Review of "The Shroud of Turin: Radiation Effects, Aging, and Image Formation" by Ray Rogers

By Robert A. Rucker, Giulio Fanti, Mark Antonacci, Tony Fleming, and Keith Propp

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Abstract

The 2005 paper "The Shroud of Turin: Radiation Effects, Aging, and Image Formation" by Ray Rogers (Ref. 1) was reviewed to determine the correctness of his conclusions. This review was done because this paper was evidently never published or peer reviewed, yet is frequently referenced. His main conclusion as stated in his abstract is that formation of the image on the Shroud of Turin "could not have involved energetic radiation of any kind; photons, electrons, protons, alpha particles, and/or neutrons." Review of Rogers' paper found that this conclusion is not justified by the evidence that is presented, and in fact, the certainty of this conclusion contradicts the tentativeness of his last sentence in the body of the paper which says "I believe that the current evidence suggests that all radiation-based hypotheses for image formation will ultimately be rejected." (Underlining added.) This contradiction may have resulted from Rogers not completing this paper due to his ill health and eventual death at the beginning of 2005. In contradiction to Rogers' conclusion, this review also includes a summary of the reasons why radiation ought to be regarded as the most likely cause of the image on the Shroud of Turin.

Introduction (by Robert A. Rucker)

The Shroud of Turin is a burial cloth that is located in the city of Turin in northwestern Italy. The astonishing thing about this burial cloth is that it contains a front and back image of a naked bearded man who was crucified exactly as the gospels in the New Testament say that Jesus of Nazareth was crucified, and at the same time, it gives no indication of being a painting. But the study of the Shroud of Turin, sometimes referred to as sindonology, involves several difficulties. The subject of the study, the Shroud of Turin, is not generally available for scientific testing, so that usually only very small samples, i.e. single fibers or threads or items removed by sticky tapes, are available to scientists. Often such small samples require new experimental procedures to be developed to allow detection of extremely small levels of chemicals or isotopes that may be present. Another difficulty is the generally held worldview of methodological naturalism, which says that only explanations which agree with the laws of science (usually defined as our current understanding of the laws of science) are acceptable. This causes the general public to denigrate the study of the Shroud of Turin, which reduces funding for the research. Naturalism also appears to be presumed by a large fraction of those doing research on the Shroud of Turin. As a result of these difficulties, there have arisen various advocates within the Shroud research community that support differing and often contrary viewpoints. One example of this is whether radiation could have encoded the image of the crucified man onto the Shroud. Those that reject the possibility that radiation caused the image often make reference to Ray Rogers' paper where "It is concluded that the image could not have involved energetic

radiation of any kind" (last sentence of the abstract in Ref. 1). He wrote this paper in 2005, which was the year of his death. This paper was apparently never published or peer reviewed. As a result of this radiation vs. non-radiation dispute, the evidence and logic in Ray Rogers' 2005 paper ought to be carefully reviewed to determine whether his evidence proves his conclusion as he stated it in his abstract. My perspective is that radiation played a key role in the formation of the image on the Shroud, so that I am motivated to carefully review Rogers' 2005 paper in order to help resolve this conflict.

The study of the Shroud of Turin is a very multi-disciplinary study. As a result, it is often difficult or impossible to find a person that is ideally suited to review a document. My education and experience is in nuclear engineering. I have not worked with a polarizing microscope, I am not a textile expert, and I have not worked hands-on with any of the Shroud of Turin fibers. But I am familiar with the behavior of radiation and based on my experience in writing and reviewing technical engineering documents, I feel comfortable in making reasonable comments regarding the quality of another person's document based on his evidence, judgment, and logic. But before I start my review of Rogers' paper, I would like to make some comments on the value and nature of the peer review process.

The Peer Review Process

Feedback from one's peers is of great value in producing a correct technical document. Such peer reviews ought to go far beyond just checking the English, such as spelling, grammar, and sentence structure. It ought to go to the heart of the issue, such as elimination of errors in calculations and solving of equations, consideration of assumptions and appropriateness of data that is used, checking the flow of logic in the progression of the argument, and assuring that the conclusions logically follow from the data and various considerations such that the statement of the conclusions is not overly broad nor unnecessarily narrow. Peer's doing such a review ought to be qualified in the technical specialty, and preferably some of the peer reviewers ought to be more qualified than the author in that specialty. But people, including those doing a peer review, are human beings – prone to make mistakes, prone to compromise on a quality document in order to meet management's schedule driven by the funding limitations perhaps as the result of being the lowest bidder on a project, prone to please others to advance one's own career, prone to blame others to avoid personal responsibility, prone to cut corners on a review based on the assumption that others have done their work properly, and prone to follow their own biases and worldview without due consideration or even awareness of alternatives. In my career as a nuclear engineer, this has resulted in me finding multiple documents that have been fully reviewed by a long chain of reviewers and thus fully meeting all the qualifications of an extensive peer review system, and yet the documents were technically wrong in some essential argument or conclusion. The following lessons should be learned from this:

- We should not blindly trust a document simply because it is assumed that it has been peer reviewed, or simply because it was published in a journal that supposedly used a peer review system. We should make our own assessment on the merits of the data, arguments, and conclusions in each document. This is often not easy to do.

- We should consider the quality of a peer review, including the number and technical qualifications of the peer reviewers, the nature and thoroughness of their review, and their specific comments and how those comments were resolved. Unfortunately, this information is seldom available to us, so that we are in effect asked to just trust them regarding the adequacy of their peer review.

- Anyone can be wrong, even people that everyone gives highest honors to can be wrong. Since each of us can be wrong, we all must focus on truth and humility as our priorities.

It should also be noted that the peer review often required for publication of an article in a technical journal can on occasion actually hinder the advancement of science. This can occur when a scientist that is trying to publish an article is using a non-standard methodology or is far advanced beyond the level of those that are expected to do the peer review for the technical journal. By this process, a friend of mine that wanted to publish articles regarding his calculations on the interior of the sun was prevented from publishing in the United States because it was claimed by the peer reviewers that his methodology was highly unorthodox, though they did not claim that his methodology was wrong. As a result, he had to publish his articles in Europe instead.

Review of Rogers' 2005 Paper (by R. A. Rucker)

Recognizing my own limitations in doing a peer review of Rogers' 2005 paper, I asked several others to also make comments regarding Rogers' paper. Those that responded to my request for comments (Giulio Fanti, Mark Antonacci, Tony Fleming, and Keith Propp) are included in subsequent sections.

My review of "The Shroud of Turin: Radiation Effects, Aging, and Image Formation" by Ray Rogers (Ref. 1) is discussed below. Each item should be judged on its own merits.

1. This paper is available from www.shroud.com. The paper obtained from this source contains no indication that it was published in any journal. There is also no indication that it was peer reviewed. This may be an indication that Ray Rogers wanted to do additional research to include in this paper, which is listed with a date of 2005, but was prevented from doing so by his poor health followed by his death on March 8 of 2005. Thus, Ray Rogers may not have regarded this paper as finalized. If this is so, it would help to explain the conflict between the last sentence of the abstract and the last sentence of the body of the paper (see points 2B and 13 below).

2. Regarding the abstract:
   A. The third sentence in the abstract says "Comparisons are made between image fibers and non-image fibers." Unfortunately, in the paper, it is not discussed how what he claims to be an image fiber was obtained other than that it came from the region of the wrist, and no evidence is given that the fiber taken from the wrist region was discolored or not. Since an image region on the Shroud would contain mostly non-discolored fibers, with the discolored fibers primarily on the surface of the thread facing the body, whether the piece of the fiber from the wrist region was discolored or not needs to be determined, and not just assumed.

Hopefully this fiber was discolored, but if this fiber was not discolored, then the entire comparison is questionable and perhaps meaningless.

B. The last sentence of the abstract says "It is concluded that the image could not have involved energetic radiation of any kind; photons, electrons, protons, alpha particles, and/or neutrons." But what does he mean by "energetic" radiation? In the context of his paper, he must mean radiation with energies above the values for which he tested. Rogers should also have included the conclusion that any of these radiations could have been involved in the image formation process if they had energies below the values for which he tested. This statement quoted above from his abstract is an overstatement, especially in comparison to the very tentative nature of the final statement in the body of his paper which says "I <u>believe</u> that the current evidence <u>suggests</u> that all radiation-based hypotheses for image formation <u>will ultimately</u> be rejected." (Underlining added)

3. Page 1, first two sentences of the main body: "Science should proceed by developing hypotheses to explain problems, and the hypothesis should all be tested rigorously against the same observations, facts, and laws of nature. When natural laws or observations disagree with any critical component of the hypothesis, it should be rejected." The underlying assumption here is that the "natural laws" are the "same … laws of nature" that everyone ought to consider as proven to be true, that they are perfectly known so that they are unalterable, and that these laws of nature are complete. While these two sentences may sound good from our culture's typical worldview, they are merely a statement of the philosophy of naturalism, specifically methodological naturalism, which is based on the theological belief that either God doesn't exist or if he does exit he can not violate the laws of science in the universe (assuming that we know what the laws of science are in an absolute sense), so that violations of the laws of science as we currently understand them are impossible. But if this philosophy of naturalism is assumed from the start, then the conclusion is already predetermined before the scientific investigation begins, for radiation coming from a dead body is contrary to our current understanding of the laws of science.

   According to this philosophy of naturalism, the possibility of radiation being emitted from a dead body must be rejected because it contradicts the "laws of nature" that everyone ought to believe are true, perfectly known, and complete. Similarly, according to this reasoning, the disappearance of Jesus' body from within the Shroud must be rejected because that would be a violation of the laws of science, and to violate the laws of science is impossible by definition. In investigating the Shroud of Turin, the issue of the philosophical presupposition of naturalism is very important because such a presupposition can bias the consideration of the scientific evidence.

   The logic of the philosophy of naturalism as it applies to the scientific study of the Shroud of Turin, and the rebuttal to this philosophy, can be summarized as follows:

   - The laws of science have been proven to be true by repeated experiments in laboratories while carefully controlling for all variables (influences) that could affect the results.

     Rebuttal: Scientists, as human beings, are finite in their knowledge, so that they would only control for variables that they recognized could affect the results of the experiments. Scientists could not prove that in their experiments they controlled for all variables that

could possibly affect the results of the experiments, because of the difficulty for anyone including scientists to know what they don't know. So scientists can never be sure that they have controlled for all variables that could possibly affect the results of their experiments.

- The experimental process in the laboratory has determined the laws of science in an absolute sense, i.e. the laws of science discovered in the laboratory are one and the same as the absolute laws of the universe that apply universally to all space, time, and matter.

  Rebuttal: There is a general belief that our current laws of science are one and the same as the absolute laws of the universe. But this belief is merely an assumption and cannot be proven scientifically, i.e. by repeated experiments in the laboratory with control of all variables that could affect the results, as stated in the above rebuttal. It can also not be proven scientifically that the same scientific laws apply universally to all space, time, and matter. It is often assumed, but it cannot be proven.

- As they are currently defined, the laws of science are fully known and complete.

  Rebuttal: The history of science indicates that the "the laws of science" at any point in time are usually not entirely correct and will usually change in the future as new scientific discoveries are made. The "laws of science" are assumed to be "fully known and complete" only due to human pride and ignorance of the future. As an example, the laws of physics discovered by Isaac Newton were believed for generations to be absolutely true and thus fully known and complete because they were derived by repeated experiments with supposedly all the variables being controlled that could affect the results. Newton's laws were believed to be true until Einstein developed his theory of relativity. The theory of relativity includes velocities approaching the speed of light and very high gravitational fields such as around stars and black holes, but the experiments that led to Newton's laws did not control for either of these two variables, and so could not take them into account. While Newton's laws were true under conditions of slow speeds relative to the speed of light and under relatively low gravitational fields, they were not true for speeds approaching the speed of light or for very intense gravitational fields. Thus, Einstein proved that Newton's laws were only a subset of the larger understanding of reality given by relativity theory. Perhaps a future scientist will prove that our current understanding of the laws of science is only a subset of a larger understanding of reality. For example, experts in "string theory" believe that to explain all of the experimental evidence of modern physics requires our normal understanding of three spatial dimensions and one time dimension to actually be a subset of a larger dimensionality of up to 10 to 26 dimensions. Our current understanding of the laws of science could thus be only a subset of a larger reality because they are based on experiments that did not control for alternate dimensionalities.

- As a result, nothing has happened or can happen that is contrary to our current understanding of the laws of science, which is usually abbreviated as "the laws of science cannot be violated".

Rebuttal: On the contrary, there are many examples in the history of science where new discoveries violated the laws of science that were accepted as true at the time. For example, Einstein developed his theory of relativity in response to experiments that violated the laws of science that were accepted at the time. This refers to the Michelson-Morley experiments starting in 1887, and measured results of the rate of advance of the aphelion of the elliptical orbit of mercury around the sun that violated Newton's laws. It is probably true that many of the greatest advancements in science result from a recognition that under certain conditions, the currently accepted laws of science are violated. We must conclude that the laws of science as they are currently known can be "violated" because these laws of science may only a subset of a larger reality, including the possibility of alternate dimensionalities. Our current understanding of the laws of science could very well change in very surprising ways in the future. An important principle in the philosophy of science is that our understanding at any point in time of the laws of science should always be recognized as tentative, so that our understanding of the laws of science can change in respond to new discoveries, in particular when conditions are found that contradict or violate our previous understanding of the laws of science.

- A "miracle" is a violation of the laws of nature. Therefore, by definition, a miracle cannot happen.

  Rebuttal: According to the above rebuttal, it should be recognized that events can happen that contradict or violate our current understanding of the laws of science, because our current understanding of the laws of science may not be perfect and absolute. Previously in the history of science, when such violations of the laws of science have occurred, they have not been called miracles. For example, the results of the Michelson-Morley experiments and the measurement of the advance of the aphelion of Mercury's orbit were not called miracles even though they violated the laws of science that were accepted as true at that time. So neither of the above two statements are reasonable.

The above bullet points respond to the philosophy of naturalism from the scientific perspective. The issue can also be responded to from a Biblical/theological perspective. In the philosophy of naturalism, there is a hidden assumption of God's nonexistence, in the traditional sense of God as a powerful being that can interact with this physical universe in a way that is not limited by our current understanding of the laws of science. If God exists, and he is the author and sustainer of how this physical universe operates, then he is free to act in this universe, only limited by his character and the rules of logic. God is not limited by our current understanding of the laws of science. Since repeated experiments in the laboratory under controlled conditions have never been done which disproved God's existence, from consideration of science alone, God's existence should be considered as a possibility. Thus, it is unscientific to make a presupposition of naturalism.

In dealing with the Shroud of Turin, a natural implication of seeing the image of a crucified man on the Shroud ought to be that we are at least potentially dealing with an image that was left by the body of Jesus, so that at least potentially we are dealing with the question of God's existence. So in this case of the Shroud of Turin, when a scientific researcher begins his study with a philosophical presupposition of naturalism, it does not bode well to obtain an

objective scientific study, because the scientific data must then be interpreted within the constraints of the philosophy of naturalism.

And the last phrase in Rogers' first two sentences is "it should be rejected." This also raises questions. Why not allow for the hypothesis to be modified as needed. This becomes an important issue in that the energy of the radiation that caused the image may simply be lower than that considered in Ray Rogers' paper.

4. Page 1, third sentence: "highly improbable hypotheses" – In the context of the previous two sentences, this apparently refers to his categorization of hypotheses as being highly improbable if they contradict his philosophical presupposition of naturalism. This indicates the context for his thinking.

5. Page 1, second paragraph of the body, last two sentences: "In flax fibers, any photon or particle with energy above about 3 eV (e.g., light with a shorter wavelength than green) can directly break a few bonds in the crystallized polymer chains. This produces free radicals and distortions in the crystal." This is a very important statement yet it is made without references or scientific evidence. Is this supposed to be just accepted as common knowledge? The stated limit of 3 eV would still allow for photons of electromagnetic energy in the microwave range, the infrared range, and red light. Particles with energies below this value could also be involved. For example, in my MCNP calculations (Ref. 2), I determined that the Shroud being dated to the middle-ages by the 1988 C^{14} dating could be explained by 3.0×10^{18} neutrons being emitted homogeneously from within the body in the tomb, if the neutrons were emitted uniformly in all directions at a speed of 2200 meters per second. This is the speed of neutrons at an energy of 0.0253 eV, which is the peak energy of a "thermal energy" distribution of neutrons at a room temperature of 20º C = 68º F (Ref. 3).

6. Page 3, last paragraph, comment: Thorium is 100% Th-232, which decays with a 4.08 MeV alpha particle (Ref. 4).

7. Page 6, paragraph above figure 8: As indicated in his paper, his experience with radiation causing damage to flax fibers includes 1.4 MeV protons (figure 2), presumed damage from 6.28 MeV alpha particles from polonium decay (page 3), 4.08 MeV alpha particles from Th-232 decay (figures 3 and 4), and apparent damage from electrons and photons at unspecified energies. But up to this point in his argument, he has not shown that he has any experience with low energy radiation, so his conclusion is not justified.

8. Figure 7 compared to figure 8: Figure 8 is very fuzzy and so is a poor basis for making conclusions. He gave no evidence that figure 7 was a discolored fiber from the wrist region, but let me assume this is the case for the sake of argument. The main difference between figures 7 and 8 is the 3 or 4 dark regions on figure 7 where there has been significant annealing of the defects due to recombining or decomposing of the free radicals, to use Rogers' terminology from page 4. Using Rogers' reasoning on page 4, this would have to be due to the fiber in figure 7 being much older than the fiber in figure 8, but how can this be if both fibers came from the Shroud of Turin? Both fibers must be of the same age, yet how could the damage in figure 7 already be mostly annealed yet only a very small part of the damage in figure 8 be annealed? It ought to be concluded that something else is going on

that we don't understand, so that no conclusion can be drawn about whether or not radiation was involved in the image formation.

9. Page 6, caption under figure 9 and the last paragraph: This discusses a piece of Egyptian linen that was irradiated with neutrons having a speed of 2200 meters per second. This is the speed of neutrons at an energy of 0.0253 eV, which is the peak energy of a "thermal energy" distribution of neutrons at a room temperature of 20º C = 68º F (Ref. 3). A "recoil proton" would be ejected in an elastic scattering event where the resulting energy of the recoiled proton plus the energy of the scattered neutron after the scattering event would have to equal the energy of the neutron before the scattering event due to the conservation of energy. As a result, the peak energy of the recoiled protons would have to be less than or equal to 0.0253 eV. But Rogers previously stated (page 1) that at least 3 eV is required to break bonds in a flax fiber. So how can the damage shown in figure 9 be the result of protons recoiled from elastic scattering events due to 0.0253 eV neutrons? Something is wrong! Also, Rogers claims that short dim tracks in the middle of the fiber in figure 9 are evidence of recoil protons, and that such features are extremely rare in Shroud fibers. But it is not clear that such tracks can not be seen in the fiber from the wrist area shown in figure 7. It is also not discussed how many neutrons went through the fiber shown in figure 9 compared to how many neutrons should have gone through a fiber from the Shroud of Turin when the image was formed. Perhaps significantly fewer neutrons went through the fiber when the image was formed than were received by the fiber in figure 9.

10. Page 7, second paragraph: "Image formation did not involve any kind of intense heating, radiation, or stress that exceeded the mechanical limits of the material." But mild heating, radiation, or stress that did not exceed the mechanical limits of the material would still be allowed.

11. Page 7, third paragraph: "Image formation proceeded at normal temperatures. Image-color formation did not require neutrons, protons, high-energy photons, or mesons." I believe that he may have provided evidence that suggests that high-energy photons were not involved in the image formation process but the other aspects of these two sentences remain unproven.

12. Pages 7-9, on the corona discharge hypothesis: Rogers' comments on the corona discharge hypothesis are only related to one possibility as to how radiation could have caused the image on the Shroud, so that they are not sufficient to prove that radiation played no part in encoding the image onto the Shroud.

13. Page 8, second paragraph, Rogers says "In order for the body to charge to a high voltage, it must not be grounded. Because there is no such thing as a perfect insulator, materials in contact assume the same potential. Without a potential difference, ionization is impossible." Here Rogers argues that since Jesus' body was laying on the cloth, which was in contact with the limestone bench in the tomb, there could not have been any potential difference in electrical charge between the body and the cloth so that an electrical discharge between the two would not occur. But Rogers is not considering the current concept of the image formation process. If there was a very brief pulse of radiation emitted from the body, it could create a charge difference between the body and the cloth for a long enough time to cause an electrical discharge between the two.

14. Page 8, third paragraph, In reference to the free electrons and positively-charged ions that would be produced by a corona discharge, Rogers says "Neither the electrons nor the positive ions attain high velocities like beta particles or fission fragments. They do not become penetrating, ionizing particles." This misses the point that in the current concept of the image formation hypothesis, it is the radiation that is emitted from the body that is the penetrating particles, not the products of the corona discharge. And his statement "They do not become penetrating, ionizing particles." is contradicted in paragraph 7 when Roger's says "Because plasma is neutral, it does not charge the surface of an insulator, ultimately repelling itself, as does an electron beam. It penetrates the entire structure."

15. Page 8, fifth paragraph, Rogers says "Given enough time or intensity, a plasma in air will completely consume a linen sample. Even a short exposure will erode the surface of flax fibers." This is stated as though it is an argument against a corona discharge, but it is my understanding that the surface of the fibers where the discoloration occurs does appear to be slightly eroded. In the image formation process, we are hypothesizing an extremely brief pulse of radiation emitted from within the body. When the radiation hits the cloth, it causes a corona discharge to be emitted from the high points along the fibers. This electrical discharge creates heat on the high points along the fibers, which dehydrates and discolors the outer circumference of the top fibers. The short duration of this event limits the erosion of the fibers to less than 0.4 micros thickness – less than the wavelength of light.

16. Page 9, Figures 11 and 12 show a fiber of modern linen that underwent the corona/discharge experiments described in the last three paragraphs on page 8. Rogers then says on page 9 in reference to Figures 11 and 12: "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." But the experiment discussed on page 8 does not accurately model the hypothesized image formation process. And the apparent effect on the modern linen in Figures 11 and 12 has not allowed approximately 2000 years for annealing of the damage, as fibers from the Shroud have had. So Rogers' last sentence in this paragraph "Corona discharges and/or plasmas made no contribution to image formation." is without reasonable foundation.

17. Page 9, last sentence in the body of his paper: "I <u>believe</u> that the current evidence <u>suggests</u> that all radiation-based hypotheses for image formation will <u>ultimately</u> be rejected." (Underlining added) Note the tentative nature of this statement: "I believe", "evidence suggests", "will ultimately". Rogers did not say "This evidence <u>proves</u> that all radiation-based hypotheses for image formation <u>must now</u> be rejected." Rogers evidently understood that much more study and evidence would be needed before "all radiation-based hypotheses for image formation will ultimately be rejected". But the tentative nature of Rogers' last sentence in the body of his paper is not reflected in the last sentence of the abstract, which says "It is concluded that the image could not have involved energetic radiation of any kind."

    Why would Rogers write these two statements in such a contradictory manner? My speculation is that Rogers may have written the abstract prior to doing the research that he discusses in the body of the paper. In my experience, individuals writing a technical document will often write the abstract first, before the research is even started. If this is done, the author will write the abstract based on what they believe their research will

ultimately prove, in order to help them focus on their goal in doing their research. And then after their research is completed, they go back and revise their abstract if necessary to conform to the results of their actual research as it was reported in the document. Ray Rogers may not have been able to do the additional research that would have been needed to prove the last sentence of the abstract, or perhaps to even revise his abstract to be consistent with his research that he had completed because of his deteriorating medical condition in the last few months of his life. Thus, my review of Rogers' paper indicates that his last sentence in the body of his paper properly indicates the tentative and partial nature of his evidence presented in the paper, and that the last sentence of the abstract is an overstatement and not justified by the evidence presented in his paper.

18. Page 10, reference 4 on Rinaudo's "Protonic Model of Image Formation": Rinaudo's presentation was delivered on June 6, 1998, at the conference on the Shroud of Turin held in Turin, Italy. A finalized paper on his presentation does not seem to be available, though he gave out copies of a draft paper in English to certain individuals that were at the conference. (See Ref. 5)

Comments by Dr. Giulio Fanti

1. Raymond Rogers accurately described in his paper the supposed effects of radiation on linen fibers but he was not a textile expert, nor does it seem that he consulted any expert in this matter before writing the paper in question. This fact leads to a problematic formulation of the reference model with which to discuss his partial experimental results. In fact he made reference to an over-simplified model of a linen fiber that prevents a reliable interpretation of the experimental facts. A linen fiber is principally composed of an external Primary Cell Wall (PCW), 0.2 micrometers thick, made of various polysaccharides; a thicker Secondary Cell Wall (SCW) made prevalently of cellulose and an internal lumen (Ref. 6 & 7). Instead of this complex structure to the linen fiber, R. Rogers assumed a linen fiber to be a homogeneous cylinder composed of cellulose. He therefore was not able to take into account the frequent sliding between the PCW and the SCW in the fibers being tested. When in other papers (Ref. 8) he was forced to consider the presence of the PCW, he very doubtfully interpreted this thin layer as a layer of additional material that he supposed was primarily composed of starch. Furthermore R. Rogers wrongly interpreted the kink-bands (or dislocations) (Ref. 6) of the linen fibers, frequently produced by the slippage between the PCW and the SCW as "growth nodes". These growth nodes in fact exist in a fiber but can't be as frequent along the fiber length as he detected. On the basis of the supposed model, it is obvious that the conclusion of R. Rogers is quite doubtful.

2. R. Rogers, when discussing the results of his experiments, he thinks that he "easily" sees "straight ion tracks crossing the fiber", "alpha tracks", and "beta tracks" while they are not so evident and some of them can be also interpreted as defects of the PCW (Ref. 9).

3. Figure 6, which is declared to be a fiber from the Holland Cloth, is not typical of this fabric. It is puzzling why R. Rogers selected such a rare fiber to represent this fabric. In addition the defects in question may easily be attributed to a slippage between the PCW and the SCW perhaps during the mechanical stresses produced by the sticky tapes used to pick up these fibers (Ref. 9).

4. Figure 7 is a bad example to discuss the age of the Turin Shroud. R. Rogers debates the features of a fiber coming from the wrist area in terms of defects produced by supposed "alpha particles" or "protons" while these defects may have many other different explanations perhaps related to the PCW. It is nevertheless important to observe that R. Rogers discusses the features of this fiber as typical of the Turin Shroud forgetting that it is instead a particular fiber, an image-fiber and as such it could have been exposed to other kinds of radiation (Ref. 10).

5. Page 6 above Figure 8: "Direct comparisons 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 (e.g., figures 7 and 8)." It is my judgment that this statement is subjective, not demonstrated by scientific facts, and simply not true. The following deduction in the next sentence is therefore also very debatable. The big problem is that R. Rogers does not have the right or qualifications to select one piece of fiber among the hundreds present in his sticky tapes to sustain a preconceived thesis. He should have shown the mean features of image and non-image fibers to discuss their appearance in cross-polarized light. In the paragraph below Figure 8, R. Rogers admits: "Photomicrographs do not tell the whole story: more is learned by dynamic viewing through a microscope. Different features can be emphasized with different mounting media, lighting systems, degrees of polarization, and focus."

6. Page 7, second paragraph: "Whatever caused the shroud image did not affect the crystallinity of the flax fibers." This sentence is very subjective and it can't be considered the result of the deduction of scientific facts (Ref. 11). The results described in the figures, which are not well interpreted due to an over-simplified theoretical model of the fiber, are certainly not able to lead to this conclusion. The very subjective conclusion that follows this sentence is therefore completely lacking of scientific value.

7. Pages 7 to 9, discussion of corona discharge: It is difficult to discuss Rogers' explanation of corona discharge and the results of his experiments because he mixes scientific facts with both personal limited view of the complex phenomenon (Ref. 12) and personal hypotheses. His interpretation of the results that he obtained is therefore highly goal oriented and refers to a very limited series of experiments that did not consider some important facts such as the time-development of color in single line fibers with aging (that can be simulated by ironing).

Comments by Mark Antonacci

1. On page 6 of Rogers' article he discusses the effects of irradiating linen from an Egyptian mummy. I don't know if this was the same 4000-year-old Egyptian linen discussed on page 4, but being from an Egyptian mummy, it is evidently very ancient linen. He states in the caption to figure 9 that the Egyptian linen "was irradiated with reactor (2200 m/s) neutrons and some associated gamma rays." This neutron speed corresponds to a neutron energy equal to 0.0253 eV (see point 5 of Rucker's comments). Below the caption he states that neutrons produce "recoil protons" when they hit protons in organic material. Rogers says "When you look very closely, you can see a *few* short, dim tracks from recoil protons in the middle of the fiber" (emphasis added). While "extremely rare", he states such features

can also be found in Shroud fibers. My main point is that while I don't know how many of these "few short, dim tracks" are visible if you look closely at recently irradiated linen, I do know that this Egyptian linen was *already* several thousand years old when it was irradiated. Furthermore, if the Shroud was neutron irradiated, this irradiation would have occurred when the cloth was *new* and it's admittedly hard to see effects would now be 2000 years old. Roger's approach seems backwards. I don't know if or how many "short, dim tracks from recoil protons" would still be visible in 2000-year-old linen that was irradiated when it was new. It's not necessarily valid to compare the Shroud, which could have been irradiated 2000 years ago, to ancient linen that was recently irradiated. I also wonder if "short, dim tracks from recoil protons" might be more likely to appear in newly-irradiated *ancient* linen than in newly-irradiated modern linen.

2. Rogers attempts to rule out all forms of energetic radiation and disparages hypotheses involving it. Yet, he didn't even attempt to irradiate modern linen and observe the microscopic, as well as a *variety* of other effects at various stages as the linen is artificially aged. Particle radiation emanating from the dead body wrapped within the Shroud actually appears to be one of the best hypothetical explanations for its various image characteristics. This hypothetical event could even be tested and proven to have occurred. Although it could be shown to have occurred, the precise energy, intensity and even the duration of the particle or other accompanying radiation that the cloth received during the image-encoding event would never be known for certain. Similarly, the extent of its exposure to air and the corresponding aging effects on the cloth at its various locations throughout its actual history would also never be known for certain. Yet, irradiating modern linen and observing its microscopic and a wide variety of effects as it artificially ages, at least, displays an attempt to understand or investigate some of the leading radiation hypotheses as they are presented.

3. I don't know how he or anyone else would identify the "few ionizing-particle tracks" mentioned in his caption to Figure 10. There is not a corresponding photo of the "extremely rare … short dim tracks from recoil protons … in shroud fibers" (quoted from page 6). I assume these are somewhat similar, but there's no basis of comparison provided to a lay reader. It's all somewhat subjective and you have to take his word for it, which most readers do.

My judgment overall is that Rogers in this paper is trying to give several general implications and impressions based on his work which is generally incomplete, undocumented and subjective.

Comments by Tony Fleming

1. In retrospect we can be critical of Roger's paper written in 2005. However his investigations were useful forming a benchmark for future efforts to clarify if radiation was involved in the formation of the Shroud. His paper discusses several candidate mechanisms for radiation from an experimental perspective. His conclusion in the body of his paper states "current evidence suggests that all radiation-based hypotheses for image formation will ultimately be rejected." To the contrary, the past ten years of further research have tended to support the hypothesis that a radiation based mechanism was responsible for the image. One of these areas of research has been a global increase in research into biophotonics (Ref. 13) including

protection against melanoma, a form of skin cancer prevalent in sunny climates where UV is a danger (Ref. 14). Developments in laser design including improved spatial and temporal coherence have allowed lasers to be used to investigate possible biological changes within Shroud-like linen (Ref. 15).

2. As discussed by another reviewer (Fanti) the linen Shroud has a microstructure that is in large part a cylindrical plant cell with an outer surface or 'skin' having a complex biological substructure. It is certainly not homogeneous as Rogers suggested. Such assumptions of approximate structures are similar to Maxwell's early examination of cells (Ref. 16).
3. On Page 1 in the last paragraph, Rogers states "the primary step in photochemistry is the absorption of radiation" and does nothing to test this. In this regard melanin, which is a chemical complex used as a prophylactic against damage from UV, mainly against breaks in DNA strands, is found ubiquitously in plant life forms and mammalian life forms alike. A test for the absorption by melanin would have been very useful given his pertinent comments about absorption of radiation.
4. It is surprising when discussing putative radiation mechanisms for the image of the Shroud that Rogers did not discuss electromagnetics apart from heating effects. Instead he looks mainly to ionizing radiation for effects of radiation via radon gas and neutron bombardment. There are electromagnetic interactions including melanin he could have investigated.
5. There are observable indications that the image of the Shroud may be a dielectric effect. This includes the diffuse luminance apparently emanating from beneath the right foot perhaps due to the presence of blood in the feet. While most cells in the body have an oriented structure such as the epidermis, blood cells do not because they are able to rotate; hence the light from the blood would be diffuse which is indeed what is observed. Also there are possible x-ray like images especially the metacarpals within the hands indicating both a loss of blood in the upper body and radiation from within the metacarpals that were able to impact the Shroud (Ref. 14).

Comments by Dr. Keith Propp

Upon reading the paper by Raymond Rogers my first encounter was the strong statement in the leading abstract that the conclusion of the paper is to be that "the image could not have involved energetic radiation of any kind; photons, electrons, protons, alpha particles, and/or neutrons." I was therefore immediately anxious to see if the observations and arguments presented in the paper would reach this lofty goal and thus dismiss a group of radiation hypotheses of Shroud image formation. The hope was that he would define quantitatively what levels of particle energy are levels above which particles are energetic radiation. Each kind of particle is expected to have its own value of this energy level. Also, then, what about the non-energetic realm? I want to see too that there is no confusion between individual particle energy and the overall intensity of the radiation involved.

The opening paragraph of the paper then coaches the reader that hypotheses constructed so as to explain a mechanism of image formation should be dismissed as a "theory" if it is

"highly improbable" in relation to known natural laws and processes. This kind of subjectivism is not welcome in the scientific method, but I continued reading.

While the author is not a textile expert himself he does a fair job of describing the physical nature and structure of linen fibers by presenting a description based upon a reference which likely contains such information for its own needs. This is important for the author to explain his own observations.

The author, a chemist, then directs the discussion away from the chemical changes that may be imparted in the linen by the energy deposition from the radiation. The effect to be further discussed is seen to be effects upon the crystalline structure of the flax fibers. This probably, though not explicitly stated, is done to restrict the discussion to "energetic" radiation.

The author then proceeds to describe what an observer must look for (with the aid of a petrographic microscope, the technical specifications being unmentioned) to identify the flax fiber changes pertinent to his arguments. Photomicrographs are shown with explanations in the text of items of interest. My copy of the paper was not a published original but even at that, the pictures are often of too low quality in both focus and magnification, to adequately present a subset of his observations. While the words in the text were usually adequate, none of the images had labeled arrows added to point out what the reader should be focused upon. These things make his discussion harder to follow and to verify agreement with his observations but do not necessarily reduce the validity of his arguments.

Rogers then presents a list which is an assortment of natural sources of radiation, none of which could be responsible for the Shroud image because the imaging radiation must have come from within the volume wrapped by the cloth if the image was the result of the use of the Shroud in the burial of Jesus. But, such sources could be responsible for some or all of the observed defects in Shroud fiber samples. In fact, such random defects, because they would accumulate over time, have suggested to some a way to estimate the age of the Shroud if its radiation environment history were known to be free of large variation. Rogers only mentions that the defects (tracks in the fibers) will accumulate over time and also mentions that they will anneal over time as well.

To illustrate and experiment with the effects of radiation on flax fibers Rogers and an associate exposed linen to a radioactive source (thorium). The description of the source and its radiation output shows Rogers' lack of experience with radiation. Units of radiation flux should have included a "per area" and it would have been nice to have the gamma flux expressed in the same units. It is not clear that thorium actually emits all of the particle types that the author lists but such is implied. However, what is seriously lacking is the energy levels of the radiations. None of the images show juxtaposition of "before exposure" and "after exposure". The pictures are very poorly focused and are not labeled. The cloudiness, is it poor focus or caused by gamma radiation? Why does gamma radiation cause cloudiness while other particles are purported to cause discrete tracks?

Rogers makes an important point. If radiation defects are a record of the Shroud over time, then it must all be homogeneous as indicated by sample studies from many positions. He

also implies that all of these defect-causing radiations are the same for image areas and non-image areas. If he actually did such a study, I am only left to assume what he has seen. Also, he seems to lump gamma radiation in with all other photon energies to rule out light in general.

A refutation of his arguments regarding corona discharge is handled by the proponent of the coronal discharge hypothesis, Giulio Fanti. I will only touch the topic to say that Rogers experimented by blasting linen with a "worst case" high energy UV beam that created a highly destructive (heat and impulse) response in the linen. Such experiments are never appropriate for ruling out more gentle approaches (lower energies or intensities).

Rogers concludes the paper in the same way he concludes the abstract with a one sentence statement. But he seems to realize that the paper has not served to rule out all radiation yet because his argument is lacking in presentation and scope (especially in the vacuum UV photon realm). It seems that he hopes that all "theories" of radiation image formation will "ultimately be rejected".

Summary of Evidence for Radiation (by Robert A. Rucker)

The individuals who did some of the most important research on the Shroud of Turin in the 75-year period between 1898 and 1973 (Dr. Yves Delage, Dr. Paul Vignon, Dr. Pierre Barbet, Dr. David Willis, and Dr. Robert Bucklin) used their expertise in biology, anatomy, and the nature of blood flow from wounds to investigate the Shroud of Turin primarily from the perspective of the wounds that are shown on the cloth. They all concluded that the Shroud of Turin wrapped a real human body that in some way must have caused the image and the blood marks on the Shroud.

The Shroud of Turin Research Project (STURP) in 1978 concluded (Ref. 17) that "No pigments, paints, dyes or stains have been found on the fibrils. X-ray, fluorescence and microchemistry on the fibrils preclude the possibility of paint being used as a method for creating the image. Ultra Violet and infrared evaluation confirm these studies. … Microchemical evaluation has indicated no evidence of any spices, oils, or any biochemicals known to be produced by the body in life or in death. It is clear that there has been a direct contact of the Shroud with a body, which explains certain features such as scourge marks, as well as the blood. … The scientific consensus is that the image was produced by something which resulted in oxidation, dehydration and conjugation of the polysaccharide structure of the microfibrils of the linen itself. … We can conclude for now that the Shroud image is that of a real human form of a scourged, crucified man. It is not the product of an artist." This evidence corroborates the results of the earlier researchers that the body that was wrapped in the Shroud in some way must have caused the image and the blood marks on the Shroud.

But if the body that was wrapped within the Shroud in some way caused the image on the Shroud, then how did this happen? In contrast to Rogers' attempt to prove that radiation was not involved in encoding the image of the body onto the Shroud, scientific research increasingly indicates that the most reasonable understanding for what caused the image on the Shroud of Turin is radiation. But to recognize this, the researcher must allow himself to follow the

scientific evidence where it leads rather than being constrained by a philosophical presupposition of naturalism.

Characteristics of the image that can be explained by vertically collimated radiation emitted from within the body (Ref. 18) include the following:

- The front and back images of the crucified man are high resolution images, even though there would have been air gaps between the body and the Shroud at most points.
- There are no side images of the body on the Shroud.
- The image on the Shroud is a negative (reverse) image.
- There is 3D or topographical information content in the pattern of discolored fibers in the image on the Shroud that indicates the distance of the cloth from the body that was wrapped within the Shroud.
- The image is not due to foreign materials such as particles from paint, dye, a rubbing, a print, etc., but is due to single carbon bonds being altered into double carbon bonds in the cellulose molecule. This characteristic usually results from a process of oxidation and dehydration of the cellulose molecule, as occurs in aging. But simple aging of the Shroud would not form the image of crucified man.
- The image is due to discoloration of only the top one or two layers of fibers in a thread. In a discolored fiber, the discoloration is only on the outside circumference of the fiber but there is no discoloration on the inside of the fiber. This discolored layer has a thickness of less than 0.4 microns – less than a wavelength of light.
- Where one thread crosses over another thread, there is a white spot on the underlying thread as though the top thread has protected or shielded the underlying thread from something, e.g. particles or photons, which are going in a straight line from the body to the cloth. The same appears to be true for one fiber that crosses over another fiber.
- Each section of fiber that is discolored is discolored to the same straw yellow color, so that, for example, a darker area of the image is achieved by more and/or longer sections of fiber being discolored, and not due to the discolored areas having a darker discoloration of the fibers.
- Some of the bones that are near the surface of the skin appear to be encoded in the image, such as the teeth, vertebrae, bones in the hands, and bones in the skull.
- The intensity of the image is similar on the front and back images, in spite of the fact that the weight of the body was entirely on the back side. On the front side, only the weight of the cloth was pressing the cloth and the body together.
- The image has no indication of two-dimensional directionality as would occur due to brush strokes in painting.
- The discoloration shows no sign of capillarity (absorption of liquids) within or between fibers or threads, so the image could not be due to any liquid such as an acid or a chemical in a solution.
- There is nothing binding the discolored fibers together as would occur in a painting.

- The discoloration is independent of any temperature gradient that would have been present due to the 1532 fire, so the image could not be caused by organic molecules.
- There is no indication of chipping or cracking of the image due to rolling and folding of the cloth over many centuries, as would occur with a painting.
- The image has no outline. This contradicts artistic methodologies of previous eras.

Another important argument for the necessity of radiation in the formation of the image is based on the presence of information content in the image. We can see the image of a crucified man on the Shroud because the pattern of discolored fibers on the Shroud contains the information content that defines the appearance of a crucified man. This information content is what allows our minds to interpret the pattern of discolored fibers as an image of a crucified man. This information content must have come from the body, because it was only inherent to the body, and not to its surroundings. This information content was communicated from the body to the cloth in terms of the vertical cloth-to-body distance at every point. In considering how information content can be communicated from one location to another, the body-to-cloth distance information that is contained in the pattern of discolored fibers on the Shroud could only have been communicated from the body to the Shroud by radiation emitted from within the body that traveled across the body-to-cloth gaps (Ref. 19). How the body could have emitted radiation in the process of disappearing from within the Shroud is considered in Ref. 20. Experiments have shown that protons (Ref. 5) and ultraviolet light (Ref. 15) can produce a discoloration on the top fibers of a linen thread that is similar to the bizarre characteristics of the discoloration on the image fibers on the Shroud.

For the above reasons, as well as others, it is hypothesized by many authors (Ref. 10, 12, 15, 21 to 29) that radiation was emitted from the body, and that this radiation deposited its energy onto the Shroud to form the image, whether by a corona discharge or by some other mechanism.

Conclusion

Ray Rogers' 2005 paper, "The Shroud of Turin: Radiation Effects, Aging, and Image Formation" was reviewed for technical accuracy and logic. It was found that his experimental procedures described in this paper were not sufficiently thorough to conclude that radiation could not have been involved in the formation of the image. His assumption regarding the internal structure of a linen fiber was wrong and his observations were very subjective so that his conclusion in the abstract is not justified. This view is confirmed by the very tentative and partial nature of Rogers' last sentence in the body of his paper ("I believe that the current evidence suggests that all radiation-based hypotheses for image formation will ultimately be rejected." Underlining added.), which contradicts the very conclusive and universal nature of the last sentence in his abstract, i.e. that formation of the image on the Shroud of Turin "could not have involved energetic radiation of any kind." Thus, review of Rogers' paper indicates that his last sentence in the body of his paper properly indicates the tentative and partial nature of his evidence presented in the paper, and that the last sentence of the abstract is an overstatement and not justified by the evidence presented in his paper.

Why would Rogers write a paper containing such a contradiction regarding the conclusion? It is suggested that perhaps Ray Rogers never adequately finished this paper since he died on March 8 of the same year in which the paper is dated (2005). This would also explain why this paper was evidently never published. It is concluded that much more research on the Shroud's fibers would be required to prove that radiation played no part in formation of the image. And on the other side of the consideration, based on several types of evidence, it appears that radiation is the best explanation of the characteristics of the images that are on the Shroud as well as how the information content related to the body-to-cloth distance could have been communicated to the Shroud. Some aspects of that radiation can be determined but additional research is needed to determine the full nature of that radiation.

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