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A Scientist's Perspective on the Intertwining of Science, Faith, Free Will, and the Message of the Shroud of Turin

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Abstract: The 5-square-meter flax fabric known as the Shroud of Turin is one of the most sacred religious icons, and one of the most debated subjects in science. Here we summarize and translate into simple terms the state of the art of scientific studies on the Shroud of Turin with regard to the body imprint and the age of the Shroud fabric. Based on the available results, we discuss whether science can determine if the imprint on the Shroud was left by the historical Jesus. Then, we argue the intriguing possibility that the Shroud is a peculiar example of how the rules and constraints of the scientific method can corroborate the concept of faith and free will, and discuss the reasons why the message of the Shroud cannot be limited to the issue of authenticity.

Keywords: image analysis, photochemistry, radiocarbon dating, science and religion, scientific method.

Contribution: Unlike previous articles available in the literature, here we provide the relationship between the Shroud, science, free will and faith from the perspective of scientists who have experienced firsthand the difficulties of analyzing the Shroud and replicating the distinctive characteristics of the imprint. Individual contributions: conception, PDL; research and analysis, PDL and DM.

Use of AI: This paper has been written based on the authors' experimental results and research, taking into account the available literature, without any use of AI.

Introduction

The flax fabric known as the Shroud of Turin (ST) bears the image of a scourged and crucified man, whose reference to the Passion of Jesus makes it a unique religious reality, but also capable of arousing the intellectual interest of scholars from multiple disciplines. The nature of the body imprint is a mystery that has defied all attempts at solution, making the ST one of the most fiercely debated topics in contemporary science.

There is extensive literature on the relationship between ST, science and faith. Among the most recent contributions see for example (Fernández-Sánchez 2024; Casabianca 2025; Karapanagiotis 2025). Unlike previous references, here we provide the point of view of scientists who have experienced firsthand in the laboratory the difficulties of analyzing and replicating the distinctive characteristics of the ST imprint.

The purpose of this paper is not to take a position on the authenticity of the ST as the burial cloth of the historical Jesus. Rather, we present a summary of the main scientific findings as they are, so that everyone can make up his or her own mind. Then, we argue the intriguing relationship between the scientific study of the ST and faith and free will. Finally, we wonder what the deepest message of the ST is today.

1. The body imprint on the Shroud

The ST is a rectangular linen cloth, about 4.42 meters long and 1.13 meters wide. Imprinted on the cloth are the front and back images of a crucified man, with wounds and scourging marks consistent with the Jesus' Passion described in the Gospels.

The images appear to have been formed with the cloth folded lengthwise around the corpse, see Figure 1. Lateral images of the body are missing, as if the imprint were a vertical projection of the body onto the cloth.

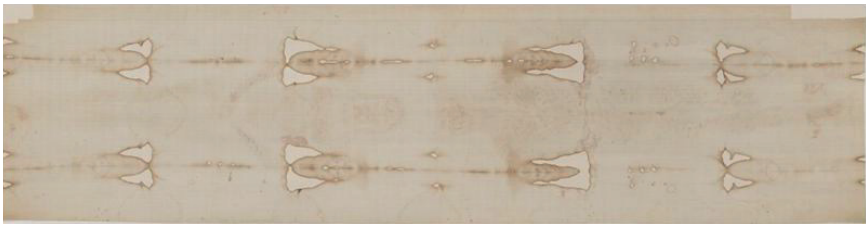

Figure 1. The Shroud of Turin photographed in natural contrast. The body imprints, front on the left and back on the right, are difficult to recognize, because they have almost the same color as the cloth. Blood stains, holes caused by the fire of 1532 and water stains are visible.

The body imprint is barely visible due to poor contrast. Many readers will be uncomfortable looking at Figure 1, because the pictures of the ST that we are used to see on books, magazines, papers and websites have been retouched by artificially increasing the contrast, in order to help the untrained eye recognize faint body features. However, digital enhancement of the imprint on the ST should be used with caution, because when taken to excess, could make you perceive writing and outlines of objects that do not exist on the ST (Di Lazzaro et al. 2013).

2. The scientific investigation of 1978

Most of the physical and chemical characteristics of the ST imprint were discovered through *in situ* measurements carried out in 1978 by a group of 33 scientists under the aegis of the Shroud of Turin Research Project (STuRP).

Here we list the most significant STuRP results related to the ST imprint.

(1) The color of the body imprint on the ST is caused by oxidation, dehydration and conjugation of the cellulose of flax fibrils. The fibrils inside the imprint have undergone accelerated aging compared to those outside.

(2) The color gradient is given by the alternation of colored and uncolored fibrils, not by a change in color of adjacent fibrils. The colored fibrils–each 20 thousandths of a millimeter wide–are sparser in the less dark areas and closer in the more dark areas.

(3) The color depth of the imprint is 200 millionths of a millimeter thick, corresponding to the depth of the primary cell wall of the linen fibril. It is about 350 times thinner than a single hair, impossible to achieve with conventional techniques.

(4) Overall, measurements results rule out that the body imprint was painted, printed, scorched by contact with a hot bas-relief, or rubbed on a sculpture (Heller and Adler, 1981; Schwalbe et al. 1982; Jumper et al. 1984; Jackson et al. 1984).

The official summary of the STuRP's conclusions stated that "the imprint on the ST is not the product of an artist". Considering the results of STuRP measurements and the recent experimental evidence, we do not know of any fabric imprints with characteristics similar to those of the ST, which are as rare as they are difficult to reproduce.

3. The dating of the Shroud

In 1988, 4-square-centimeters of the ST cloth were cut and subjected to radiocarbon dating. Radiocarbon dating uses the time decrease of the rare atomic isotope C-14, as if it were a sort of atomic hourglass that starts at the moment of death of the animal or plant organism. The smaller the number of residual C-14, the older the sample. The technology of counting C-14 is complex but provides accurate results. The main uncertainties arise from the calculation relating the residual C-14 to the age of the sample. This calculation is approximate and may give incorrect results if, for example, contaminants have added new C-14 after the organism has died. For this reason, the samples are cleaned with chemicals before measurement. However, textiles are more permeable to external agents than solid samples, and chemical cleaning may not be sufficient. Beta Analytic, one of the leading companies in C-14 dating, warns: "Textile samples that are well preserved, have a good structure, and have not been treated with any conservation materials will provide accurate results. Samples taken from textile applied with additives or preservatives will have a false radiocarbon age".

The 1988 C-14 dating provided the age of the ST between 1260 and 1390 AD (Damon et al. 1989), a period reasonably consistent with its documented history (Nicolotti 2020).

The news of the ST's medieval dating was widely reported in the media. The discovery of yet another false relic conformed to the prevailing *Zeitgeist* at the end of the '80s, and the effect on studies on the ST was dramatic, because no one had interest in studying another medieval fake relic and most research on ST has been discontinued.

Interest in dating the ST was revived in 2010, when Prof. Riani presented the results of a "robust"[1] statistical calculation analyzing the

[1] Statistics are called 'robust' when they provide reliable estimates of the relationship between variables even in the presence of outliers or violations of traditional assumptions. Robust statistics minimizes the impact of outliers, producing more accurate and stable parameter estimates. This makes robust statistics valuable in analyses where data integrity may be compromised by outliers or non-Gaussian distributions.

C-14 data in (Damon et al. 1989). Riani and colleagues (Fanti et al. 2010) calculated all 387,072 possible positions of the different subsamples into which the four samples delivered to the three laboratories were divided. Robust statistical methods (Riani et al. 2013) allowed finding the most probable position of each of the dated subsamples, and the results provided two important information: the first is that radiocarbon age decreases systematically from one piece to the other adjacent in the direction of the middle of the cloth, as shown in Figure 2.

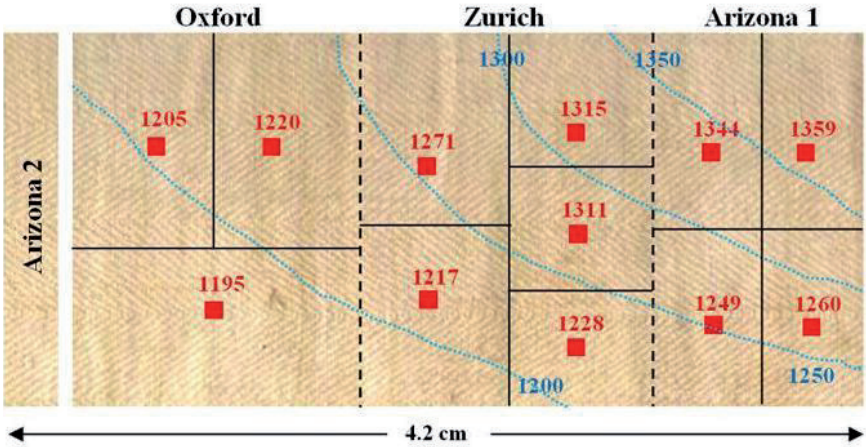

Figure 2. The dashed lines delineate the three samples dated by Oxford, Zurich, and Arizona. Robust statistical analysis reveals that the Arizona 2 sample was not dated. Solid lines indicate the most probable distribution of the subsamples whose average age in AD years is shown in red. The dotted lines and blue numbers indicate the isochrones clearly showing the monotonic decrease in age from bottom left (outer part of the Shroud) to the top right (inner part). Graphic elaboration by the authors.

The monotonous spatial variation in the age of the subsamples shown in Figure 2 is abnormal, because usually the ages of adjacent samples fluctuate around an average value that represents the most probable age. Also, the systematic decrease in the age of adjacent pieces makes the calculation of average age mathematically meaningless.

Homogeneity is the main pre-requisite for obtaining a reliable mean age of any sample, and Riani's result demonstrate the C-14 data are not

homogeneous, i.e., they are not nearly identical age estimates based on repeated measurements of samples. One possible reason for the lack of homogeneity of the measured data could be the presence of fabric added to repair parts missing due to damages and donations of threads to the allied sovereigns of the House of Savoy, owners of the ST. This hypothesis is supported by the discovery of spurious cotton in some threads adjacent to the area where the dated sample was taken (Rogers 2005).

The second result of Riani is that robust statistics provides consistent results only by distributing data on three of the four flax samples delivered to laboratories. Namely, one of the two samples given to the laboratory in Arizona was not dated, see Figure 2. Missing sample dating is not mentioned in (Damon et al. 1989), where general statements imply that all samples were dated.

Few months after the presentation of Riani, Prof. Jull, responsible for the laboratory in Arizona, showed the photo of a piece of the ST never used for measurements, thus confirming that not all the samples had been dated (Freer-Waters et al. 2010).

The next step in figuring out the ST's radiocarbon measurement was in 2017, when a European legal request led the release of almost all of the 'raw' data from the C-14 dating of the ST, i.e. the original subsample data whose average yielded the final, integrated results reported in (Damon et al. 1989). The statistical analysis of the raw data showed that they contain "serious inconsistencies" (Casabianca et al. 2019).

Additional analyses of the C-14 data have recently been published in (Di Lazzaro et al. 2020; Walsh et al. 2020; Schwalbe et al. 2021), respectively showing the assessment of error in the use of the non-standard sampling procedure followed by Damon et al. (1989, a possible inherent variation in the carbon isotopic composition of samples, and how differences in the cleaning procedures of the three laboratories may have given rise to differences in residual contamination. Therefore, there is now a wide range of scientific evidence suggesting that the results of the 1988 dating of the ST do not meet current standards of accuracy.

It is worth noting that the above papers do not provide the true age of the ST. The analyses show that the homogeneity of the C-14 data is lacking, and the dating 1260–1390 AD is unreliable for various reasons, in

particular because the average of any monotonic decreasing or increasing function is meaningless, as it makes no sense from a mathematical standpoint.

It would seem logical to repeat the C-14 dating measurement, avoiding the errors made in 1988 and using current standard procedures. However, in (Di Lazzaro et al. 2020) doubts are expressed about the possibility of obtaining a reliable dating of the ST, because it has been exposed to preservatives and mothproofing substances, whose phenolic groups easily bind via a zero-enthalpy process with the cellulose in the linen, thereby adding new C-14 indistinguishable from the original, which has the potential to alter the results of the C-14 measurement.

4. Attempts to reproduce a Shroud-like body imprint

The first photographs of the ST in 1898 attracted the attention of scientists, and several researchers attempted to create a ST-like imprint. Until the STuRP measurements of 1978, attempts were considered successful when an imprint similar to the original was obtained with the naked eye. The 1978 STuRP measurements revealed the microscopic complexity of the ST imprint, which is much more difficult to achieve than the mere macroscopic similarity to the naked eye.

4.1. CICAP experiment

An attempt to create a life-size reproduction of the imprint of the ST was funded by CICAP (the Italian Committee for the Control of Claims about Pseudoscience) which aimed to verify whether a medieval forger could create a ST-like imprint. The results in (Garlaschelli, 2010) show a copy similar to the original seen with the naked eye, obtained using diluted acid pigments rubbed on the flax covering the body of a volunteer.

The many differences between the CICAP's copy and the ST appear evident under the microscope (Fanti et al. 2011). In defense of his results, Garlaschelli states that it is impossible to reproduce the

microscopic characteristics of any ancient objects, because natural aging and manipulations cannot be faithfully reproduced in the laboratory. Garlaschelli claims that, despite the many differences highlighted, his copy demonstrates that a medieval artist would have been able to create a ST as we see it today. However, we observe that none of the characteristics of the imprint referred to in §2 are found in CICAP's copy, which has completely different chemical and physical characteristics from the imprint on the ST (Fanti et al. 2011). Contrary to the intentions of CICAP, these results confirmed how difficult it is to reproduce the characteristics of the ST imprint in a modern laboratory, let alone in the workshop of a medieval forger.

4.2. Ultraviolet light

So far, the coloration most closely resembling that of the ST imprint at the microscopic level has been achieved by non-contact physical techniques, most notably ultraviolet light (UV). By irradiating flax fabrics with short durations and high-intensity UV laser pulses, a ST-like coloration was reported in (Di Lazzaro et al. 2012; Di Lazzaro and Murra, 2015a 2015b).

Recently, Raman spectroscopy (Botti et al. 2024) showed that UV laser light irradiation generated photolysis of polymer chains and oxidation of flax cellulose, with a strong increase in C=O and C=C chemical bonds compared to the non-irradiated area, see Table 1.

The results in Table 1 suggest a close similarity between the oxidation reactions generated by UV light and the oxidation and dehydration observed in the body imprint on the ST. Indeed, the analysis of the ST imprint showed the presence of C=O double bonds that, when isolated, are unable to impart a yellow hue. To achieve the yellowish hue of the imprint, C=O are conjugated with C=C bonds, forming -CH=CH-C=O structures that shift the absorption of light from the UV to the blue-green spectrum, resulting in the yellow hue we perceive. The drastic increase of C=C and C=O in flax cellulose after UV irradiation provides an overlapping framework of the chemistry of the ST imprint reported in (Heller and Adler 1981).

Table 1. Five dimensionless markers measured before and after UV irradiation. R_H is the degree of polymerization of cellulose; O_I is the degree of the oxidation process, being proportional to the number of C=O double bonds in the carbonyl groups; $M_{C=C}$ is proportional to the number of double bonds C=C; $M_{C=O}$ is proportional to the number of double bonds C=O; I_C is the crystalline percentage of cellulose.

Markers	Unirradiated flax	UV-irradiated flax
R_H	2.6 ± 0.4	0.9 ± 0.1
O_I	0.56 ± 0.07	1.2 ± 0.1
$M_{C=C}$	0.05 ± 0.01	0.16 ± 0.02
$M_{C=O}$	0.11 ± 0.02	0.17 ± 0.08
I_C	0.5 ± 0.1	0.75 ± 0.08

As a matter of fact, no one has succeeded in producing a linen coloration that has all the microscopic characteristics of the body imprint listed in §2, see Table 2. The UV light attempt is the only one to have achieved coloration with both physical and chemical characteristics similar to the ST imprint. However, obtaining a 1:1 scale ST-like imprint with UV lasers is beyond current technology.

Table 2. Summary of the main attempts to reproduce the body imprint of the Shroud

Year and main authors	Technique	Main problems
1902 Vignon	Vaporography	Poor spatial resolution. Not superficial
1939–41 Cordiglia, Romanese	Aloe and myrrh on corpses	Not superficial
1966 Ashe 1982 Pesce	Heated bas-relief	Not superficial
1983 Nickell	Iron oxide powder rubbed on bas-relief	Different at the thread level
1993 Allen	Photograph ante-litteram	Photosensitive chemicals unknown until the 19th century

Table 2. Summary of the main attempts to reproduce the body imprint of the Shroud (Continued)

Year and main authors	Technique	Main problems
2010 Garlaschelli	Diluted acid pigments rubbed on human body and bas-relief	Different at the thread level
2013 Fanti	Corona discharge between metal dummy and flax	Works with metal dummy only. The imprint is on the back of the flax, not in contact with the dummy
2014 Di Lazzaro	Flax irradiation by UV laser pulses	Making the imprint of the whole human figure is beyond current technology

5. Science, faith and the message of the Shroud

From a scientific point of view, the ST of Turin is a complex and elusive object. The balance of all physical and chemical measurements on the ST is stalled. None of the attempts to reverse-engineer the alleged forger's technique have succeeded, see Table 2. The body imprint is seared on to the cloth with a method that has yet to be explained.

5.1. Limits of the scientific results

The experimental results that come closest to the microscopic complexity of the ST imprint were obtained by irradiating flax with UV light, as shown in §4. However, these results do not constitute scientific proof that the body imprint was formed by UV light. Rather, they reflect the current state of knowledge: UV light succeeds where chemical and thermal processes fail. On the other hand, these results do not rule out the possibility that UV light played a role in the formation of the ST imprint.

In addition, we do not know the age of the ST. In fact, the C-14 measurement of a peripheral piece of the ST yielded unreliable results, as

discussed in §3. This is not an indictment of the laboratories that did the dating, nor is it just a conjecture of the faithful. There are purely scientific reasons to believe that the 1988 radiocarbon dating results do not match current accuracy requirements.

Against this backdrop, it is clear that science must recognize its limits. We have to admit that we still do not have sufficient data to determine whether this is an authentic relic or a forgery, and to be content with probabilities (Ball 2008). Anyone who claims that they are certain that the ST is a medieval artifact, or conversely that the ST is the actual burial cloth of Jesus, adds a leap of faith to the available data.

5.2. The Scientific Method and the Shroud

What can science answer to the 'question of questions': is Jesus the man who left his imprint on the ST?

From a scientific point of view, we can never be certain that the man who left the imprint on the ST is Jesus. The ST is an object in which there are many clues, but no absolute proof. Let us remind that since early 20th century, after the discoveries of quantum mechanics, we have been aware that science cannot achieve absolute truths, but only results that can progressively approach the truth. There is no 'definitive' evidence in science, because all results are provisional, being obtained 'to the best of our knowledge' and accepted 'until proven otherwise'. In other words, science is a method that allows errors to be reduced, not eliminated.

Perhaps some readers may be puzzled by the above statements, as the approach of the scientific method is little known. Let us discuss it with the help of distinguished scientists and philosophers who have addressed the subject.

One of the greatest philosophers of science, Karl Popper, noted that if a theory could never be challenged, then it was not truly scientific. A real scientific theory, he argued, must make predictions that could be tested and potentially proven false. Rather than seeking confirmation, Popper urged scientists to try to disprove their ideas. If a theory survived repeated attempts to falsify it, it grew stronger. If not, it had to go. In this way, science wasn't a steady march toward truth, but an error-prone process

of conjecture and refutation. Popper moved the goalposts: science is not about certainty, but about being testable and open to revision. According to Popper, science should proceed by constructing hypotheses, discarding or adjusting them in light of new experimental results. If the hypothesis is confirmed by experiments, a theory is developed that is provisionally valid until proven otherwise, i.e. until new experimental evidence forces it to be corrected or replaced (Popper 1972).

Regarding the limits of science, Nobel Prize laureate Giorgio Parisi in an interview noted that

> Scientific truths are always 'approximations to the truth'. The way a physicist looks at truth is different from what is commonly expected. The truths of a physicist are appropriate for that time, context, reality, for the end that is proposed. It may sound strange, but scientists use the word 'error' more often than the word 'truth'. An experimental measurement is useless if we do not know its margin of error. Genuine scientists are well aware of the provisional value of truth (Parisi 2011).

As a further food for thought, we note that scientific results tend to disprove rather than confirm a hypothesis. In this regard, Nobel Prize laureate Albert Einstein said:

> The scientist is not to be envied. For Nature, or more precisely experiment, is an inexorable and not friendly judge of his work. It never says 'Yes' to a theory. In the most favorable cases it says 'Maybe', and in the great majority of cases simply 'No'. If an experiment agrees with a theory it means for the latter 'Maybe', and if it does not agree it means 'No'. Probably every theory will someday experience its 'No' –most theories, soon after conception" (Dukas et al. 2013).

In the case of the ST, for example, even if all results converged towards a cloth datable to the first century, we could only say 'we cannot exclude that Jesus is the man of the Shroud'. Conversely, it is enough for a single result to be contrary to the hypothesis to disprove it This asymmetry between the difficulty of obtaining confirmation and the ease of obtaining refutation is an essential part of the scientific method.

5.3. Science, faith, free will

We have seen that turning to the scientific method to answer the question of whether the man of the ST is Jesus seems an uphill path. Yet, the limitations of the scientific method can in a sense assist the faith. Let us consider this point: if science were able to explain everything, including age and formation of the ST imprint, and if it could prove that the imprint on the ST was caused by UV light miraculously emitted from Jesus' body during the resurrection, what would become of free will? What would happen to faith, understood as "the assurance of things hoped for, the conviction of things not seen" (Heb. 11:1 ESV)? The scientist and theologian Blaise Pascal insightfully noted: "God has put enough light in the world for those who want to believe, and enough shadow to blind those who don't". It is as if the ST exists precisely to support this observation. The fact is, even if the ST were of Jesus, it merely suggests. It might be extraordinary evidence of a unique, miraculous event, but what the event was, from the standpoint of science, is unknown and perhaps unknowable.

5.4. The message of the Shroud

On the elusiveness of the results of the ST studies, as early as 1902, Yves Delage, professor at the University of Paris, wrote: "In this whole matter of the Shroud there is nothing that is proved in the manner of a mathematical truth or an experimental fact; but there is a set of considerations, for and against which one has the right to make a balance" (Delage 1902). Apparently, we are left to balance the evidence for and against authenticity. Yet, the ST carries a message that goes far beyond the question of authenticity. In this regard, one of the greatest scholars of the ST, Msgr. Giuseppe Ghiberti, wrote:

> In the margin of uncertainty that the study of the Shroud leaves us with, it is possible to see an educational role: by giving this aid to faith, without freeing it from scientific uncertainties, it seems that the Lord invites us to focus on the essence of the message. The weakness of the instrument does not make it less loved. Quite the reverse, it reconciles it with our weakness: the little we

know invites us to love more. It is not foreign to the Lord's style to use weak things" (Ghiberti 2004).

What, then, is "the essence of the message" referred to by Msgr. Ghiberti? Barrie Schwortz, STuRP photographer, suggested a key: "The Shroud is not there to answer our questions, but to make us ask them. People often ask me, does this prove the resurrection? The answer to faith isn't going to be on that piece of cloth, but more likely in the eyes and the hearts of those who look upon it" (Schwortz 2013).

Conclusion

We have summarized and translated into simple terms the main findings of scientific studies on the body image and the age of the ST as they stand, without a prejudicial position on whether the ST is the burial cloth of the historical Jesus. Then we discussed the intertwining of the ST studies, the scientific method, the concept of faith, and free will. Finally, we wondered what the most important message of the ST is, reporting relevant comments of eminent philosophers, Nobel laureates, churchmen, and scientists, not because their answers should be followed by the principle of authority, but because in their reasoning it is possible to identify a common thread that allows everyone to ponder and find their own answer.

The ST is not part of the general revelation; therefore, belief in its authenticity is not binding on Catholics. The Vatican takes no official position on the ST's authenticity, although it encourages the faithful to venerate it as a symbol of Jesus' suffering. As St. John Paul II put it "The Shroud is a challenge to our intelligence. It requires of every person, particularly the researcher, that he humbly grasp the profound message it sends to his reason and his life. Since it is not a matter of faith, the Church has no specific competence to pronounce on these questions" (John Paul II 1998).

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