Raymond N. Rogers' observations and conclusions
concerning the body image that is visible on the Shroud of Turin

Exhaustive documentary research done by Yannick Clément, January 11, 2013

2013 updates: May 27, August 8, September 11 & December 31
2014 updates: June 29

Here's a list of the most important quotes taken from Raymond N. Rogers' official publications that he wrote during the period 2001-2005 and that concern the body image that is visible on the Shroud of Turin:

1- Direct microscopy showed that the image color resides only on the top-most fibers at the highest parts of the weave.[1]
2- Darker-appearing, pure image areas did not penetrate significantly more deeply into the cloth than did lighter areas. The effect was much different than that produced by scorching a cloth with a hot statue.[2]
3- The image of the dorsal side of the body shows the same color density and distribution as the ventral and does not penetrate the cloth any more deeply than the image on the ventral side of the body.[3]
4- Whatever produced the image produced identical surfaces in both the front and back images.[4]
5- Thermography proved that the emittance of the image was the same in all areas. The entire image was formed by the same mechanism. Spectra and photography confirmed this observation.[5]
6- The image is extremely faint and difficult to see. Many more details can be seen in contrast-enhanced and ultraviolet photographs; however, they are somewhat misleading for studies on image formation. Whatever produced the image color did not produce very much color.[6]
7- The image on the Shroud is not a painting. No foreign materials were added to the cloth in image areas.[7]
8- No fibers in a pure image area were cemented together by any foreign material and there were no liquid meniscus marks. These facts seemed to eliminate any image-formation hypothesis that was based solely on the flow of a liquid into the cloth. This also suggests that, if a body was involved in image formation, it was dry at the time the color formed.[8]
9- Body fluids (other than blood) did not percolate into the cloth.[9]
10- All of the observational methods agreed that no pigments, normal painting vehicles, or natural exudations (other than the blood) had been added to the cloth after its production.[10]
11- Neither aloes nor myrrh could be detected on the cloth.[11]
12- There is no image color or erosion inside the pores of the cloth.[12]
13- The cloth does not show any phosphorescence.[13]
14- The distribution of image color on the surface of the cloth is discontinuous[14]. This can easily be seen in macrophotographs of the image areas.[15]
15- The layer (of image color) is approximately one wavelength of visible light thick (200-600 nanometers), and it is amorphous[16].[17]

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[1] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008 (http://www.lulu.com/shop/raymond-n-rogers/a-chemists-perspective-on-the-shroud-of-turin/ebook/product-17416203.html). Note: Rogers finished the writing of this book before his death in 2005 but was published in 2008.
[2] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002 (http://www.shroud.com/pdfs/rogers2.pdf).
[3] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[4] *Ibid.*
[5] *Ibid.*
[6] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004 (http://shroud.com/pdfs/rogers5faqs.pdf).
[7] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[8] *Ibid*.
[9] *Ibid*.
[10] *Ibid*.
[11] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[12] Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004 (http://www.shroud.com/pdfs/rogers6.pdf).
[13] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[14] a. Marked by breaks or interruptions; intermittent; b. Consisting of distinct or unconnected elements, such as the physical features of a landscape;, c. Being without sequential order or coherent form (http://www.thefreedictionary.com/discontinuous).
[15] Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004.
[16] a. Lacking definite form; shapeless; b. Of no particular type; anomalous; c. Lacking organization; formless (http://www.thefreedictionary.com/amorphous).
[17] Emmanuel M. Carreira, *The Shroud of Turin from the viewpoint of the physical science*, 2010 (http://www.shroud.com/pdfs/carreira.pdf).

16- The thickness of the image color must be less than a sodium-D wavelength (589 nanometers).[18]
17- Water-stained image areas on the Shroud showed that the image color does not dissolve or migrate in water. Maillard products are not water soluble, and they do not move when wetted.[19]
18- Adhesive-tape samples show that the image is a result of concentrations of yellow-brown fibers.[20]
19- No proteins could be detected in either image or non-image areas; however, they were easy to detect in blood stains.[21]
20- No image formed under the bloodstains (the blood was on the cloth before the image formed) and the image formation mechanism did not damage, denature, or char the blood. The image formation process was sufficiently mild that it did not destroy or damage the blood. [22]
21- Image color does not appear under the blood stains when they are removed with a proteolytic enzyme. Whatever process produced the image color must have occurred after the blood flowed onto the cloth, and the image-producing process did not destroy the blood.[23] ***<u>Personal note</u>:*** *The expression "blood flowed onto the cloth" used by Rogers here can be somewhat misleading. It's important to emphasize the fact that Alan Adler's analyses concerning the blood and serum stains on the Shroud indicate that most of these stains were caused by exudates of moistened (or remoistened) blood clots and not by recent blood that just come out of an open wound and that would still be in a liquid state.*
22- Heller and Adler found that the image fibers could be decolorized with diimide, a powerful reducing agent. Reduction left colorless cellulose fibers. They concluded that the color was a result of conjugated double bonds, agreeing with the spectrometry of Gilbert and Gilbert (from STURP).[24]
23- Prof. Alan Adler of Western Connecticut University found that the image color could be reduced with a diimide reagent, leaving colorless, undamaged cellulose fibers behind. All image color resides on the outer surface of the fibers. This confirmed spectral data that indicated that the image color was a result of complex conjugated double bonds; however, it proved that image color was found *only* on the outer surfaces of colored image fibers. Until this time, we had assumed that the image color was a result of chemical changes in the cellulose of the linen. The most likely change would involve the dehydration of the cellulose to produce conjugated-double-bonds systems. Adler's observation proved that the cellulose was not involved in image formation. *This is an extremely important observation.*[25] ***<u>Personal note</u>:*** *In this particular quote, Rogers only attribute the observation concerning the diimide to Alan Adler instead of Adler and Heller (see the precedent quote), who collaborated together for STURP*[26]*, most probably because Adler was truly the one who made the original observation. We have to remember that Adler was a true chemist expert, whereas Heller specialized in biophysics.*
24- The color formed by dehydration (caramelization) of any type of carbohydrate impurity (e.g., starch and/or sugars) would be the result of the same kinds of conjugated structures as produced by cellulose, and the color would appear on the surface of the fibrils only. All of the analytical tests described by Heller and Adler would apply to these impurity colors. All colored fibrils should color to approximately the same degree, depending on the amount/thickness of the impurity layer, explaining the "half-tone" effect STRUP reported.[27] ***<u>Personal note</u>:*** *Conjugated double bonds in the cellulose of the fibers were the official conclusion of STURP concerning the chemical structure of the colored fibers in the image area. At the time Rogers was writing this particular paper (in 2001), he was favoring instead a caramelization (coloration) of some carbohydrate impurities on the surface of the cloth through an interaction between them and some perspiration (sweat) and/or secretions that could have been present on the skin and hair of the Shroud man. The next year, he changed his mind about those potential catalytic compounds and proposed a new hypothesis involving some post-mortem gases released by the corpse that would have initiated a Maillard reaction in the impurity layer (instead of a caramelization). It should be noted that less heat is needed to start the chemical process known as a Maillard reaction than to start a*

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[18] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[19] *Ibid.*
[20] *Ibid.*
[21] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002 (http://www.shroud.com/pdfs/rogers2.pdf).
[22] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[23] *Ibid.*
[24] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[25] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[26] Heller and Adler wrote together these two different papers for STURP: John H. Heller and Alan D. Adler, "Blood on the Shroud of Turin," *Applied Optics*, 19 (16), 1980 and John H. Heller and Alan D. Adler, "A chemical investigation of the Shroud of Turin," *Canadian Society of Forensic Science Journal*, 14 (3), 1981.
[27] Raymond N. Rogers, *An Alternate Hypothesis for the Image Color*, 2001 (http://www.shroud.com/pdfs/rogers10.pdf).

caramelization process (see quotes #136). For Rogers, his fact was fitting better with the known data coming from the Shroud and particularly those we found in quotes #20, 74 and 95.

25- The image can be chemically reduced with diimide leaving colorless cellulose fibers. The color resides only on the surface of the fibers, and it is the result of conjugated double bounds. The underlying cellulose (linen) fibers are not colored.[28]

26- The image color can be reduce chemically (diimide and sodium borohydride), leaving colorless, lustrous linen fibers.[29]

27- The layer of color can be specifically reduced with diimide, leaving a colorless flax fiber behind. Diimide reduction confirmed the presence of double bounds.[30]

28- Heller and Alder also reported that “ghosts” of color were stripped off of fibers by the adhesive of sampling tapes when they were pulled out of the adhesive and that the insides of the fibers were colorless. I have confirmed this observation. The color is only on the surface of the image fibers. Another important observation was that the “ghosts” had the same chemical composition as expected from dehydrated carbohydrates.[31]

29- The color of image fibers was often stripped off of their surfaces, leaving molds of the fibers in the adhesive. The molds show both growth nodes and image color. The layers of color are extremely thin.[32]

30- The medullas of colored image fibers are not colored. The cellulose was not involved in color production. The cellulose of the image has not changed as a result of image formation.[33]

31- The color resides only on the surface of the fibers, and it is the result of conjugated double bounds. The underlying cellulose (linen) fibers are not colored.[34]

32- Later we found that the image color resides only on the outer surfaces of image fibers: the flax fiber was not colored at all.[35]

33- At high optical magnifications, up to 1000X, no coatings could be resolved on the surfaces of the image fibers; however, the surfaces appeared to be “corroded.” That observation suggests that a very thin coating of carbohydrate had been significantly dehydrated on the outer surfaces of the fibers.[36]

34- The color of the image is indeed a result of a thin coating. “Thin” is the important word. Surface cracking (“corrosion” as Adler called it) of the color can be seen, and flakes can be seen in the “ghosts” on the sampling tapes.[37]

35- Because the cellulose was not involved in image formation, the color must have formed in impurities on the surfaces of the image fibers. Independent observations have proved that all of the image color resides in a very thin layer on the outside surfaces of the colored fibers.[38]

36- The fact that the color resides only on the fiber surfaces leads to the hypothesis that the color formed as a result of chemical reactions involving impurities on the surface. The spectra strongly suggest that the impurities were carbohydrates that dehydrated as a result of image-formation process. The hypothesis of carbohydrates impurities is supported by observations of traces of some starch fractions on image fibers.[39]

37- Microchemical tests with iodine detected the presence of starch impurities on the surfaces of linen fibers from the Shroud. Impurities were detected that could take part in color-producing Maillard reactions.[40]

38- A search for carbohydrate impurities on the Shroud confirmed McCrone’s detection of some (wheat) starch fractions. Starch and low-molecular weight carbohydrates from crude starch would color much more easily than would cellulose as a result of either thermal dehydration or chemical reactions.[41]

39- Nothing other than dehydrated carbohydrate could be found in the image area.[42]

40- An impurity layer could be seen by phase-contrast microscopy.[43]

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[28] Raymond N. Rogers, *A Chemist’s Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[29] Emmanuel M. Carreira, *The Shroud of Turin from the viewpoint of the physical science*, 2010.
[30] *Ibid.*
[31] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[32] Raymond N. Rogers, *A Chemist’s Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[33] *Ibid*.
[34] *Ibid*.
[35] Emmanuel M. Carreira, *The Shroud of Turin from the viewpoint of the physical science*, 2010.
[36] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[37] Raymond N. Rogers, *A Chemist’s Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[38] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[39] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[40] Raymond N. Rogers, *A Chemist’s Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[41] *Ibid*.
[42] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[43] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.

41- Because chemical rates are exponential with temperature, cellulose would react much more slowly than other carbohydrates at the same temperature.[44]

42- Bands of different-colored yarn can be observed in the weave of the cloth. Where darker bands intersect image areas, the image is darker. Where lighter bands intersect an image area, the image appears lighter. This proves that the image color is not solely a result of reactions in the cellulose of the linen. Something on the surface of the different batches of yarn produced color and/or accelerated color formation. This observation is extremely important when tests are being made on image-formation hypotheses. If image color is not simply a result of color formation in the cellulose of the linen fibers, image formation must be a much more complex process than we originally thought.[45]

43- The color density of any specific image area depends on the batch of yarn that was used in its weave. Bands of different color can be observed, and they correspond to the batches of yarn that were used to weave the cloth. Image density is greater where darker bands cross, and it is lighter where lighter bands cross. This suggests that significant variations in impurity concentrations existed among yarn batches.[46]

44- Similar bands of light and dark can be seen visually with some difficulty on the Shroud, but they appear much more clearly when contrast is enhanced. They appear in both the warp and the weft. The observations of bands of color agree with historical reports on the methods used to produce ancient linen. This indicates a very mild bleaching technique, unlike that used after the last crusade in AD 1291.[47]

45- The density of the color of an image area reflects the changes in color density seen in the bands of different color. The image is not simply a result of changes in the cellulose (linen). Pure cellulose is relatively hard to color by chemical means, but many common impurities on cloth can be colored much more easily. Most of the components of crude starch are carbohydrates (sugars and low-molecular-weight polysaccharides) that are closely related to cellulose, but they can be quite easy to color by either “caramelization” (heating) or reactions with amines.[48]

46- Microscopy proves that image fibers and scorch fibers are quite different in structure and composition. The distribution of color is different, even at the level of single fibers. The image was *not* formed by scorching the linen fibers. When viewed in parallel light under a microscope, a scorched fiber is colored through its entire diameter, and the medulla (a tubular void down the middle of the fiber) usually appears to be darker than the mass of the fiber as a result of reactions at its surface and its shorter radius of curvature. The medullas of image fibers do not show any coloration or charring. The medullas are usually clean and colorless. Fibers that were scorched in a fire in AD 1532 show some scorching in the medullas.[49]

47- The bands of color, and the fact that all the color appears only on the outer surfaces of the fibers, suggested that image formation involved a thin layer of impurities. Since the cellulose was not colored, the impurities had to be significantly less stable than cellulose. This also suggested that the impurities were the result of cloth-production methods and they should appear on all parts of the cloth.[50]

48- Slightly different amount of impurities on the different batches of linen yarn would cause slightly different surface energies. One major linen impurity is “flax wax”, and it produces a hydrophobic surface. Liquids wet the threads as a function of the difference between the surface tension of the washing solution and the surface energy of the specific linen yarn. This would explain the “banded” appearance of the Shroud.[51]

49- Another important observation is the fact that the image-forming process produced slightly different color densities (but identical spectra) on the different lots of yarn. We see this as the bands of different color in both the background and the image. The color-density of the image is not simply a function of the chemical properties of cellulose: It also depends on the individual properties of the batches of yarns. The observed effects must have been caused by different amounts of impurities that originally coated the surface of the different hanks of yarn as a result of slightly different bleaching conditions.[52]

50- The density of the image is not simply a function of the chemical properties of the cellulose. It also depends on the individual properties of the thread, both warp and weft, used to weave each specific part of the cloth.[53]

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[44] Raymond N. Rogers, *A Chemist’s Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[45] *Ibid.*
[46] *Ibid.*
[47] *Ibid.*
[48] *Ibid.*
[49] *Ibid.*
[50] *Ibid.*
[51] *Ibid.*
[52] *Ibid.*
[53] Raymond N. Rogers, *An Alternate Hypothesis for the Image Color*, 2001.

51- All of the bleaching processes used through history remove lignin and most associated flax impurities (e.g., flax wax and hemicelluloses). The more quantitative the bleaching process, the whiter the product. The bands of different color on the Shroud are the end result of different amount of impurities left from the bleaching process. [54] ***Personal note:*** *This quote shows that, in Rogers mind, there is a true possibility that some deposits of hemicelluloses (due to the retting process, just like the pectin deposits found by Alan Adler on Shroud's samples) could have been left on the fibers after the bleaching as a part of the whole impurity layer described by Rogers along with some starch deposits (see quotes #36 through 38) and maybe also some deposits coming from a possible use of Saponaria to wash the final cloth. In Rogers' mind, it's that mix of impurities on top of the linen fibers that would have been colored during the image formation process.*

52- Evaporation concentration (of impurities) can explain the superficial nature of the image and the identical properties of the front and back images. An amine vapor that diffused from a body into the cloth could only react where impurities had concentrated. The amines do not react with cellulose.[55]

53- The Shroud cloth is tightly woven, it is relatively thick, and it does not readily absorb water. With such a cloth, any material that can be suspended by *Saponaria* will primarily migrate to a drying surface and be concentrated.[56]

54- *Saponaria officinalis* is called "soapweed" in some areas. It acts as a surfactant: It reduces the surface tension of water making it a good wetting agent. Both hydrophobic and hydrophilic materials that had been on the raw linen would be put into solution or suspension by the *Saponaria* solution. These properties could be of importance in considering the Shroud.[57]

55- I think that any impurity in solution or suspension in a system with a relatively low surface tension (***Personal note:*** *As in the case of the Shroud*) would migrate to the drying surface of a piece of saturated cloth and be left in a much higher concentration than anywhere else after the solvent dries.[58]

56- An "impurity hypothesis" immediately suggests possible traces of starch and/or Saponaria on the threads at the time of image formation. Saponaria, being a surfactant, would flow smoothly over the cloth. A dilute solution would form a very thin layer on the upper surface of the cloth. The most soluble fractions of starch should also appear on the top-most surface.[59] ***Personal note:*** *Traces of starch have been found on the Shroud by both McCrone and Rogers, while saponaria residues have never been found on the Shroud, even though there is circumstantial evidence that still suggests that it really had been used to wash the cloth.*

57- The deposit of an impurity (layer) as a result of washing would help explain the fact that colored fibrils appear predominantly on the very tops of the top-most threads on the Shroud.[60]

58- The puzzling "half-tone" effect has been mentioned. All of the colored image fibers showed approximately the same color intensity under a microscope. Assuming that the color formed by reactions with a very thin deposit of superficial impurities on the fibers, all of the fibers should have shown identical spectra and roughly the same intensity of color. They did.[61]

59- The (possible) use of *Saponaria officinalis* to wash the cloth could explain the fluorescence of the background. The image either filters or quenches that fluorescence.[62] ***Personal note:*** *The residues of pectin found on the Shroud samples by Alan Adler are another possible explanation for the weak fluorescence of the non-image areas of the cloth. In sum, it is possible that these two products are both partially responsible for that weak resulting fluorescence. It's important to note that, to this day, there is no positive confirmation of the presence of* Saponaria *officinalis on the Shroud. For the moment, this is just a hypothesis that still needs to be scientifically confirmed. As Rogers wrote*: "I could not prove the presence of pentose sugars on the Shroud, so I could not prove that the cloth had been washed with *S. Officinalis*. Only the fluorescence evidence remains to suggest the use of struthtium (*S. Officinalis*)."[63]

60- Chemical tests showed that there is no protein painting medium or protein containing coating in image areas. It follows that microbiological activity did not produce the image.[64]

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[54] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[55] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[56] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[57] Raymond N. Rogers, *An Alternate Hypothesis for the Image Color*, 2001.
[58] *Ibid.*
[59] *Ibid.*
[60] *Ibid.*
[61] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[62] *Ibid.*
[63] *Ibid*.
[64] *Ibid*.

61- The image was not painted with glair (egg white), and there is no significant amount of microbiological coating on the cloth. Both McCrone's hypothesis that the image was painted with glair and hematite and Garza-Valdes' hypothesis that it was a result of microbiological activity can be rejected.[65]

62- Reflectance spectra, chemical tests, laser-microprobe Raman spectra, pyrolysis mass spectrometry, and x-ray fluorescence all show that the image is not painted with any of the expected, historically-documented pigments, including iron oxides.[66]

63- Features identical to the "filamentous bacteria" are common in linen samples. They are what are called "ultimate cells." Linen fibers are made of parallel bundles of these cells, cemented together with lignin and hemicellulose. Ultimate cells are easy to differentiate from bacteria, because the ultimate cells are crystalline and birefringent. It is too bad that the "bioplastic-polymer" proponents did not do any analyses of their samples. They have caused massive confusion and mischief.[67]

64- Other than observing colored medullas, crystallinity and birefringence enable differentiating between scorched and image fibers. The evidence is strong that the image is not a result of dehydration of the cellulose by any mechanism, thermal or radiation.[68]

65- If preexisting impurities enabled image formation, some should have still been on the Shroud at the time of the 1532 fire. A search of tape samples from lightly-scorched areas revealed ghosts that appeared to be identical to those from image areas. Thin layers of colored impurities had stripped off from scorched fibers that were completely isolated from image areas.[69]

66- The image spectra were essentially identical to those of aged linen and light scorches. The structures of all forms of dehydrated carbohydrates would be very similar, containing complex systems of conjugated double carbon bonds. Cellulose is not unique. Sugars and starches give the same types of dehydration/conjugation chemical structures. Identical colored structures are produced by low-temperature reactions between reducing carbohydrates and amines, i.e., Maillard reactions.[70]

67- When I took a tape from a non-image area of the Shroud, I found that it pulled much more easily than tapes pulled from the patches. The large difference in ease of pulling tapes from the surface made me decide to use the applicator to measure the force required to remove tapes. Tapes pulled from the darker body-image areas with extreme ease: I could barely measure the pulling force.[71]

68- Dehydration causes shrinkage; therefore, any coating of carbohydrate impurities would "craze" during dehydration. Such a crazed coating would be easy to pull off with adhesive, explaining the easy removal of tapes from image areas.[72]

69- Results of kinetics studies support a low-temperature image formation process. The temperature was not high enough to change cellulose within the time available for image formation, and no char was produced.[73]

70- All parts of the Shroud are the same age, and all parts have been stored in the same location through the centuries. Therefore, all parts should have been exposed to the same kinds and amounts of (natural) radiation. Any additional radiation effects found in image areas would indicate excess radiation in that location. Direct comparison between image and non-image parts of the Shroud show exactly the same amounts and types of radiation damage in the two types of areas. This suggests that the image was not produced by any mechanism that involved heat, light, or ionizing radiation.[74] ***Personal note:*** *This particular observation of Rogers can be seen as a very good confirmation of a spectral analysis done by Alan Adler in the 1990s on four non-image fibers coming from various locations of the frontal part of the Shroud (i.e. the head, chest, knees and feet areas)*[75]*. Adler was clear about the fact that his spectroscopic results showed that there were no evident differences in the chemical content for all of these areas, which indicates, like Rogers said in his paper, that each part of the cloth is really showing the same age and the same degree of natural oxidation. It is very important to note that such a*

[65] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[66] *Ibid*.
[67] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[68] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[69] *Ibid*.
[70] *Ibid*.
[71] *Ibid*.
[72] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[73] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[74] Raymond N. Rogers, *The Shroud of Turin: Radiation Effects, Aging and Image Formation*, 2005 (http://www.shroud.com/pdfs/rogers8.pdf).
[75] Alan D. Adler, *The Orphaned Manuscript: A Gathering of Publications on the Shroud of Turin*, Effata Éditrice, Torino, Italy, 2002 (http://holyshroudguild.org/orphaned-manuscript.html). You can also listen online and for free a presentation Adler's did at a Shroud conference in Dallas in 1996, in which he explains the results of his numerous analyses (one of them being the spectral analysis I just mentioned concerning four non-image fibers of the Shroud), by following this link: http://shrouduniversity.com/podcasts/aladler.mp3).

conclusion is in total contradiction with the Mandylion hypothesis proposed by Ian Wilson. Effectively, if Wilson's hypothesis was correct, the region of the face on the Shroud would have been the only one exposed to light, dust, air and natural radiations for many centuries (if not for over 1000 years). In that context, we should expect to see evident signs of an accentuated aging (i.e. more oxidation of the fibers, along with more dust) for the non-image fibers located in the vicinity of the face, but the observations of Rogers and Adler (and also those of other STURP members, like Samuel F. Pellicori and Mark S. Evans[76]) proved that this is not the case. Along with Rogers own observations cited here, this homogeneity in Adler's spectral results concerning a non-image fiber coming from the head region of the frontal side of the Shroud and other non-image fibers coming from different locations can be seen as a very strong physico-chemical proof that Wilson's hypothesis is surely incorrect and this should lead Shroud's historians to search elsewhere in order to find a better explanation for the apparent silence of ancient documentary and artistic sources concerning the presence of a Shroud of Christ that was showing all his stigmata and his complete body image before the first attested appearance of the Shroud of Turin in the small town of Lirey, France, ca. 1357. I know that some defenders of Wilson's hypothesis will pretend that the Mandylion was probably kept almost constantly inside a reliquary and that would explain Rogers and Adler's conclusions but this kind of rationalization is totally contradicted by the evident difference that exists in the aging aspect of both sides of the Shroud. Effectively, during their direct examination of the cloth in 1978, the STURP team (including Rogers himself) easily noticed that the back side of the cloth (i.e. the one protected by the Holland backing cloth for some 444 years at the time of the examination) was showing less signs of aging (oxidation) than the frontal side (i.e. the one exposed that showed the body image), even though we know for a fact that, during all that time, the Shroud had been kept almost constantly inside a reliquary, except for some pretty rare public and private showings. Here's the first impression of Ray Rogers when he was able to see a portion of the back side of the cloth in 1978: "The back side is whiter than the front.[77]" *It's important to note that such an observation was made very easily with the naked eye and without any need for the use of a microscope. So, in all logic, if Wilson's hypothesis was correct, we should expect to see the same kind of accentuated signs of natural aging (i.e. more oxidation and most probably more dust and dirt also) for the region of the face versus the rest of the cloth than what the STURP team easily noticed in 1978 for the frontal side of the cloth versus the back side. Unfortunately for Wilson and the partisans of his hypothesis, Rogers and Adler's observations and analyses proved that this is absolutely not the case.*

71- All parts of a cloth will show the same (natural) radiation damage, unless there has been specific radiation in limited areas. Image areas (of the Shroud) do not show any evidence for excess radiation.[78]

72- The primary result of irradiation of cloth with energetic photons is heat. The blood was never heated to a temperature concordant with an intense flux of vacuum ultraviolet photons.[79] ***Personal note:*** *When Rogers said that the blood on the Shroud was never heated to high temperatures, it's important to understand that he's only talking about the majority of the bloodstains on the cloth that are located in areas that were not damaged at all by the fire of AD 1532 in Chambery, France.*

73- Simple heating would change both the cellulose and the blood. Both protons and neutrons leave characteristic tracks in flax fibers. The image fibers could not have been colored by energetic radiation.[80]

74- Image formation proceeded at normal temperatures in the absence of energetic radiation of any kind.[81]

75- If any form of radiation (thermal, electromagnetic, or particle) degraded the cellulose of the linen fibers to produce the image color, it would have had to penetrate the entire diameter of a fiber in order to color its back surface. Some lower fibers are colored, requiring more penetration. Radiation that penetrated the entire 10-15-μm[82]-diameter of a fiber would certainly color the walls of the medulla. All image fibers show color on their surface but not in the medullas.[83]

76- An average flax fiber is 10-20 μm in diameter, and some lower fibers are colored in image areas. Any radiation that colored the circumference of two, superimposed fibers would have to penetrate at least 20-40 μm of cellulose.

[76] Samuel F. Pellicori and Mark S. Evans, "The Shroud of Turin Through the Microscope," *Archaeology* 34, 35, January-February 1981. Note: In that paper, Pellicori and Evans describe the direct microscopic examination of the Shroud they did while they were in Turin in 1978 and never reported any noticeable differences between the level of oxidation of the non-image fibers located around the face and the level of oxidation of the non-image fibers located elsewhere on the cloth. Also, they never reported a more important presence of dust in the region of the face versus the rest of the cloth.

[77] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.

[78] Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004.

[79] *Ibid.*

[80] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.

[81] *Ibid.*

[82] μ means micro and is a multiplier of 1/1,000,000, μm = micrometer, http://wiki.answers.com/Q/What_does_mu_stand_for_in_measurement

[83] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.

Radiation that penetrated the entire 10-20-μm-diameter of a fiber would certainly affect the entire volume of the fiber, including the walls of the medulla (the cylindrical void in the center of the fiber). All image fibers (from the Shroud) show color on their outer surfaces, but the body of the fiber and the walls of the medulla are not colored.[84]

77- No radiation hypothesis alone can explain how the entire outer surface of image fibers could become colored without coloring the inside and the medullas.[85]

78- We had found starch fractions on the cloth during chemical testing. I had to hypothesize that image color had formed in a layer of impurities. I studied the chemical kinetics of the impurity materials and conclude that it was improbable that the impurities had been scorched by heat or any radiation source: the crystal structure of the flax image fibers was no more defective than non-image fibers. It would take very good temperature control specifically to scorch impurities without producing some defects in the cellulose.[86]

79- Neutrons produce "recoil protons" when they hit a material that contains hydrogen. The loss of hydrogen also causes crosslinking and double-bond formation. Neutrons cannot be invoked for image formation. Energetic neutrons would penetrate the entire diameter of the fibers.[87]

80- If the image was a scorch or any part of the Shroud had been heated enough to make significant changes in the rates of decomposition of any of its components, we would see changes in the structure of the flax fibers and blood. The blood still evolves hydroxyproline on mild heating, and the cellulose crystals are largely undistorted. The image is not a scorch. The cloth was not heated, not even boiled in oil.[88] ***Personal note:*** *When Rogers said that the cloth was not heated, it's important to understand that he's talking about the cloth as a whole. His statement doesn't consider the fact that some small parts of the cloth were burned during the fire of AD 1532 in Chambery, France. The conclusion that the cloth was never boiled in oil is Rogers' scientific answer to a claim that has been made by some Shroud historians and researchers over the years, which is based on a 16th century account that is certainly legendary instead of being historical.*

81- Proteins are much less stable than most other natural products. The appearance of a low-temperature emission of hydroxyproline sets a definitive upper limit on the highest temperature that could have been seen by the blood after it appeared on the cloth.[89] ***Personal note:*** *It's important to understand that Rogers' conclusion about this upper limit of temperature only concerns the majority of the bloodstains on the cloth that are located in areas that were not damaged at all by the fire of AD 1532 in Chambery, France. His statement doesn't address the few bloodstains that are located in some areas of the cloth that were burned or scorched during this fire of AD 1532. It's also important to note that Rogers did not give any precise number concerning the upper limit on the highest temperature that could have been seen by the blood after it stained the cloth,. However, in a paper he wrote concerning his Maillard reaction hypothesis for image formation, Rogers gave this relevant quote on that subject, which he took from a paper written by Heller, Adler et al.:* "The absence of products expected from a high-temperature cellulose degradation… suggests that the process that formed the final chemistry (of the body image) took place at lower temperatures (less than 200°C) because no pyrolytic compounds were found. The fluorescence of the scorch areas, however, demonstrates the presence of high-temperature pyrolytic products in these areas."[90] *Here, it's important to understand that, for Rogers, this upper limit of less than 200°C concerning the highest temperature the blood could have been submitted to is still much higher than what most probably happened in reality. Effectively, the pyrolysis mass spectrometry analysis he performed on a tiny sample of blood that was taken from the heel area on the Shroud in 1973 (note: this particular quote #81 is taken from a description of this analysis) lead him to conclude that the blood was probably never submitted to any abnormal heat (see quote #80) and consequently, that the Shroud had never been boiled in oil during its long history (see again quote #80) and that the image formation process proceeded at normal temperatures (see quotes #74 and 95), which strongly suggest to Rogers that it was totally natural.*

82- The blood produced hydroxyproline in pyrolysis/ms spectra. It was never heated significantly. Image formation had to be a low-temperature process.[91] ***Personal note:*** *When Rogers said that the blood on the Shroud was never*

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[84] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[85] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[86] Emmanuel M. Carreira, *The Shroud of Turin from the viewpoint of the physical science*, 2010.
[87] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[88] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[89] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[90] Eric J. Jumper, Alan D. Adler, John P. Jackson, Samuel F. Pellicori, John H. Heller and James R. Druzik, *A Comprehensive Examination of the Various Stains and Images on the Shroud of Turin*, ACS Advances in Chemistry, Archaeological Chemistry III 205, 1984
[91] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.

heated significantly, it's important to understand that he's only talking about image formation upper temperature limits affecting the majority of the bloodstains on the cloth that are located in areas that were not damaged at all by the fire of AD 1532 in Chambery, France.

83- The blood could be removed with proteolytic enzymes. The blood had not been cross-linked by irradiation. It is extremely unlikely that any form of radiation interacted with the cloth.[92]

84- Whatever caused the Shroud image did not affect the crystallinity of the flax fibers. Image formation did not involve any kind of intense heating, radiation, or stress that exceeded the mechanical limits of the material.[93]

85- Any radiation that is energetic enough or sufficiently intense to heat the cloth enough to cause the initial dehydration reactions of cellulose would penetrate into a fiber to a distance determined by its energy.[94]

86- Energetic radiation of all kinds causes defects in the cellulose crystals of the flax fibers. The defects are visible between crossed polarizers in a petrographic microscope. Shroud fibers show only normal aging.[95]

87- If Jackson were correct, and energetic photons caused the image color, the image areas should show significantly different amounts of diffuse radiation damage than the non-image areas. They do not.[96]

88- Jackson postulated that Jesus' body became "a body of light" and that "the light penetrates air a millimeter or two ("if at all"); i.e. the air is opaque to the radiation." This sets rigid limits of the kind of "light" that can be considered. Light that does not penetrate air is energetic enough to ionize or excite (raise to a more energetic molecular quantum state) oxygen and nitrogen; therefore, it is energetic enough to break all bonds in cellulose, blood and serum. It erodes the surface. Excited oxygen (e.g. the triplet state) oxidized all organic compounds, including cellulose, very quickly. It is used in a process called "cold oxidation". None of these effects can be observed in the Shroud.[97]

89- Jackson said: "The cloth falling into the body is a transitional event, not instantaneous." This means that the more time the cloth spent in the "energy field" the more extensive would be destruction to the cloth. There is absolutely no evidence for destruction in any of the image fibers: other than possessing a colored coating, they are identical to non-image fibers. If the image were produced by radiation, image and non-image fibers should be much different.[98] ***<u>Personal note</u>:*** *The expression "destruction" used here by Rogers must be understood in the sense of "damage" to the structure of the linen fiber.*

90- According to Jackson, "Only the fibers on the cloth that were fully exposed in the energy field were imaged… Deeper fibers were protected from the energy field by the fiber lying on top of them and therefore not imaged." Not even all of the fibers that would have been facing the "energy field" are colored. The distribution of the image color on the surface of the cloth is discontinuous. This can easily be seen in macrophotographs of image areas.[99] ***<u>Personal note</u>:*** *This objection of Rogers concerning the hypothesis proposed by Jackson can also be applied to any other image-formation hypothesis that involves a sudden burst of energetic radiation of some sort that would have come from the dead body enveloped in the Shroud. In a recent paper[100] published in 2011, Fazio and Mandaglio, two Italian scientists, have been able to confirm this particular conclusion of Ray Rogers. Effectively, these two researchers have been clear about the fact that, in theory, the stochastic (unpredictable or, in the case of the Shroud, discontinuous) distribution of the image fibers on the Shroud could not have been caused by any kind of energetic radiation. Here's what they say about that: "Recently, we have studied the possible interaction between radiation and the Shroud of Turin. The analysis performed has shown that any hypothesis of the Shroud body image formation by radiation must be rejected. In fact, the hypothesis of thermal, visible, UV, and particle radiation, together with a corona discharge and an excimer laser irradiation, does not yield the discrete distribution of the yellowed fibrils that was found in the image." However, it's important to note that, in the same article, these authors have been able to reconsider the idea that thermal radiation coming from the dead body could have produced the coloration of the image on the Shroud while using new factors for their calculations. By doing so, they ended up concluding that such a thermal radiation or a low-temperature chemical process (like Maillard reactions) are the two most probable mechanisms that could scientifically explain the image on the Shroud.*

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[92] Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004.
[93] Raymond N. Rogers, *The Shroud of Turin: Radiation Effects, Aging and Image Formation*, 2005.
[94] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[95] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[96] Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004.
[97] *Ibid*.
[98] *Ibid*.
[99] *Ibid*.
[100] Giovanni Fazio and Giuseppe Mandaglio, *Stochastic distribution of the fibrils that yielded the Shroud of Turin body image, Radiation Effects and Defects in Solids*, Vol. 166, No. 7, July 2011 (http://www.tandfonline.com/doi/abs/10.1080/10420150.2011.566877).

91- Fibers hit by intense, energetic radiation vaporize; fibers hit by energetic radiation change crystal structure. A light shining on an irregular surface illuminates the entire surface. The entire facing surface should be affected by radiation hitting it. The surface of the Shroud does not show the effects of radiation.[101]

92- If any kind of radiation had caused the image, the characteristic effects of the radiation would be clearly visible in the flax fibers of the Shroud. In addition to that fact, more damage should be observed in image areas than in non-image areas. Such a situation is not observed (on the Shroud).[102]

93- If the image were caused by any form of radiation, the structure of the flax fibers in the image areas must be significantly different from those in non-image areas. They are not.[103]

94- Jackson theory cannot be supported by the observations that have been made on the Shroud of Turin or the masses of information available on radiation effects.[104]

95- The crystal structure of the flax fiber of the Shroud shows the effect of aging, but it has never been heated enough to change the structure. It has never suffered chemically significant radiation with either protons or neutrons. No type of radiation that could produce either color in the linen fibers or change in the C^{14} content (radiocarbon age) could go unnoticed. All radiation has some kind of an effect on organic materials. This proves that the image color could not have been produced by thermal or radiation-induced dehydration of the cellulose. Image formation proceeds at normal temperatures in the absence of energetic radiation of any kind.[105]

96- Image fibers and non-image fibers show exactly the same kinds of defects and defect populations. The image was not caused by energetic radiation.[106]

97- The image does not fluoresce under ultraviolet illumination. Scorch margins from the fire of AD 1532 fluoresce. The image was not caused by scorching, intense heating, flash heating, flash photolysis, ionizing radiation, or any other process that would produce second-generation, fluorescent, chemical-decomposition products. Image color formed under mild conditions.[107]

98- Fibers from scorched areas of the Shroud are entirely different from image fibers.[108]

99- Scorching by contact with hot irons, statues, etc., must be ruled out, because heat flow by conduction penetrates the cloth. Different colors can be seen as a function of the depth into the cloth, and fibers are colored through their entire diameter. The medullas of scorched fibers are colored. The Shroud image is entirely different. If a scorching event involves confinement, as with a hot iron, the scorch is fluorescent. The image does not fluoresce.[109]

100- The flame from a very high-temperature torch can be used to "paint" an image, and the scorching event is open to the air. The scorch does not fluoresce. The flame is repelled from the surface of a cloth by the ablation of the material, and the color does not penetrate very far. However, all fibers that were pointing upward in the nap of the cloth are burned by the flame, and individual fibers are colored all the way through.[110]

101- It is clear that a corona discharge (plasma) in air will cause easily observable changes in a linen sample. No such effects can be observed in image fibers from the Shroud of Turin. Corona discharge and/or plasmas made no contribution to image formation. I believe that the current evidence suggests that all radiation-based hypotheses for image formation will ultimately be rejected.[111]

102- A corona discharge charges the surface of an insulator like dry linen, and maximum charge concentrations are observed at points. These charges repel electrons; therefore, upward-pointing fiber ends would not char. I could not produce any colors by this method.[112]

103- Image-formation hypotheses that are based solely on any kind of electromagnetic energy must also be ruled out.[113]

104- Hypotheses based on ionizing and/or non-ionizing particles suffer from the same problem as photon-energy transfer: The entire facing surface is colored. Image color appears on the Shroud only at the highest part of the weave.[114]

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[101] Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004.
[102] *Ibid*.
[103] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[104] Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004.
[105] Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
[106] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[107] *Ibid*.
[108] *Ibid*.
[109] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[110] *Ibid*.
[111] Raymond N. Rogers, *The Shroud of Turin: Radiation Effects, Aging and Image Formation*, 2005.
[112] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[113] *Ibid*.

105- Rapid heating, as when linen is scorched with a torch, leaves characteristic, small balls of solidified melt at the ends of the fibers. There are none on the Shroud.[115]

106- High temperatures and energetic radiation absolutely cannot explain the properties of the image. That statement does not suggest a miracle.[116]

107- If radiation is not sufficiently energetic directly to cause chemical bonds to break, it's only effect is to heat the material. Red and infrared light do not color linen unless they are so intense that they heat it to a temperature where the rate of dehydration is significant. The heat will penetrate the cloth.[117] ***Personal note:*** *Rogers was clear about the fact that this kind of result is incompatible with the properties of the Shroud's image.*

108- We consider iridescence (optical interference in thin layers) and electrons trapped in crystal defects. Those could easily been discarded. All remaining ways must involve chemical changes.[118]

109- Any image-formation mechanism that would result in color formation inside the linen fibers must be rejected. Some "theories" that have been mentioned that would cause color inside fibers are penetrating radiation, high-temperature scorching (hot statue, painting with a torch, etc.), and catalyzed dehydration of the cellulose. Image fibers are colored only on their surfaces.[119]

110- Hot irons, statues, etc., must be ruled out, because different colors can be seen as a function of the depth into the cloth. Color penetration is different for contact and non-contact areas, and fibers are colored through their entire diameter.[120]

111- When linen is heated, water immediately begins to be desorbed and the linen dries out. As the temperature increases, the cellulose melts with decomposition. Quickly heated and cooled linen shows little black balls where it melted. As it melts, the carbohydrates (cellulose and sugar-based hemicellulose impurities) start to dehydrate chemically. The colored products of dehydration are extremely complex, but they have some well-known chemical properties and structural units.[121] ***Personal note:*** *For Rogers, this is not what happened on the Shroud during the image formation process. For him, the entire structure of the linen fiber (including the primary cell wall, which is the external part of the fiber made of cellulose, hemicellulose and pectin) was probably not affected at all (including no dehydration or coloration) by the image formation process, which would not have produced an important heating of the fibers. In fact, for Rogers, only possible residues of the primary cell wall of the linen fiber (like hemicellulose or pectin residues that could have been extracted by the retting process of the flax plant and left on the fibers at the end of this treatment) could have taken part in the image formation (as a minor contributor) instead of the fiber itself (including the primary cell wall of the fiber), because those residues "extracted" from the linen fiber would have been the only elements of the flax plant that could have been dehydrated (colored) by the mild chemical process (i.e. a Maillard reaction) he thought was responsible for the formation of the body image, along with other carbohydrate residues made of starch and possibly also of saponaria. In another paper, Rogers said this:* "Some type of carbohydrate dehydration reaction seems most probable as an explanation for the image color; however, the color appears only on the surface of the individual fibers. The color of the image does not involve the cellulose."[122] *Here, the word "cellulose" should be understood as meaning "the entire linen fiber".*

112- The only image color visible on the back side of the cloth is in the region of the hair. The color density of the hair image is much lower on the back side of the cloth than on the front. Any image-formation hypothesis must explain how the hair image could penetrate the cloth while the body image did not.[123] ***Personal note:*** *This possible image of the hair (including the beard and mustache) on the back side of the Shroud is still waiting for a scientific confirmation.*

113- The photographs of the back side of the cloth that were taken in June and July of 2002 show faint image color on the back of the cloth in the area of the hair. No body image is visible. What kind of radiation would penetrate the cloth and color it in the area of the hair and not penetrate the cloth anywhere else? Also, fibers taken from the face and hair images in 1978 are identical to all of the other image fibers: They are colored only on the surface.

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[114] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[115] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[116] *Ibid*.
[117] *Ibid*.
[118] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[119] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[120] Raymond N. Rogers, *The Shroud of Turin: An Amino-Carbonyl Reaction (Maillard Reaction) Could Explain the Image Formation*, Melanoidins, Vol. 4, Ames J.M. ed., Office for Official Publications of the European Communities, Luxembourg, 2003 (http://www.shroud.com/pdfs/rogers7.pdf).
[121] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[122] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[123] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.

The cellulose was not colored. How can energetic radiation color just the outside of a very small fiber?[124] ***Personal note:*** *In the context of that part of Rogers' book, we can easily assume that the expression "the outside of a very small fiber" that he used in his last question refers to the thin layer of carbohydrate impurities that he thought was present on the surface of the linen fibers of the Shroud, instead of the external part of the linen fiber itself called "the primary cell wall".*

114- When a cloth is dried on a line, impurities concentrate on both evaporating surfaces, however, more impurities will deposit on whichever surface dries faster. Any concentration of impurities can take part in the image-formation reactions. This can explain the "doubly-superficial" image.[125]

115- Evaporation concentration can explain how most of the color-producing impurities were concentrated on the upper surface of the cloth. The faint image of the hair on the back of the Shroud indicates that some impurities appeared on the back, as they do in most of my experiments.[126] ***Personal note:*** *Rogers is referring here to some lab experiments he did to analyze the evaporation concentration phenomenon in the context of the washing and drying of a linen cloth. For that kind of experiment, he used a colored dye to have a better look at the resulting concentration of "impurities" on both surfaces of his samples of cloth. In his book, Rogers give us a good example of that kind of experiment, along with the results he recognized:* "The phenomenon can be demonstrated with a simple experiment. Prepare a dilute solution of food coloring, and divide it into two parts. Add a drop of liquid detergent to one part. Cut some squares of white cloth that are about 10 cm on a side. Saturate cloth samples with one or the other of the solutions. Mark the samples for identification. Lay some saturated samples of cloth on smooth, non-absorbent surfaces (e.g., a sheet of plastic). Lay some samples on dry sand in the sun. Hang some samples from a line. Let the liquid evaporate. Different types of cloth will show different degrees of concentration of the dye on the evaporating surfaces, even on different adjoining fibers. It is possible to get dye concentration on both surfaces, while leaving the interior of the cloth white.'[127] ***Personal note:*** *The fact that "different types of cloth will show different degrees of concentration of the dye on the evaporating surfaces, even on different adjoining fibers" is a strong indicator that if there really is an impurity layer on the surface of the Shroud, it should be uneven, thus offering a very good, simple and rational explanation for the discontinuous distribution of colored fibers in the image area.*

116- The observation of colorless cores in image fibers, ghosts pulled from fibers by the adhesive, the reduction of the color with diimide, lack of fluorescence in an image area, and optical differences between image and scorch fibers eliminate any high-temperature heating event or energetic radiation in image formation.[128]

117- There is no evidence for tissue breakdown (formation of liquid decomposition products of a body). This suggests definite time limits for image formation and cloth-body contact. Some reports from forensic pathologists suggest an upper limit of about 30 hours.[129] ***Personal note:*** *Elsewhere in his book, Rogers is less precise about that upper limit of time, as he wrote:* "Vass et al. report that putrefaction (structural degradation) generally starts between 36 and 72 hours after death, although rates do depend somewhat on clothing. The Shroud shows no obvious signs of putrefaction products. Perhaps we can assume that the cloth could not have been in contact with the body for more than three days."[130] *It is then more prudent to estimate the upper limit of time for image formation and cloth-body contact as a variable period of time that goes between 36 and 72 hours after death, because of the numerous unknown factors surrounding the death and burial of the man of the Shroud.*

118- Although high-temperatures and energetic radiation must be ruled out for image formation, lower-temperature processes are still possible. All that is required is that temperatures never reach the level where cellulose begins to dehydrate at a significant rate. Cellulose start to dehydrate rapidly between 275 and 300˚C.[131]

119- The emissivity of a human body is like other non-metals or organic materials. Image formation that involves thermal radiation (from a dead body) cannot be ruled out; however, it cannot explain all of the features of the Shroud.[132]

120- The thermal conductivity of linen is low…; therefore, the temperature gradient extending outward from any heated area will be quite steep: It will be much hotter near contact points and cooler away from them. This is

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124 Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
125 Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004.
126 Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
127 *Ibid*.
128 Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
129 Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
130 *Ibid*.
131 *Ibid*.
132 *Ibid*.

important in considering the chemical rates of processes that can form a color on a shroud that is in contact with a body.[133]

121- Pellicori of STURP studied contact and material-transfer hypotheses, and no image-formation hypothesis that is based solely on a vapor-diffusion and/or material-transfer mechanism can be accepted. Vapors and liquid penetrate the cloth: materials that will color the surface will also diffuse into and color the inside of the cloth.[134]

122- Diffusion of gaseous reactants or dyes into the cloth would have produced a color gradient (darker on the surface, lighter at depth).[135] ***<u>Personal note</u>:*** *Here, Rogers talks about the most probable result that would happen if it is the linen fibers themselves that would be colored. It's important to understand that if the coloration would only affect a thin layer of impurities that is concentrated on the surface of the cloth (this is Rogers' own hypothesis), a color gradient wouldn't be present inside the cloth.*

123- In the context of image-formation hypotheses that involve reactive gases, remember that cloth is porous. Gases diffusing to the surface can pass through the pores and be lost. This phenomenon will restrict vapor concentrations as a function of the distance from contact points where a body touches a cloth. Cloth surfaces are active and absorb gases rapidly, a fact that further limits concentrations as a function of distance. John Jackson's mathematical analysis of image resolution suggested that no single, simple molecular-diffusion or radiation mechanism could produce the image observed. However, a combination of systems could offer an explanation, e.g. anisotropic heat flow by radiation from the body to the cloth, attenuated heat-flow in the cloth, gaseous diffusion, convection, surface properties of the cloth, and the dependence of chemical rates on temperature.[136]

124- The diffusion properties of gases suggest an hypothesis for image formation that involves amines and an impurity on the cloth, and it might help explain the rather good resolution of the body image. Some gases must be produced by the body, and some color-producing reactions must occur on the cloth as a result of interactions between the gases and the cloth.[137]

125- An interesting corollary of hypothetical diffusion/reaction relationships is the fact that image resolution will be much better when the reactive amines appear slowly. If the amines are reacting with the cloth as they diffuse, their concentration decrease with both time and distance. If all of the decomposition products were to appear at once, resolution would be poor. Reaction rates could not keep up with diffusion.[138]

126- Little circular currents called "convection cells" are established between a warm surface and a cooler one. The rising warm air hits the cooler surface, it cooled, become heavier, and sinks toward the warm surface again. Convection cells act to mix gases from either surface with the air. Convection cells are smaller when the distance between the hot and cold surface is less. Convection will decrease image resolution. For best resolution, the decomposition products of a body would have to be emitted slowly with the body at the same temperature as the cloth.[139]

127- The facts fit together. It takes a few hours for a body to cool after death, and it takes a few hours for heavy amines to be produced in significant amounts.[140]

128- Vapor diffusion parallel to the cloth's inner surface would follow Graham's Law of diffusion, and it would be slow for high-molecular-weight decomposition amines. Image density would fall off rapidly away from the body, increasing resolution. Gaseous reactive amines can be lost by diffusion through the porous cloth, reducing concentration and reaction rates inside the cloth.[141]

129- Image characteristics indicate that ammonia diffused from the nose and mouth, suggesting that the body was wrapped fairly soon after death. The body image has good resolution, suggesting that heavy amines appeared slowly at lower temperature.[142]

130- A number of components for the development of a complex image-formation hypothesis are suggested by the bands of color on the cloth, the difference between image and scorched fibers, the interactions between the bands of color and the image areas, the density of the image in the vicinity of the nose and mouth, and the resolution of the body image (especially the fingers).[143]

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[133] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[134] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[135] *Ibid*.
[136] *Ibid*.
[137] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[138] *Ibid*.
[139] *Ibid*.
[140] *Ibid*.
[141] *Ibid*.
[142] *Ibid.*
[143] *Ibid.*

131- Formal statement of the impurity hypothesis for image formation to be tested: The cloth was produced by technology in use before the advent of large-scale bleaching. Each hank of yarn used in weaving was bleached individually. The warp yarns were protected and lubricated during weaving with an unpurified starch paste. The finished cloth was washed in *Saponaria officinalis* and laid out to dry. Starch fractions, linen impurities, and *Saponaria* residues concentrated at the evaporating surface. The cloth was used to wrap a dead body. Ammonia and other volatile amine decomposition products reacted rapidly with reducing saccharides on the cloth in Maillard reactions. The cloth was removed from the body before liquid decomposition products appeared. The color developed slowly as Maillard compounds decomposed into final colored compounds.[144]

132- The chemistry of the color does not answer all questions about how the "photographic" image formed. The image seems to show the body of a man, and it is darkest in areas that should have been closest to the body's surface; however, the "resolution" of the image has been puzzling. I believe that its resolution is a natural consequence of the image-formation process.[145]

133- Post-mortem body temperatures can reach 43°C (110°F), and steep temperature gradients would exist across the cloth as a result of the low thermal diffusivity of linen and the angular dependence of radiant heat flow from a nonmetallic surface. The temperature gradients will have a large effect on Maillard reaction rates. I believe that the combination of factors could produce a distribution of reaction products with the appearance of the (Shroud's) image; however, the cloth would have to be removed from the body before liquid decay products appeared. This is a testable hypothesis.[146]

134- Post-mortem body temperatures can reach 43°C (110°F), and steep temperature gradients would exist across the cloth as a result of the low thermal diffusivity of linen and the angular dependence of radiant heat flow from a nonmetallic surface. The temperature gradients will have a large effect on Maillard reaction rates and image resolution before the body cools, i.e., while ammonia is the predominant amine.[147]

135- If there can be a large change in (reactive-gas) concentration in a small distance, resolution can be good. It is not valid to assume a diffuse image when gaseous diffusion is involved in the image-formation mechanism.[148]

136- The (Maillard) reactions occur at significant rates at much lower temperatures than the caramelization (thermal dehydration) of any of the sugars. A good example of Maillard reactions is the production of dark beers at low temperatures by reactions between maltose and any reducing starch components and the proteins or amino acids in the wort. Cheaper beers may be colored more rapidly by heating the wort with ammonia (the simplest amine).[149]

137- The first steps of the Maillard reactions are rather fast at much lower temperatures, and they produce colorless compounds (for example, glycosylated-proteins). The rates are even higher at body temperatures; however, they increase by factors between two and three for each 10°C (18°F) increase in temperature. The colorless compounds are unstable, and they rearrange to give brown polymeric materials, melanoidins, most of whose structures are still unknown. It takes some time at lower temperatures for the color to appear. The color is not a result of oxidation.[150]

138- Several Shroud researchers have wondered why there is no mention of an image on the "cloth" reportedly found in Jesus' tomb. Assuming historical validity in the accounts, such a situation could be explained by the delay in the development of the Maillard reactions' colors at moderate temperatures. No miracle would be required.[151]

139- Many of the final products of Maillard reactions are identical to those produced by caramelization of sugars. The structures that produce the color are conjugated double bonds, just as hypothesized from the spectra taken by STURP (concerning the Shroud's image). Some of the most important products in color formation do not contain any nitrogen. This fact could help explain why we did not observe any nitrogen compounds in image areas.[152]

140- Most of the very volatile ammonia diffuses out through the nose and mouth soon after death. This fact may explain the darker image color between the nose and mouth and penetration of image color in the vicinity of the hair.[153]

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[144] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[145] *Ibid.*
[146] *Ibid.*
[147] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[148] *Ibid.*
[149] *Ibid.*
[150] *Ibid.*
[151] *Ibid.*
[152] *Ibid.*
[153] *Ibid.*

141- I believe that impurities in ancient linen could have been suspended by the surfactant property of a *Saponaria officinalis* washing solution. They would be concentrated at the drying surface by evaporation. Reducing saccharides would react rapidly with the amine decomposition products of a dead body. This process could explain the observations on the chemistry and appearance of the image on the Shroud of Turin. Such a natural image-formation process would not require any miraculous events; however, it would support the hypothesis that the Shroud of Turin had been a real shroud.[154] ***Personal note:*** *Even when Rogers used the term "amine decomposition products of a dead body," it's important to understand that such products can be released by a corpse before the appearance of the putrefaction (structural degradation) of the body.*

142- When amines and reducing sugars come together, they will react. They will produce a color. This is not a hypothesis: this is a fact. A cloth with crude starch on it will ultimately produce a color, if it is left in close proximity to a decomposing body.[155] ***Personal note:*** *Here, it's very important to understand that, in Rogers mind (and scientifically speaking, he's right), a dead body is already in the first "decomposition" state way before the appearance of the putrefaction (structural degradation), which generally starts between 36 and 72 hours after death (see quote #117). It is a known fact that a dead body can emit post-mortem gases before the appearance of the putrefaction of the body.*

143- It is important to recognize that Maillard colors will form every time amines and simple starches and/or sugars come together.[156]

144- The ammonia and many of the decomposition amines are volatile and basic (they increase the pH into a more favorable range for Maillard reactions), and they rapidly undergo Maillard reaction with any reducing saccharides they contact. The reactions are rapid at room temperature, or even lower. Such sugar-amines reactions offer a natural explanation for the color on the Shroud.[157] ***Personal note:*** *Again, it's very important to understand that when Rogers talks about "decomposition" amines, that doesn't mean he was thinking of a gaseous diffusion that would have occurred after the arrival of the putrefaction (structural degradation), which generally starts between 36 and 72 hours after death (see quote #117). It is a known fact that a dead body can emit post-mortem gases before the appearance of the putrefaction.*

145- The amine/saccharide experiments (made by Rogers himself) showed that the following variables are important (concerning his Maillard reaction hypothesis): 1) When the "body" temperature is too high, convection cells are too active, diffusing amines too widely for good resolution. Resolution improves at lower temperatures. A body that had cooled for several hours but has not yet produced high concentrations of amines would give better resolution than a hot body. 2) The amines must be released slowly. Too much amines badly reduced resolution. A decaying body would give much better resolution than any object that had been painted with pure amines. Too much amine would color the entire cloth, obliterating the image. A successful image that involved a real body would require removal of the cloth before extensive decomposition. 3) The experimental assembly must be kept in a space that his cool and still. 4) An increase in the concentration of reducing saccharides (impurities) on the cloth improves resolution. 5) Modern linen that does not contain suitable impurities will not produce an image.[158]

146- Experimental manipulations of concentrations and one-dimensional migration of solutions (of *Saponaria*), as in a large cloth, could produce the same front to back color separation and color density as observed on the Shroud. The fibers on the top-most surface are the most colored when observed under a microscope, and the color is a golden yellow similar to that on the Shroud. The coating of Maillard products is too thin to be resolved with a light microscope, and it is all on the outside of the fibers. There is no coloration in the medullas: The color formed without scorching the cellulose. There is very little color on fibers from the middle of the back surface. The color-producing saccharides had concentrated on the evaporating surface. Water-stained image areas on the Shroud showed that image color does not dissolve or migrate with water. Maillard products are not water soluble, and they do not move when wetted.[159] ***Personal note:*** *This is the summary of the results obtained by Rogers after he did a preliminary coloration test with a "primitive-type" linen sample (i.e. made with the ancient technique used to manufacture linen cloths) that had been treated at room temperature for 10 minutes with ammonia vapor. As Rogers said:* "A very light color could be observed on the top surface after standing 24 hours at room temperature."[160] *But, in order to obtain a similar coloration than what is observed on the Shroud, he had to heat*

[154] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[155] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[156] *Ibid*.
[157] *Ibid*.
[158] *Ibid*.
[159] *Ibid*.
[160] *Ibid*.

his sample, which indicates that such coloration would only appear after a pretty long period of time (which could possibly be counted in years). That means the image on a linen cloth that can be obtained with a Maillard reaction is a latent image that can only become fully visible a long time after the initial reactions occurred.

147- Assuming the amine-impurity image-formation mechanism, the image on the Shroud required just exactly the correct conditions, or it would not have been produced with the resolution and color density observed.[161]

148- However, identification of a probable chemical process does not explain one of the perplexing observations on the Shroud, the discontinuous distribution of the color on the top-most parts of the weave.[162] ***Personal note:*** *This quote from Rogers should not be understood as meaning that the discontinuous distribution of the colored fibers in the image area is not compatible with a natural mechanism for image formation that would involve a chemical process like the Maillard reaction he proposed before his death in 2004. In fact, this quote from Rogers only means that, in order to explain properly the discontinuous distribution of the colored fibers in the image area, some more factors others than a chemical process like a Maillard reaction (for example, the presence of an uneven[163] and very thin layer of impurities on the top-most fibers of the cloth and/or a very small amount of energy involved in image formation process), must have been active during the image formation. This interpretation found a pretty good confirmation in a recent paper[164] that was published in 2011 by two Italian scientists named Giovanni Fazio and Giuseppe Mandaglio. Effectively, in this paper, the two researchers came to the conclusion that, in theory, the stochastic (unpredictable or, in the case of the Shroud, discontinuous) distribution of the image fibers on the Shroud could only have been caused by a natural process, which could have implied a low-temperature chemical process like the Maillard reaction proposed by Rogers and/or thermal radiation released by the dead body of the Shroud man. Here's what they say about that: "As the distribution of the fibrils that yield the image is not due to the presence of materials on the body (this conclusion completely agrees with Rogers' conclusion in quotes #8 and 9), it is necessary to establish the actual source that has furnished the small quantity of energy to the cloth in the region where the Shroud body image lies. For us, the explanation of the image formation has to be in the context of natural mechanisms." Elsewhere in their paper, they also wrote: "We suggest thermal radiation or low-temperature chemical processes as possible natural sources to explain, by stochastic effects, the Shroud body image formation." And finally, they wrote this in the conclusion of their article: "This result (of calculation) makes the above process (thermal radiation) the most interesting of the attempts to explain the formation of the image." However, even if this particular conclusion of Fazio and Mandaglio is interesting, we must consider one particular quote of Ray Rogers that is truly relevant (see quote #119):* "Image formation that involves thermal radiation (from a dead body) cannot be ruled out; however, it cannot explain all of the features of the Shroud."[165] *In this context, we can postulate that a combination of thermal radiation and Maillard reactions (both coming from the dead body) can possibly offer the best explanation for the stochastic (discontinuous) distribution of the image fibers on the Shroud. It should be noted that such a scenario agrees perfectly with Rogers' own hypothesis and, because he only had time (before his death in 2004) to do some preliminary tests to verify its validity, it would be great to see a biochemist or a forensic expert taking over Rogers work in order to study his hypothesis more deeply. Who knows if the "secret" of the Shroud's image is not hidden in this kind of combination of natural processes? One thing is for sure: in their article, Fazio and Mandaglio have completely rejected the possibility that, in theory, the kind of stochastic (discontinuous) distribution of the image fibers that we see on the Shroud could have been produced by any kind of energetic radiation (see my personal note concerning quote #90). For these two researchers, such a*

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[161] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.

[162] *Ibid*.

[163] In his paper entitled *An Alternate Hypothesis for the Image Color* (2001), Rogers reported an evaporation-concentration experiment he made with a cotton nap and a dye solution and described the result like this: "The photomicrograph shows that the main concentration of dye on the top surface appears on the fibrils of the nap that are pointing straight up and on the top-most surfaces of the threads." This is a clear indication that when an evaporation-concentration phenomenon is active inside a cloth, it normally produces an uneven layer of impurities that concentrate mostly on the top surface of the cloth, thus giving us a possible explanation for the discontinuous distribution of colored fibers in the image area of the Shroud (as well as the extremely superficial aspect of the image). Effectively, starting from this result obtained by Rogers, we can presume that, after the active phase of the image formation process (which was most probably mild), only a portion of the coated fibers located on the top surface of the cloth (i.e. the ones that were coated by a thicker layer of impurities) were able to get colored enough to help produce the body image that we see on the Shroud, because the amount of impurities, in their case, would have been sufficient to produce such a result. Notice also that Rogers reports the same kind of evaporation-concentration experiment with dye in his book "A Chemist's Perspective on the Shroud of Turin", while mentioning that the degree of dye concentration can be variable even between two adjoining fibers (see quote #115), which confirms very well this personal interpretation of the previous quote coming from his paper entitled *An Alternate Hypothesis for the Image Color* (2001).

[164] Giovanni Fazio and Giuseppe Mandaglio, *Stochastic distribution of the fibrils that yielded the Shroud of Turin body image, Radiation Effects and Defects in Solids*, Vol. 166, No. 7, July 2011.

[165] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.

distribution of colored fibers can only happen when minor quantities of energy (gaseous and/or thermal, etc.) are transferred to the fabric, which is also consistent with Rogers conclusion that the image formation process must have been very mild (see quotes #20 and 95).

149- A partial explanation for the discontinuous and superficial nature of the image color and its chemistry might be found in a study of the technology of the production of the cloth. The technology coupled with Pellicori's observations (coming from a study of contact and material-transfer hypotheses[166]) might explain the nature and distribution of the color of the image.[167] ***Personal note:*** *Rogers is referring here to the ancient technology of the production that was most probably used to manufacture the cloth (see quotes #35 through 59), which would have caused a concentration of carbohydrate impurities on the top-most fibers of the cloth. At the end of his life, Rogers was thinking that it is a very thin and uneven layer of impurities like this that was colored (and nothing else) during the image formation process, thanks to a chemical and natural process known as a Maillard reaction, which would have come from the release of some post-mortem gases by the dead body (like ammonia gas and maybe some heavy amines), thus causing a dehydration of this layer of impurities on a portion of the coated fibers. This kind of natural interaction between the dead body and the top-most fibers of the linen cloth it covered would then give a very good and rational explanation for the fact that the colored fibers are all located on the top-most fibers of the cloth with a discontinuous distribution. It should be noted that when Rogers wrote the paper from which this quote #149 has been taken (in 2001), he was still trying to find what natural substance (or substances) could have been responsible for the dehydration of the colored fibers. He had not yet found the Maillard reaction coming from post-mortem gases that he would eventually propose. That's why he was referring here to the study made by Samuel F. Pellicori of STURP, which showed that some natural substances like skin perspiration (sweat) containing skin oils or some ancient Palestinian burial products like olive oil or myrrh could gradually color a linen cloth with spectral properties that are very similar to what is seen in the body image area on the Shroud. As it seems, before he was able to develop his Maillard reaction proposal, Rogers was thinking that the substances tested by Pellicori, and especially the biological ones* (i.e. skin perspiration and/or skin secretions, including skin oils) [168]*, could offer some potentially valid options concerning the question of what would have been responsible for the dehydration of the colored fibers in the image area of the Shroud. Nevertheless, it's important to note that, in Rogers mind, this kind of natural and biological process could not have happened in the way it was described by Pellicori (i.e. with a transfer mode involving only direct-contacts between the cloth and the numerous body parts that left their imprint on it), but could only have happened with a combination of transfer modes including both direct-contact and diffusion instead (see next quote). But after he did more studies and reflected on the subject, it seemed that Rogers became totally convinced that the "catalytic compounds" that were responsible for the dehydration of the colored fibers were not the ones tested by Pellicori (see quotes #8 and 9 for a possible explanation for Rogers' change of mind) but post-mortem gases instead (like ammonia gas, along with maybe some heavy amines) that would have been gradually released by the enshrouded corpse. Finally, it should also be noted that, at the time he wrote his 2001 article, Rogers was already thinking that heat coming out of the dead body could have taken part in the image formation process. Here's what he wrote about that:* "…I do not think we can rule out long-wave heat transfer (from a dead body) as contributing to the image-formation process. It could not have been the sole contributor."[169] *Now, if you look at quote #119, you'll notice that he wrote almost the same thing in his book about the Shroud (published in 2008), proving that, until his death, Rogers never changed his mind about that.*

150- I believe that a combination of relatively rapidly decomposing impurities on the surface of the cloth with transfer/diffusion of catalytic compounds from a body, as discussed by Pellicori, could explain the observations on the chemistry and appearance of the image on the Shroud. It should explain the shallow penetration of the image, the fact that the color did not penetrate more deeply at presumed contact points, its "half-tone" appearance, and its predominantly discontinuous distribution. Both catalyst concentration gradients and angle-dependent emittance of energy from a body would contribute to the 3-D relief seen in the image.[170] ***Personal note:*** *Again, Rogers is referring here to the image formation study made by Samuel F. Pellicori of STURP as being able to*

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[166] Samuel F. Pellicori, "Spectral Properties of the Shroud of Turin," *Applied Optics* 19, June 15 1980. Samuel F. Pellicori and Mark S. Evans, "The Shroud of Turin Through the Microscope," *Archaeology* 34, 35, January-February 1981.

[167] Raymond N. Rogers, *An Alternate Hypothesis for the Image Color*, 2001.

[168] In his paper entitled *An Alternate Hypothesis for the Image Color* (2001), Rogers made a specific reference to "human sebaceous secretions that includes free acids, combined fatty acids, triglycerides, and considerable "unsaponifiable" material." Then, Rogers wrote this: "Some of these (biological) materials should catalyze the decomposition of low-molecular-weight carbohydrate impurities."

[169] Raymond N. Rogers, *An Alternate Hypothesis for the Image Color*, 2001.

[170] *Ibid*.

offer some potentially good options to explain the dehydration of the colored fibers in the image area of the Shroud (see my personal note concerning the previous quote). Again, it's important to emphasize the fact that later on, when he elaborated his Maillard reaction hypothesis, Rogers became convinced that it was not the biological "catalytic compounds" proposed by Pellicori (i.e. skin perspiration (sweat) and/or skin secretions, including skin oils) that were responsible for the dehydration of the colored fibers on the Shroud (and also for all the specific characteristics of the body image mentioned in the present quote), but instead a release of post-mortem gases from the dead body (including ammonia gas, along with maybe some heavy amines). Nevertheless, it's important to understand that the natural hypothesis described by Rogers in the 2001 paper from which this quote #150 had been taken was not so much different than the Maillard reaction he eventually proposed later on, in the sense that it was already relying on a natural interaction (that included diffusion as one of the transfer processes) between an uneven and thin layer of impurities located mainly on the top-most fibers of the cloth (left there thanks to the ancient manufacturing technique that was probably used to make the cloth) and some biological substances coming from the body. Also, just like it was for the Maillard reaction hypothesis, this previous hypothesis of Rogers was also leaving the door open to the possibility that a release of heat from the dead body could have played some role in the formation of the body image. Finally, another evident similarity exists between the two natural hypotheses proposed by Rogers, which is, in both cases, a "latent" type of image was expected, which means that the body image was supposed to have become truly visible only many months, if not years or decades after the body was separated from the cloth. Taking notice of all these similarities, we can conclude that the Maillard reaction proposed by Rogers at the end of his life was simply a more refined version of the hypothesis he described in his 2001 paper.

151- The observations (concerning the Maillard reaction hypothesis) do not prove how the image was formed or the "authenticity" of the Shroud. There could be a nearly infinite number of alternate hypotheses, and the search for new hypotheses should continue.[171] *In page 57 of Rogers' book, he writes about a pyrolysis mass spectrometry analysis that he did on different samples from the Shroud. Here's one important thing he said about this analysis:* "Mass 131 appeared at much higher temperatures in all of the spectra, but those are in the range of cellulose, lignin and hemicellulose."[172] *In page 86 of his book, Rogers shows an image (figure X-7) that is the result of an experiment he made with a linen sample prepared with the same antique method described by Pliny the Elder in order to test the hypothesis of the corona discharge. About his result:* "A single fiber from the center of figure 2 in water. Hemicelluloses and pectins have been oxidized, leaving most of the more stable cellulose."[173] *In page 131 of his book, Rogers discusses the chemical treatment of the reliquary of the Shroud that was done after the 1988 C14 sampling:* "A significant amount of thymol could have absorbed on the wood, and wood has a large cellular surface area. More thymol would have reacted with the cellulose and more reactive hemicelluloses, lignin, and plant gums of the wood."[174] *In page 54 of his book, Rogers makes it clear that he knew very well the exact chemical composition of a linen fiber when he writes:* "The Shroud is nearly pure linen, but linen is not pure cellulose like cotton."[175] ***Personal note:*** *In recent years, some have questioned the knowledge of Ray Rogers concerning one particular aspect of the structure of a linen fiber known as the primary cell wall (that is mainly composed of hemicelluloses and pectins, along with cellulose), which they thought could have been colored by the image formation process. All these particular quotes clearly show that Rogers knew perfectly well the chemical structure of the primary cell wall of the linen fiber, even if he didn't use the term in his writings and nevertheless, he never considered this kind of chemical structure as a valid option to explain the color of the body image on the Shroud. In other words, he never considered the primary cell wall as being the real chromophore of the body image on the Shroud, even though he knew perfectly well the existence of that external part of a linen fiber. And we can find a confirmation of that in quote #76 above, where we can read this:* "All image fibers (from the Shroud) show color on their outer surfaces, but the body of the fiber and the walls of the medulla are not colored."[176] *This particular quote is very clear about the fact that, for Rogers, the color on the Shroud only resides in a layer of carbohydrate impurities located on top of the fiber ("outer surface" in Rogers' words) and the entire linen fiber, which includes the primary cell wall of the fiber ("the body of the fiber" in Rogers' words), was not affected at all during the image formation process. In other words, for Rogers, the chromophore of the body image on the Shroud is only a mix of substances (starch, pectin, hemicellulose, saponaria, etc.) that were*

[171] Raymond N. Rogers and Anna Arnoldi, *Scientific method applied to the Shroud of Turin - A Review*, 2002.
[172] Raymond N. Rogers, *A Chemist's Perspective on the Shroud of Turin*, Barrie Schwortz Editor and Publisher, July 2008.
[173] *Ibid*.
[174] *Ibid*.
[175] *Ibid*.
[176] *Ibid*.

added on top of the most superficial linen fibers of the cloth (on both surfaces of the cloth) during the making, washing and drying, because of the ancient technique used. It should be noted that, in a paper he wrote in 2001, we can find another similar statement made by Rogers that helps a bit more to confirm the fact that, in his mind, the entire linen fiber was probably not affected at all during the image formation process and only a thin layer of impurities residing on top of it was. Here's the quote: "It appears that the scorched fibrils colored all of the way through their diameter, but the medullas of the image fibrils were not affected by the image-forming process. That observation supports Adler's observation that all color resides on fibril surfaces, but it still needs confirmation."[177] *The most important part of this statement made by Rogers is "on fibril surfaces" because it shows quite clearly that, in his mind, all the image color was most probably independent from the entire structure of the linen fiber (including the primary cell wall). Or else, if Rogers would have thought that the most external part of the linen fiber (i.e. the primary cell wall) could have been affected by the image formation process, he would have certainly wrote something like "in fibril surfaces" or "inside the fibril surfaces" instead of "on fibril surfaces". In sum, the expression "on fibril surfaces" used by Rogers here can be seen as a parallel expression to the "on their outer surfaces" that we find in quote #76, which was used by Rogers, as we've just seen, to differentiate the colored layer of carbohydrate impurities from the entire (uncolored) structure of the linen fiber (i.e. the body of the fiber and the walls of the medulla). Before concluding this note, I would like to comment a bit on the last part of Rogers' statement, which reads:* "…but it still needs confirmation." *versus the probable fact that the color resides only on an external layer of impurities located on top of the linen fibers. Here, it's important to understand that this particular statement of Rogers was written in 2001, at a time when he had not made any new chemical tests on his old STURP samples in order to see if some traces of starch, saponaria or some residues possibly produced by the retting process of the flax plant (i.e. pectin, hemicellulose, etc.) could be found on some fibers, which is something, as Rogers clearly said in his 2001 paper, that was not on the test plan of STURP after their 1978 investigation in Turin. But later on, after he made some new chemical tests on his Shroud samples, he was able to confirm the presence of some starch residues, which is something that had already been found by Walter McCrone in his microscopic investigation of STURP samples back in the 1980s, but had never been confirmed by any official members of the STURP team until these new chemical tests made by Rogers (see quotes #36 through 38). And concerning the other possible substances that could have been present in the layer of impurities described by Rogers, it should be noted that none of them were found during his new chemical tests. However, when we read carefully all official writings of Rogers about the Shroud, it doesn't seem that he specifically looked for anything else than traces of starch and saponaria, most probably because these are the two substances he was suspecting of composing the major part of the impurity layer he proposed for the image chromophore. It should be noted that he wasn't able to find residues of saponaria, even though he found some circumstantial evidence that suggests it was really present in the impurity layer. In the end, there's still a possibility that this particular product could simply have evaporated or even been washed away from the surface of the fibers over the centuries and it's also possible that the chemical tests used by Rogers were not precise and/or not specific enough to detect the presence of minute traces of this particular product. It should also be noted that Alan Adler of STURP, while using a different chemical test than used by Rogers, was able to detect the presence of pectin residues on fibers samples that had been taken from the Shroud by Rogers himself in 1978 (see my personal note concerning quote #59), which suggest that this particular element could have also been part of the layer of carbohydrate impurities proposed by Rogers (and maybe in a more important proportion than what he was thinking), along with the starch deposits he was able to find on his samples and possibly some other unconfirmed residues of saponaria, hemicellulose, etc. Nevertheless, for the moment, we must remain prudent versus Adler's finding because it has not been scientifically confirmed yet by an independent expert, while there is still a possibility of a false positive result that would be due to the fact that pectin is already present in the primary cell wall of the linen fiber (along with cellulose and hemicellulose). In other words, there's still a possibility that Adler had only detected the pectin that is naturally present in the primary cell wall instead of a layer of pectin residues that could have been left on top of the fibers by the ancient method of manufacturing linen cloths.*

[177] Raymond N. Rogers, *An Alternate Hypothesis for the Image Color*, 2001.

Note #1: For an even more complete understanding of Ray Rogers' point of view concerning the body image on the Shroud of Turin, see: Thibault Heimburger, *Rogers' Maillard Reaction Hypothesis Explained by Rogers Himself*, August 2012 (http://shroudofturin.files.wordpress.com/2012/08/rogers-maillard-reaction-for-dan-blog-2.pdf).

Note #2: Sometimes in this article, you can find two different quotes of Rogers that look very similar. I have decided to keep them separated instead of merging them into one single quote because those repetitive quotes clearly indicate that the particular observations they contains were considered by Rogers as being very important regarding the exact nature of the Shroud's image. So, I thought it was important to keep them the way we found them in Rogers' writings without making any changes or adjustments.

Acknowledgements: I would like to thank Mr. Andy Weiss, webmaster of shroudnm.com, for his great help in the correction and also in the layout of this article. Since English is not my first language, his help was really appreciated. I would also like to thank Mr. Giorgio Bracaglia, webmaster of Holy Shroud Guild website (holyshroudguild.org), for his professional advice on this project and Mr. Barrie M. Schwortz, who is the editor of shroud.com, for having convinced me of the importance of Ray Rogers' legacy concerning Shroud science. And last but not least, I would like to thank Mr. Raymond N. Rogers himself for having done his research about the Shroud with honesty, in the true respect of the scientific method and with only one goal in mind: trying to understand this cloth and the image it bears in the most complete way!