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

An exhaustive documentary research done by Yannick Clément

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Here's a list of the most important quotes taken from Raymond N. Rogers' official writings concerning the body image that is visible on the Shroud of Turin:

1- Direct microscopy showed that the image color resides only on the topmost fibers at the highest parts of the weave.
2- Darker-appearing, pure image areas did not penetrate significantly more deeply into the cloth than did lighter areas. The effect was much more different than that produced by scorching a cloth with a hot statue.
3- The image of the dorsal side of the body show the same color density and distribution as the ventral, and it does not penetrate the cloth any more deeply than the image of the ventral side of the body.
4- Whatever produced the image produced identical surfaces in both the front and back images.
5- Thermography proved that the emittance of the image was the same in all areas. The entire image formed by the same mechanism. Spectra and photography confirmed this observation.
6- The image is extremely faint and difficult to see. Much more details can be seen in contrast-enhanced and ultraviolet photographs; however, they are somewhat misleading to studies on image formation. Whatever produced the image color did not produce very much color.
7- The image on the Shroud is not a painting. No foreign materials were added to the cloth in image areas.
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.
9- Body fluids (other than blood) did not percolate into the cloth.
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.
11- Neither aloes or myrrh could be detected on the cloth.
12- There is no image color or erosion inside the pores of the cloth.
13- The cloth does not show any phosphorescence.
14- The distribution of image color on the surface of the cloth is discontinuous. This can easily be seen in macrophotographs of the image areas.
15- The layer (of image color) is approximately one wavelength of visible light thick (200-600 nanometers), and it is amorphous.
16- 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.
17- Adhesive-tape samples show that the image is a result of concentrations of yellow-brown fibers.
18- No protein could be detected in either image or non-image areas; however, they were easy to detect in blood stains.
19- No image formed under the bloodstains 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.
20- Image color does not appear under the blood stains when they are removed with a proteolytic enzime. Whatever process produced the image color must have occurred after the blood flowed onto the cloth, and the image-producing process did not detroy the blood. **Personal note**: 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.

21- Heller and Adler found that the image fibers could be decolorized with diimide. Reduction left colorless, undamaged cellulose fibers behind. All image color resides on the outer surface of the fibers.

22- 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.

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

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

25- Adler's observation (concerning the decolorization of the image with diimide) proved that the cellulose was not involved in image formation. *This is an extremely important observation.*

26- 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.

27- 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.

28- The "ghosts" had the same chemical composition as expected from dehydrated carbohydrates.

29- 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.

30- 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.

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

32- At high optical magnifications, up to 1000X, no coatings could be resolve on the surfaces of 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.

33- The color is only on the outer surfaces of the image fibers. This suggests that the impurities were the result of cloth-production methods and they should appear on all parts of the cloth. Until this time, we had assumed that the image color was a result of chemical changes in the cellulose of the fiber.

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

35- The spectra strongly suggest that the impurities were carbohydrates that dehydrated as a result of image-formation process.

36- Nothing than dehydrated carbohydrate could be found in the image area.

37- (Starch) impurities were detected that could take part in color-producing Maillard reactions.

38- A search for carbohydrate impurities on the Shroud confirmed McCrone's detection of some starch fractions. Starch and low-molecular weight carbohydrates from crude startch would color much more easily than would cellulose as a result of either thermal dehydration or chemical reactions. The hypothesis on carbohydrates impurities is supported by observations of traces of some starch fractions on image fibers.

39- Microchemical tests with iodine detected the presence of starch impurities on the surfaces of linen fibers from the Shroud. An impurity layer could be seen by phase-contrast microscopy.

40- 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.

41- Since the cellulose was not colored, the impurities had to be significantly less stable than cellulose.

42- Because chemical rates are exponential with temperature, cellulose would react much more slowly than other carbohydrates.
43- Evaporation concentration (of impurities) can explain the superficial nature of the image and the identical properties of the front and back images.
44- Bands of different-colored yarn can be observed in the weave of the cloth. Where darker bands intersect image areas, the image is darker and where lighter bands intersect image areas, the image is 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 suggests that significant variations in impurity concentrations existed among yarn batches. The observations of bands of color agree with historical reports on the methods used to produce ancient linen.
45- Some impurities on the surface of the different batches of yarn produced the image color. 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.
46- 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.
47- The color density of any specific image area depends on the batch of yarn that was used in its weave. The cloth shows bands of slightly different color of yarn.
48- Another important observation is the fact that the image-forming process produced slightly different color densities (but identical spectras) on the different lots of yarn. 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 production conditions.
49- 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 impurities left from the bleaching process. **Personal note**: This particular quote show 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 #37 to 39) 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.
50- 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.
51- 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.
52- 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. **Personal note**: The residues of pectins found on Shroud's 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 partialy 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*).

53- Chemical tests showed that there is no protein painting medium or protein containing coating in image areas. 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.

54- It follows that microbiological activity did not produce the image.

55- Ultimate cells (note: this is an important part of the structure of a linen fiber) 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.

56- 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.

57- Other than observing colored medullas, crystallinity and birefringence enable differenciating between scorched and image fibers. The evidence is strong that the image is not a result of dehydration of the cellulose by any mechanism.

58- 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.

59- The image spectra were essentialy 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.

60- 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.

61- 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.

62- 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.

63- 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.

64- 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.

65- 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 vaccuum ultraviolet photons. **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.
66- 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.
67- Image formation proceeded at normal temperatures in the absence of energetic radiation of any kind.
68- 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-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.
69- 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. 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.
70- No radiation hypothesis alone can explain how the entire outer surface of image fibers could become colored without coloring the inside and the medullas.
71- 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.
72- Neutrons produce "recoil protons" when they hit a material that contains hydrogen. The loss of hydrogen also causes crosslinking. Neutrons can not be invoked for a miracle.
73- 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. **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.
74- 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 temperatures that could have been seen by the blood after it appeared on the cloth. **Personal note**: It's important to understand that Rogers is only talking here 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. His statement doesn't consider the few bloodstains that are located in some areas of the cloth that were burned during the fire of AD 1532 in Chambery, France.
75- The blood produced hydroxyproline in pyrolysis/ms spectra. It was never heated significantly. Image formation had to be a low-temperature process. **Personal note**: When Rogers said that the blood on the Shroud was never heated significantly, 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.
76- The blood could be removed with proteolytic enzimes. The blood had not been crosslinked by irradiation. It is extremely unlikely that any form of radiation interacted with the cloth.

77- Whatever caused the Shroud image did not affected 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.
78- Any radiation that is energetic enough or suffisciently intense to 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.
79- 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.
80- 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.
81- 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 energic 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.
82- 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. **Personal note**: The expression "destruction" used here by Rogers must be understood in the sense of a "damage" to the structure of the linen fiber.
83- 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. **Personal note**: This objection of Rogers concerning the hypothesis proposed by Jackson can also be applied to any other image-formation hypothesis that involve 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 published in 2011, Fazio and Mandaglio 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.
84- 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.

85- 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. Suc a situation is not observed (for the Shroud).
86- Jackson theory can not be supported by the observations that have been made on the Shroud of Turin or the masses of information available on radiation effects.
87- 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 ^{14}C 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.
88- Image fibers and non-image fibers show exactly the same kinds of defects and defect populations. The image was not caused by energetic radiation.
89- 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.
90- Fibers from scorched areas of the Shroud are entirely different from image fibers.
91- 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.
92- 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 are colored all the way through.
93- 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.
94- 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.
95- Image-formation hypotheses that are based solely on any kind of electromagnetic energy must also be ruled out.
96- 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.
97- 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.
98- High temperatures and energetic radiation absolutely can not explain the properties of the image. That statement does not suggest a miracle.
99- 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. **Personal note**: Rogers was clear about the fact that this kind of result is incompatible with the properties of the Shroud's image.

100- 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.

101- 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.

102- 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.

103- 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. **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) was not affected at all (including no coloration) by the image formation process. 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." Here, the word "cellulose" should be understood as meaning "the entire linen fiber".

104- 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. **Personal note**: This possible image of the hair (that include the beard and mustache) on the back side of the Shroud is still waiting for a scientific confirmation.

105- 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.

106- 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.

107- Evaporation concentration can explain how most of the color-producing impurities were concentrate 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.

108- 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.

109- There is no evidence of 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. **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."

110- 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.

111- Image formation that involves thermal radiation can not be ruled out; however, it can not explain all of the features of the Shroud.

112- 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.

113- Diffusion of gaseous reactants or dyes into the cloth would have produced a color gradient (darker on the surface, lighter at depth). **Personal note**: Rogers was clear about the fact that this kind of result is incompatible with the properties of the Shroud's image.

114- 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.

115- 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.

116- The chemistry of the color does not answer all questions about how the "photographic" image formed. The image seems to shows 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.

117- 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.

118- 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.

119- The (Maillard) reactions occur at significant rates at much lower temperatures than the caramelization (thermal dehydration) of any of the sugars.

120- 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.

121- 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.

122- 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.

123- 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.

124- 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. **Personal note**: Even if 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.

125- When amines and reducing sugars come together, *they will react*. *They will produce a color*. This is not a hypothesis: this is a fact.

126- A cloth with crude starch on it *will* ultimately produce a color, if it is left in close proximity to a decomposing body. **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 his first "decomposition" state way before the appearance of the putrefaction (structural degradation), which generally starts between 36 and 72 hours after death. It is a known fact that a dead body can emit post-mortem gases before the appearance of the putrefaction of the body.

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

128- The ammonia and many of the decomposition amines are volative 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. **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. It is a known fact that a dead body can emit post-mortem gases before the appearance of the putrefaction.

129- 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. **Personal note**: This is the summary of the very good 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 manufactured 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." But, in order to obtain a similar coloration than what is observed on the Shroud, he had to heat his sample, which indicates that such a coloration would only appeared 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.

130- 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 topmost parts of the weave. **Personal note**: In a recent paper published in 2011, Fazio and Mandaglio have come 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 imply a low-temperature chemical process (like Maillard reactions) and/or thermal radiation. 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 (note: this conclusion is in total agreement with Rogers' conclusion that we can find in quote #8), 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 attemps 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 #111): "Image formation that involves thermal radiation can not be ruled out; however, it can not explain all of the features of the Shroud." 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 explantion for the stochastic (discontinuous) distribution of the image fibers on the Shroud. Such a hypothesis should really be studied properly by a biochemist or by a forensic expert. Who knows if the "secret" of the Shroud's image is not hidden in this kind of combination of natural processes? One thing's 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 #83). For these two researchers, such a distribution of colored fibers can only happened when minor quantities of energy (gaseous and/or thermal, etc.) are transferred to the fabric, which is consistent with Rogers conclusion that the image formation process must have been very mild (see quotes #19 and 89).

131- 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.

132- In page 57 of Rogers' book, he talks 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." Then, in page 86 of his book, Rogers show 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. Here's what he said about his result: "A single fiber from the center of figure 2 in water. Hemicelluloses and pectins have been oxydized, leaving most of the more stable cellulose." And then, in page 131 of his book, Rogers talk about the chemical treatment of the reliquary of the Shroud that was done after the 1988 C14 sampling. Here's what he said: "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." And then, in page 54 of his book, Rogers make it

clear that he knew very well the exact chemical composition of a linen fiber when he said this: "The Shroud is nearly pure linen, but linen is not pure cellulose like cotton." **Personal note**: In recent years, some persons 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 shows that Rogers knew perfectly well the chemical structure of the primary cell wall of the linen fiber, even if he don'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 very good confirmation of that in quote #69 of the present paper, 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." 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, pectine, hemicellulose, saponaria, etc.) that were added on-top of the most superficial linen fibers of the cloth (on both surfaces of the cloth) during his making, washing and drying, because of the ancient technique that was used.

Here's the sources I used for my documentary research :

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).
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, *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).
4- Raymond N. Rogers paper, *Shroud of Turin FAQ*, 2004 (http://shroud.com/pdfs/rogers5faqs.pdf).
5- Raymond N. Rogers, *Testing the Jackson "Theory" of Image Formation*, 2004 (http://www.shroud.com/pdfs/rogers6.pdf).
6- Raymond N. Rogers, *The Shroud of Turin: Radiation Effects, Aging and Image Formation*, 2005 (http://www.shroud.com/pdfs/rogers8.pdf).
7- Emmanuel M. Carreira, *The Shroud of Turin from the viewpoint of the physical science*, 2010 (http://www.shroud.com/pdfs/carreira.pdf).
8- G. Fazio and G. 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)

Note: 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).