned argument ([53]; p. xv). Cleland [52] describes historical inquiry as the development of competing hypotheses to explain a puzzling body of traces (effects of past events) discovered in the field followed by the search for and selection of the hypothesis that provides the best explanation for the total body of traces (p. 4).²⁷ The historian [scientific investigator], according to Cleland [50] formulates multiple competing hypotheses about particular past events; searches for, analyzes, identifies and interprets traces; and directs efforts towards reconstructing events based on the relevant traces. Researchers may fail to recognize the significance of traces, may not have formulated the correct hypotheses (or, asked the right questions), or may lack the theoretical understanding necessary to connect the traces with the correct hypothesis ([51]; p. 490–491). Moreover, exclusions are important for narrowing down potential hypotheses or explanations, but rejecting scenarios should be done with caution (see Ref. [3] for eliminations in art connoisseurship). Fischer [53]; addressing fallacies based on false reasoning throughout this process, addresses the importance of asking the right questions in an analytical manner and demonstrating the veracity of explanations through evidence (by considering matters of relevance and context). Ginzburg [43] reminds us that our historical evidence (trace) and the inferences drawn therefrom require a specific interpretive framework; this framework should rest on the principles from which the evidence has been constructed (p. 84). From the perspective of forensic science, this means consideration of the nature of traces (e.g. Refs. [6,27,48]) and the reasoning methods utilized to interpret and reconstruct events. Based on facts, patterns and connections acquired through observation and comparison as described above, the scientific investigator (whether a historian, connoisseur or forensic scientist), moves from abduction, which suggests; to induction, which shows; and finally, to deduction, which proves ([54]; p. 181).²⁸ For the scientific investigator, it can be difficult, even impossible, to make assertions about the past with certainty, in part because of the fragmentary nature of reconstructing the past and the nature of traces used to do so;

and because the status (relevance) of traces may change over time ([50]; p. 990), making conclusions tentative and subject to revision ([52]; p. 4). “A prudent connoisseur will therefore keep an open mind and welcome additions to the set of recognizable identifiers. This is simply a matter of making use of whatever valid clues come to light. The situation is essentially the same as in historical research in general” ([3]; p. 142). For the investigator within the historical sciences framework, it is important to acknowledge such limitations and uncertainties.²⁹

Technical art history developed and subsequently challenged (and still challenges) approaches to attribution by augmenting the connoisseur’s observations, comparisons and interpretations with laboratory analytical methods. In a recent investigation into the *Flora Wax Bust*, whose attribution had caused controversy since its acquisition in 1909, researchers utilizing chemical methods and analytical spectroscopy in a historical context determined that the bust could not be attributed to Leonardo Da Vinci.³⁰ The authors assert the importance of scientific analysis in assigning attributions, “There is clearly a need for art historical research to integrate natural science investigations in order to provide information allowing an improved attribution of artworks and allowing to give another dimension to the historical value of such objects” ([55]; p. 8). Another recent example—the discovery that Emperor Constantine’s toe was actually a (very large) finger—draws attention to the importance of reexamining cases and approaching a line of inquiry with a new set of eyes. Since its acquisition, the bronze object located in the Louvre (Paris, France) was labeled as a toe. In 2010, a research student proposed the connection between a bronze hand located in a museum in Italy and the digit in the Louvre. In 2018, researchers reconstructed a 3D model of the digit and attempted a ‘physical fit’ with the hand. In 2021, the now-labeled finger and hand were reattached. Here, the role of observation and reasoning after the passage of time preceded scientific analysis. By viewing the artwork in a new way, reframing questions and developing new hypotheses, the object of cultural heritage could be studied and linked by pattern recognition and physical fit. This case also highlights the importance of communication, collaboration and reassessment by individuals bringing their own knowledge to a problem.³¹ Such strategies have long been fundamental to art connoisseurship. Reporting on the works on view at the Art Institute in Chicago, Cox [56] reframed misdirected attempts to correlate artist’s works with their purported mental status based on knowledge of a common eye imperfection, remarking “A good many attempts have been made to explain the peculiarities of this or that artist by some malady of the eye, but the explanations are seldom convincing. In the case of the later works of Theotokopoulos, however—works which used to be explained by madness—there seem to be unmistakable evidences of extreme astigmatism. Spectacles were in

²⁵ Prior to these 21st century publications, in 1968 James Osterburg [90] described criminal investigations as “a process for the study of the past” (p. 152) and in 1987, Kind addressed time and sequence in the context of criminal investigations.

²⁶ Currie (2021) [82] challenges and reframes some of Cleland’s assertions, especially when considering how the historical scientist responds to investigations in which the traces are limited or absent, such as drawing inferences from patterns and experimenting (simulations).

²⁷ In a lecture delivered in 1968, Kuhn remarked “the final product of most historical research is a narrative, a story about particulars of the past. In part, it is a description of what occurred ... Its success however, depends not only on accuracy but also on structure. The historical narrative must render plausible and comprehensible the events it describes” [76].

²⁸ Abductive reasoning was developed by C.S. Peirce (c. 1860s). According to Peirce [77]; acquired knowledge rests on observed facts. Abductive reasoning, or guesswork, requires creativity, intuition, and imagination to generate new ideas about observed phenomena and is the process of forming hunches about the world based on observation and perception [73]. See also Huxley [78] and his discussion of the common cause approach as applied to scientific investigation. Using an apparent burglary scenario, Huxley [78] addresses observation and reasoning, specifically making assumptions (guesses) based on experience and probability (abductive and inductive reasoning, respectively).

²⁹ See, for example, Talley Jr [79], who takes a critical view of the Rembrandt Research Project. Describing patterns of rigid assumptions and preconceived rules, Talley Jr. criticized the group’s repeated assumptions of “absolute knowledge about something which it is impossible to know with certainty” (1989, p. 205).

³⁰ Interestingly, the original assignment of attribution was conducted by W. von Bode, a vocal critic of Morelli’s method.

³¹ It is important to note the necessity of conveying ideas and distinguishing observations from interpretations through communication with various individuals, as they each bring their own education and experiences to bear on an investigation (as well as their own views and biases). Moreover, this communication requires that the investigator be able to accurately convey ideas and explain their reasoning behind conclusions. “Connoisseurial expertise involved active conversation and discussion ... the true connoisseur had to discern both the good and the bad within a single work, to understand what made it so, and to talk about this cogently” [80].

their infancy in his day, and such a defect of vision could not have been corrected as it would be now" (p. 611).³² According to Brown [3]; in a statement that could easily be adapted to modern crime scene investigation and the need for generalist forensic scientists,

Most of the hurtful imprecision in describing artworks comes from not any intrinsic limitation of description as such, but from the describer not knowing enough about the subject of description or from the art world at large not having developed a sufficient common understanding of the subject and sufficient descriptive resources to provide an adequate description for the purpose at hand; for instance, to articulate what in the work is truly distinctive as an artist, school or period or what properties of the work justify a particular assessment of its quality (p. 167)

In a final footnote, Collingwood [57] also points out that the critic of the historical argument (e.g. a reconstruction of events as they pertain to a crime) must have knowledge of the matter-at-hand as well in order to adequately judge the merits of the discussion, being aware of alternate hypotheses and why they were ruled out—in other words, one must not be ignorant of the subject matter (p. 222). If it is not possible for the "judge" (in the case of forensic science, this may be a police investigator, lawyer, judge or jury) to have such knowledge, the responsibility falls on the expert (scientific investigator) to explain their reasoning process in developing a historical narrative.

5. Art as a means of educating the forensic scientist

Kuhn's [41] assertions that "... institutions like the museum have no function in the professional life of the scientist" and "science is a puzzle solving enterprise that has no place for museums" (p.346) are unequivocally without merit. It has been demonstrated that there is a fundamental synergistic relationship between science, museums, and fine art. The study of art has enhanced disciplines such as medicine, law enforcement and education, specifically with regard to improving observation, reflection and communication. Several researchers have studied the utilization of art in clinical diagnoses [58–60]. By using fine art as a teaching tool, medical students demonstrated improved observation skills and abilities to describe and generate interpretations supported by evidence. In recent years, programs and courses have been developed in support of art as a tool to improve observation skills. In 2016, Herman outlined her *Visual Intelligence* program designed to educate and train law enforcement professionals and detectives. Using the model assess, analyze, articulate and adapt, Herman explains that the observer should "gather what facts you can by looking at both the big picture and the small details, step back, consider other perspectives, analyze, prioritize, ask questions and communicate clearly and concisely" ([87], p. 262–263). In her 2018 text *Slow Looking*, Tishman explains, "Slow looking ... foregrounds the capacity to observe details, to defer interpretation, to make careful discernments, to shift between different perspectives, to be aware of subjectivity, and to purposefully use a variety of observation strategies in order to move past first impressions" ([94]; p. 6). Building on the concept of slow looking, The National Gallery of Art developed a program for educators designed to teach critical thinking using works

³² Conversely, see The National Museum of Norway 2021 press release pertaining to the "hidden" message alluding to madness in the 1893 Edvard Munch painting *The Scream*. In this case, scientific analysis aided in resolving the inscription from the background (using infrared photography). The attribution of the inscription to Munch was based on handwriting comparison (in terms of both characteristics and content, the latter of which suggested to researchers that Munch was likely suffering from mental illness). See <https://www.mynewsdesk.com/uk/nasjonalmuseet/pressreleases/national-museum-of-norway-infrared-scans-reveal-author-of-hidden-graffiti-on-edvard-munchs-original-painting-of-the-scream-3075318>.

of art (referred to as *Artful Thinking*).³³ In 2016, Perciaccante et al. examined the arterial spurt of blood for four paintings depicting the beheading of Holofrenes, specifically Caravaggio (1599), Finson (1607), Gentileschi (1620) and an unknown artist (date unknown) found in a home in Toulouse in 2014 (the painting has since been attributed to Caravaggio). Framing the analysis of the paintings in a historical context, the authors determined that there was a change in trajectory of the arterial spurt of blood, and that the change aligned with Galileo Galilei's theory of projectile motion proposed in c.1604-1608. Perciaccante et al. [61] concluded that "newly acquired scientific knowledge is mirrored in the artistic representation of the carotid spurt of blood" (p. e47).

Utilized by art connoisseurs of the nineteenth and twentieth centuries and supported by these recent studies, the forensic scientist can and should develop a practiced eye through the continuous and patient study of art. When possible, the forensic scientist should study within the museum, observing works of art in situ. Moving through Morelli's approach, as outlined in Table 3, the forensic scientist should practice slow looking from the overall painting down to the details and should learn to compare similar works of art, learning to classify, identify and distinguish details and traces. The forensic scientist should move from observation of select works of art to interpretation, supporting their interpretations with facts derived from their observations. For example, considering paintings such as *Death is Fierce and Quick/Death is Violent and Fast: Quarrel in a Pub* (c. 1648; J. van Craesbeeck) and *Death of Chatterton* (1856; Henry Wallis), both depicting a scene the moment after death, observations can move to interpretations and assessments about how traces would be created within the scene, subsequently detected, analyzed and interpreted. Such an approach is also possible with *Ivan the Terrible and his Son Ivan on November 15, 1581* (1885; Ilya Repin)—this work opens up discussion about the transfer of traces between victim and suspect and the reconstruction of events. Such examinations require that the forensic scientist shift their gaze from the foreground to the background and from the overall work to the details.

These examinations also facilitate distinguishing between observation and interpretation. Using techniques developed as part of the *Visible Thinking* project and described in Ritchhart and Church [62]; an understanding map for forensic science and investigations is presented to facilitate observation, reasoning, reflection, and communication of ideas and findings (Fig. 4).³⁴ The basis of the understanding map is to organize a question-and-answer approach that can aid in the articulation of interpretations and shift the narrative from "I know it when I see it" to specific reasons why certain conclusions were drawn from observations made during the course of an investigation. In essence, the questions presented in the understanding map are iterative and intended to confirm, refute or modify hypotheses as information becomes available within the context of an investigation—from initial examination of the crime scene (the whole work of art); to the examination and analysis of the traces; and finally, to interpretations and reconstruction. The approach depicted in Fig. 4 is not meant to be a standard operating procedure or a skills test, but instead meant to structure the generation of ideas and conclusions based on inferential reasoning and facts (physical traces, knowledge) such that the investigator can structure their thinking and support assertions to move beyond vague notions of intuition.

Not all artwork studied by the forensic scientist need be depictions of violence; observing and comparing works of art can be varied by type (paintings, drawings, sculpture, etc.); period (by century); and subject

³³ *Artful Thinking*, developed through the *Visible Thinking* project of Project Zero at Harvard University Graduate School of Education, is comprised of observing & describing; questioning & investigating; reasoning; comparing & connecting; finding complexity and exploring viewpoints (<http://www.pz.harvard.edu/projects/artful-thinking>).

³⁴ Adapted from the thinking routine *Peeling the Fruit* [62].

Observing Closely & Describing What is There What do you see?

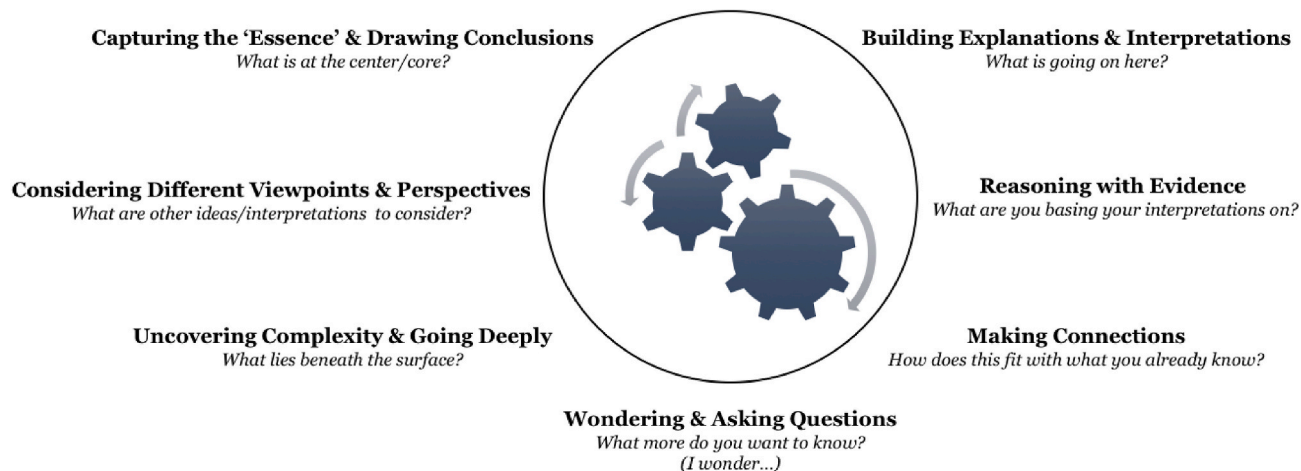


Fig. 4. Understanding map depicting an approach to understanding and investigating in forensic science.

matter (landscape, portrait, still life).³⁵ It is important to note that the utilization is not meant to be an art appreciation or art criticism approach, but one that supports the early development of meaningful observation, the detection of traces (details) and the articulation of ideas and interpretations such that forensic scientist can transmit these refined skills to casework and crime scenes.³⁶ Development of the practiced eye should begin in the early stages of forensic science higher education (both undergraduate and graduate) through the pursuit of degrees in the natural sciences (e.g., biology, chemistry, or forensic science degree with a curriculum based in science and critical thinking) and should continue throughout the forensic scientist's career as the practiced eye is cultivated and refined through long-term efforts.

6. Conclusions

Forensic science has much to learn from art connoisseurship. First, forensic scientists should consider whether or not observation and reasoning have been firmly developed along epistemological grounds so as to better educate and train existing and future forensic scientists. Observation is more than 'search the crime scene' and 'look for clues.' It, along with inferential reasoning, is what contributes to crime scene investigation being an intellectual, scientific endeavor. As forensic scientists, we are responsible for understanding the past through the detection and interpretation of meaningful traces, and explaining processes that facilitated hypothesis development and selection leading to interpretations and reconstructions. After all, as posed by historian Marc Bloch [45]; *can one perfectly understand what he does not know how to express?* (p. 27).

Despite the challenges and controversies surrounding

³⁵ The study of still life works presents interesting dimensions to the development of the practiced eye beyond observing the overall painting and the details; and the articulation and communication of ideas. From Vanitas to table settings to bouquets, still life images allow for deeper attention to the placement of objects (relative to one another and the viewer); meaning, symbolism and iconography including clues indicative of period, economic status, and societal matters (see footnote 22).

³⁶ Another example of utilizing art as a tool for forensic science education can be seen in the handcrafted dioramas of Frances Glessner Lee (1878–1962), who recreated crime scenes in miniature in order to train investigators. Akin to rooms in a dollhouse, these scenes were presented "in a nutshell" to allow for observation of and reflection on the details of a crime scene [81].

connoisseurship, notably with respect to intuition and vague "I know it when I see it" conclusions, forensic science can learn from the principles and practices that have shaped connoisseurship. Most notably, the importance of method, the need for slow looking, the focus on cultivating judgements that are based on fact, and understanding the basis of our inferences. Moving forward, forensic scientists, educational programs and crime laboratories should foster the generalist approach to forensic science by educating and training forensic scientists in observation and analytical reasoning along with the overarching study of traces and their nature. Utilizing art as a means to observe, reason, describe and interpret should be a focal point of education and continuous professional development for the forensic science student and the practicing forensic scientist, respectively. Fostering experiential learning by moving out of the classroom and into the field (whether museum gallery or crime scene) is essential—approaching the overall view of a scene (whether a work of art or a public place; whether two dimensional or three dimensional) and looking for traces should be the focus of long-term practice. This should be done in an effort to conduct meaningful comparisons, identify patterns and demonstrate well-supported exclusions and inclusions. Continuous observation, comparison and reflection will aid in the development of the forensic scientist's practiced eye.

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