

# **Role of Radiation in Image Formation on the Shroud of Turin**

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## **Abstract**

Formation of the image on the Shroud required three things: a discoloration mechanism, energy, and information. There must have been some process or mechanism that caused discoloration on the top portions of the fibers that make up the image on the Shroud. Energy would have been required for the functioning of the discoloration mechanism to alter the covalent bonds of the carbon atoms in the cellulose molecules that caused the discoloration. And information defining the shape of the body and the presence of some of the bones was needed to guide the process so that front and back images with good resolution could be formed. It is argued that if we follow the evidence where it leads and not be constrained by a presupposition of naturalism, then we find that the best explanation for the evidence on the Shroud is that the required energy was delivered to the Shroud by radiation emitted from within the body, and that this radiation must have been vertically collimated both up and down. Seventeen reasons are given for this view. The radiation that was emitted from within the body, by means of its intensity and direction, carried the necessary information from the body to the Shroud so that the image could be formed. A working hypothesis is developed for this emission of radiation from within the body in terms of when, where, what, why, and how. Responses are given to multiple questions that arise regarding this working hypothesis. And lastly a two-step image formation mechanism is proposed based on radiation emitted from within the body, which caused a corona discharge on the top portion of the fibers, which caused the discoloration of the fibers making up the images.

## **Introduction**

The Shroud of Turin, also commonly called the Turin Shroud, is a burial cloth that has been located in Turin, Italy, since 1578. The amazing thing about this burial cloth is that it contains full size good resolution images of the front and back of a naked man that was crucified exactly as the New Testament says that Jesus of Nazareth was crucified. When put on display, which usually occurs several times each century, millions of people file past the Shroud and see the images of the crucified man. Long standing tradition maintains that the Shroud of Turin is the authentic burial cloth of Jesus. Ancient documentation and a variety of ancient coins and artistic works are consistent with this view.

The scientific investigation of the Shroud of Turin began in 1898 when Secondo Pia took the first photograph of the Shroud which revealed that the image was a good resolution negative image. This contradicted the generally held opinion that the image on the Shroud was a painting, because no artist of a previous era could paint a negative image, because no artist of a previous era had ever seen a negative image. It has now been scientifically studied for over 115 years

making it the most studied ancient artifact in existence. This scientific research has shown that the characteristics of the image are so bizarre that it could not be the result of a human agent, either an artist or forger, because the technology to create this image did not exist in a previous era and still does not exist even today. Based on this scientific research, the general consensus of Shroud researchers is that the Shroud wrapped the body of a real human being that was crucified, and that in some way this body encoded front and back images of itself onto the inside of the Shroud.

Much of the time and effort spent on this scientific research has assumed that the cause of the image must be in accordance with the laws of science as understood at the time. This is done through a philosophical presupposition of naturalism – that only the laws of science as we currently understand them are allowed to be used to explain the presence of the images on the Shroud. But this approach over this long period of time has not arrived at an acceptable explanation for the image, the date, and the blood. In fact, there are several good reasons to believe that the processes or mechanisms by which the images were formed may not be within our current understanding of the laws of science:

- As discussed above, over 115 years of scientific research on the Shroud have not produced a naturalistic explanation.
- Many individuals have attempted to reproduce the images using a variety of naturalistic processes but all attempts have failed to reproduce one or more of the image characteristics.
- Many Shroud researchers (Ref. 1 to 15 and 25) have concluded that the characteristics of the front and back images on the Shroud are so bizarre that they must have been encoded onto the Shroud by radiation emitted from the dead body as it was wrapped in the Shroud. Under normal conditions, the quantity and characteristics of the radiation that could be emitted from a dead body by the decay of naturally occurring isotopes could not form such an image, and never have. Thus, the process or mechanism by which the dead body within the Shroud emitted the radiation required to form the images must be outside of our current understanding of science.
- Anyone that looks through his clothing will find that his body has not encoded good resolution front and back images of itself onto the inside surface of any of his clothing. This certainly suggests that the body of a living person cannot encode an image of itself onto a piece of cloth, i.e. that our current understanding of the laws of science does not include any mechanism for this to happen. And of the billions of people in all of human history that have died, none of their dead bodies (except the body wrapped within the Shroud) have encoded any images onto any burial cloth. So the above conclusion can be broadened to say that there appears to be no mechanism in our current understanding of the laws of science by which the body of any one, whether living or dead, can encode its image onto a piece of cloth. The images on the Shroud of Turin are a totally unique phenomenon. If the images were encoded onto the Shroud by a naturalistic process, then it is reasonable to expect that there would be other examples of such images on cloth.
- Given the nature of the image – that of a man that was crucified exactly as the New Testament says that Jesus was crucified, we need to consider the possibility that it is

indeed the authentic burial cloth of Jesus and as such is the result of his death, burial, and possibly even his resurrection. The relevant passages in the New Testament are Matthew 27:27 to 28:20, Mark 15:16 to 16:8, Luke 23:26 to 24:53, and John 19:17 to 21:25. Mark 16:9 to 20 is omitted from the above list because it is probably of lesser historical reliability, because it is probably not authentic to the original manuscript of Mark. The point of this consideration is that Jesus' followers were convinced that Jesus had disappeared from within his burial shroud as it lay in the tomb. If the disappearance of Jesus' body from within the Shroud was an actual historical event, then it would be beyond or outside of our current understanding of science. And if the images were encoded onto the Shroud at the time of the disappearance of the body from within the Shroud, then it would be reasonable to expect that the mechanism by which the images were encoded is also beyond or outside of our current understanding of science.

- Ray Rogers in a paper (Ref. 24) from 2005 claimed in his abstract 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 (Ref. 25) 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)

The above considerations point to the need to think “outside the box” created by the constraints of naturalism. Therefore, this approach will be utilized in this paper in an attempt to solve the mysteries of the Shroud. The ground rule for this approach is to follow the evidence on the Shroud where it leads, free from the constraints of a presupposition of naturalism. This approach recognizes that encoding of the front and back images onto the Shroud probably involved new phenomena that are not within our current understanding of the laws of science. And since truth ought to be the goal of science, we must be willing to follow the evidence where it leads, even to the point of questioning our own basic assumptions.

In “following the evidence where it leads”, we are essentially attempting to “reverse engineer” the image formation mechanism, i.e. to determine how the image was encoded onto the Shroud based on the characteristics of the image. This approach can also be called “solving the inverse problem”. This is the process used in forensic science, in contrast to experimental science. In forensic science, it is not required or expected to reproduce the original cause in the laboratory. For example, a detective investigating a murder scene is not required to reproduce the original murder again and again in the laboratory, but he can still scientifically investigate various features of the case to determine how the murder was most likely committed and possibly the characteristics of the person that committed the murder. Similarly, if the original event involved the disappearance of Jesus' body from within his burial shroud, as historical sources such as John 20:1-10 indicate, then we would not expect to be able to reproduce the original event in the laboratory. But using forensic science we can still scientifically investigate the image and other features of the Shroud to try to determine the most likely way in which the image was formed.

One caution in “following the evidence where it leads” is that we can only study the evidence that is on the Shroud, and this evidence may not be sufficient to guide us to answers for all of our questions. For example, the detective in following the evidence from the murder scene where it leads may not be able to obtain answers to some of the important questions, but this failure should not negate what can be learned. So it is with our study of the Shroud. An inability to answer all of the questions should not negate what can be learned, for we can only follow the evidence that is there.

When the progressive nature of our understanding of science is considered, this goal of “following the evidence where it leads” and thinking “outside the box” of naturalism should not be objected to as either unscientific or even startling. For it’s an essential axiom of science that scientists ought to be open to new phenomena and new information even if it conflicts with current scientific understanding so that the current scientific laws can be modified and expanded to cover all events that have happened. It is potentially critical for us to understand how the image on the Shroud was formed because, depending on the nature of the results, it may be information that is necessary for humanity to form a correct view of reality. Everyone’s worldview may depend on it! Naturalism is discussed further in the response to question #1 on page 17.

### Requirements for Image Formation

Formation of any image on any medium requires a mechanism to create shades or color, energy to drive the mechanism, and information to control the mechanism so that the correct amount of shading or color is placed at each location. Consistent with this, three basic things are required to encode the image of the body onto the Shroud: a mechanism to discolor the linen cloth, energy, and information:

1. A process or mechanism is needed that is able to discolor fibers in the way that the fibers are discolored on the Shroud:
  - The fibers on the Shroud are discolored with a straw-yellow color.
  - Of the 100 to 200 fibers that are in a linen thread, only the upper portions of the top one or two layers of fibers in a thread are discolored.
  - Only the outer circumference of each fiber is discolored.
  - The thickness of the discoloration on a fiber is less than 0.4 microns, i.e. less than the wavelength of light.
  - The discoloration on the fibers is not due to pigment added to the Shroud but is due to a change in the covalent bonds of some of the carbon atoms that were already in the cellulose molecule. This result is essentially the same as the oxidation-dehydration that results from aging, except that an image of a crucified man is formed.
  - There appears to be some degree of discoloration on the outside of the Shroud that indicates a slight image of the face and the hands.

Based on its location and nature, this discoloration is probably caused by a static discharge from the top portions of the fibers – essentially a “lightning rod” effect, with the resulting

heating and/or electrical current flow through the top portions of the fibers causing the change in the covalent bonding of the carbon atoms in the cellulose molecule. This is essentially the discoloration mechanism proposed by Giulio Fanti (Ref. 1 to 3) under the term “corona discharge”.

2. There must also be a source of energy to drive the image encoding mechanism, whether it is caused by a corona discharge or some other process. The proposed source of this energy to drive the image encoding mechanism is radiation possibly in the form of charged particles, such as protons and electrons, and/or low-energy electromagnetic radiation/photons such as ultraviolet (UV) light. The fact that any image on the outside of the Shroud, as it would have covered the body, is much lighter than the image on the inside of the Shroud indicates that the image was not caused by highly penetrating radiation. Particles that are electrically charged such as protons (+1) and electrons (-1) are not very penetrating because their electrical charge interacts with the cloud of electrons that surround the nucleus of each atom, so these particles are good candidates to provide the energy to drive the image encoding mechanism. On the other hand, neutrons are electrically neutral and so do not interact with the cloud of electrons around the nucleus of each atom but only interact if they hit the much smaller nucleus at the center of each atom. As a result, neutrons are very penetrating and so could not be a significant contributor to image formation, for then the image would be just as strong on the outside as on the inside of the Shroud, and discoloration would occur through the thickness of the cloth, contrary to the evidence on the Shroud. High energy electromagnetic radiation such as gamma rays are also highly penetrating and so for the same reasons could not be a significant contributor to the image formation mechanism. Thus, energy to drive the image encoding mechanism could have come from charged particles such as protons and electrons, and/or from low energy electromagnetic photons such as ultraviolet light. There is experimental evidence that protons (Ref. 4 and 5) and ultraviolet light (Ref. 6 to 14) can cause discoloration similar to that seen on the Shroud. There is inadequate basis to exclude either of these two options at this time. It is also concluded that neutrons and gamma rays were not significant contributors to the image formation.
3. There must also be information provided to the image encoding mechanism in a way that guides or controls it to produce the image of the crucified man. For example, the discoloration mechanism must be able to discolor certain fibers but not discolor other fibers right next to them based on this information. And the discoloration mechanism must be able to discolor the correct length of each fiber based on this information. This means that the information that is guiding or controlling the image encoding mechanism must be that which defines the appearance of the crucified man. This information does not need to define the color of the body for the color of the body is not indicated on the Shroud. This information needs to define only the shape of the body in terms of the vertical distance between the body and the cloth, for Shroud researchers have concluded that is what the shades of discoloration on the Shroud indicate. This is how the 3D or topographic effect is created in the image. This information could not have come from the limestone of the tomb, or from the air that was filling the tomb, for this information was not inherent to these materials. It could only have come from the actual vertical distance between the body and the cloth. So this information in some way must have been transported from the body-to-cloth gap to the Shroud. The only option to transport, or communicate, this information content from the gap

to the cloth is by radiation that passes through the gap and is thus altered by it. The other options for communicating information from one location to another (waves in a medium, flow of particles in physical connections such as wires, direct contact, and diffusion of molecules) must be rejected for the Shroud (Ref. 15). So the radiation that is necessary for the corona discharge to function (#2 above) was also the means by which the required information content was communicated from the body-to-cloth gap to the Shroud. Radiation, by means of its frequency, intensity, and direction is ideally suited to communicate information. For example, as related to a visual image, it is electromagnetic radiation, i.e. reflected photons of light, that by their frequency, intensity, and direction transfer the information related to the color, shade, and location of the items in the scene in front of us to our eyes so that we can see our surroundings (Ref. 15). Radiation is also the most common means of communicating information in our surroundings and in our culture. The role of radiation in image formation on the Shroud should not be rejected because radiation sounds strange or weird, for each of us live with radiation continually all around us. It should be noted that the information deposited on the Shroud must also include information related to the presence of the bones near the surface of the body, since images of some of these bones (teeth, vertebrae, bones in the hands and skull) are present on the Shroud. This means that the radiation that must have come from the body was not just emitted from the surface of the body but must have been emitted from within the body. This is the only way in which the radiation that must have come from the body could have picked up the information content related to the presence of these bones and communicated it to the Shroud.

So to encode the front and back images onto the Shroud, the discoloration mechanism (#1 above) had to utilize the energy provided to it by radiation (#2 above) that came from the body in a way that was controlled by the information (#3 above) carried on that radiation. This statement has very wide application. The discoloration mechanism referred to above could be a photo-chemical process, or a corona discharge, or some other process. And the radiation could be electromagnetic radiation (photons) such as ultraviolet light, or it could be charged particles such as protons or electrons. And, assuming that the body disappeared from within the Shroud, the above statement is true whether or not the image was encoded onto the Shroud as the result of the cloth collapsing into the volume previously occupied by the body.

### Evidence for Radiation

Following the evidence where it leads while rejecting the constraints of naturalism, the evidence indicates that it is highly probable that the image was formed by radiation that was emitted from within the body as it was wrapped within the Shroud. Seventeen reasons for this view are given below:

1. Science has disproven all other suggested possibilities for the cause of the image.
  - The image is not caused by paint or stain, since there is no evidence of pigments, carrier, or brush strokes in the image. Also, nothing is binding the discolored fibers or threads together and the image shows no sign of cracking or chipping due to centuries of folding and rolling. And if the Shroud were the result of an artist, then the artistic technique used to create the image is unique to the Shroud and the artist is totally

unknown. Of particular note is that the image on the Shroud has no outline, contrary to common artistic technique.

- The Shroud was in a fire in 1532 which scorched portions of the Shroud, yet this temperature difference across the Shroud did not cause any change in the gradation of the image on the Shroud. This indicates that the image is not due to the application of an organic chemical.
  - Microscopic examination of the fibers and threads found no evidence of capillarity (soaking up of a liquid) of the discoloration. This indicates that the image is not due to application of a liquid such as an acid.
  - The front and back images of the crucified man can be seen in front lighting, but cannot be seen in rear lighting. This indicates that the image is not due to the application of any substance (matter, atoms) to the front surface of the cloth. This means that the image is not a rubbing, a dusting, or a print.
  - No chemicals sensitive to light were found on the Shroud, so the image could not be the result of a photographic process.
  - No other chemicals were found on the Shroud. For example, no chemicals that might commonly be used in the burial process in the first century (myrrh or aloes, John 19:39) were found on the Shroud. The normal products of body decay were also not found on the Shroud. So the image is not due to a naturalistic process of chemicals placed onto the body reacting with chemicals produced by a decaying human body.
  - The coloration of the image makes it appear to be a scorch. A scorch is typically due to extended contact of the cloth with a hot object, like an iron on a cotton sheet. This type of scorch will fluoresce under ultraviolet light. When tested, the image on the Shroud did not fluoresce under ultraviolet light, so the image could not be a scorch due to extended contact of the cloth with a hot object.
2. The coloration of the image makes it appear to be a scorch, but the coloration is not caused by extended contact between the cloth and a hot object because the image does not fluoresce, as discussed above. But a very light scorch does not fluoresce. A very light scorch could conceivably be the result of a very brief contact with an elevated temperature or the result of an extended contact with a temperature that is not hot enough to cause a heavy scorch. Attempts to use these mechanisms to cause a very light scorch indicate that the light scorch penetrates through the entire thickness of the cloth (Ref. 23), whereas the discoloration of the Shroud images is only on the top one or two layers of fibers in a thread. Thus, the image discoloration is not due to these processes. Another possibility is that radiation absorbed by a material can cause a discoloration even if the material and the surroundings are not at an elevated temperature. This is sometimes called a “cold” scorch. Examples of this are the discoloration on a hanky left out in the sun for several days, and a sunburn on skin even when the air temperature is not elevated. Radiation can cause a scorch on cloth which does not fluoresce under UV light. Since the Shroud images do not fluoresce under UV light, this implies that they were caused by radiation that was absorbed onto the cloth. In simple terms, this implies that the front and back images are radiation burns.
  3. If the image is a radiation burn, then the radiation had to come from somewhere. Most Shroud researchers believe that the evidence requires that the Shroud wrapped a body of a

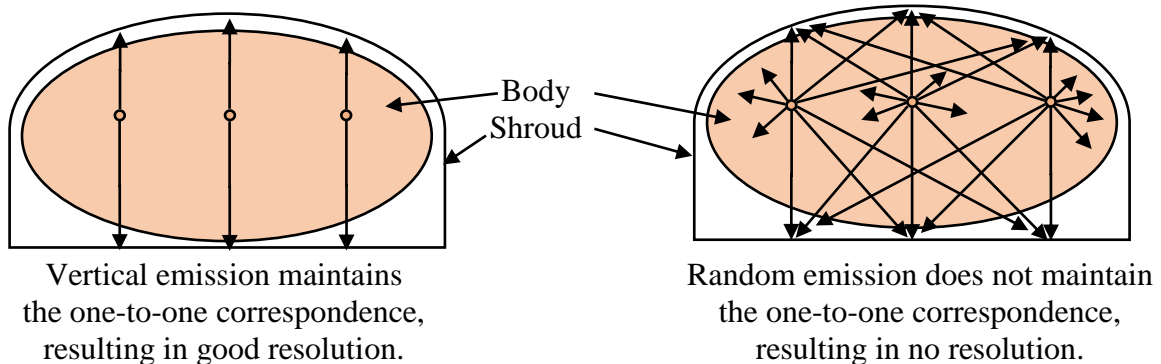
crucified man. These researchers appear to agree that the front and back images of the crucified man that show on the Shroud were created on the inside of the Shroud as it wrapped the body. This is clearly the case since the blood that is on the Shroud had to come from the body and since the blood marks that didn't soak through the cloth are on the same side as the image. Since the section of the cloth that was above the body was discolored on the bottom of the cloth that faced the body, the radiation had to come from below the upper cloth. And since the section of the cloth that was under the body was discolored on the top of the cloth that faced the body, the radiation had to come from above the lower cloth. This means that the radiation had to come from the volume between the upper cloth and the lower cloth as it wrapped the body. But since that volume was occupied by the body, the radiation had to come from the body.

4. The first several decades of research on the Shroud led researchers to conclude that the Shroud wrapped the body of a real person that had been crucified, and that this dead body in some way must have caused the front and back images that can be seen on the Shroud. But for the dead body to cause the images on the Shroud must have involved a totally unique process. A human body forming a front and back image of itself with good resolution on a piece of cloth is unique to the Shroud of Turin. There is no other example of such a thing happening in human history, whether the person was alive or dead. Because of the bizarre characteristics of the image on the Shroud, it is not possible for the image to have been formed by a human agent, either artist or forger, in a previous era or even today. Scientific research for over 115 years has not discovered a naturalistic explanation. The uniqueness of the image formation on the Shroud is consistent with it being due to a totally unique event, such as radiation being emitted from within the body that was wrapped within the Shroud.
5. Our brains recognize that the image on the Shroud is that of a crucified man because the pattern of discolored fibers on the Shroud contains the information content that defines the shape of a crucified man, specifically in terms of the vertical distance between the body and the cloth. This information could have only originated in the body that was wrapped in the Shroud, for such information was only inherent to the vertical distance of the body from the cloth. This information could not have come from the limestone of the tomb, the air in the tomb, or from the manufacturing process of the cloth. This information must have been carried (communicated) from the body-to-cloth gap to the Shroud. The only option to communicate this information to the cloth is by radiation that originates in the body and then passes through this gap and is thus modified by the air in the gap (Ref. 15), as discussed above in #3 on page 4.
6. Researchers report that the images on the Shroud show bones that are close to the surface of the body (teeth, vertebrae, and bones in the hands and skull). This indicates that something flowed from the body to the cloth that picked up the information related to the presence and configuration of the bones near the surface of the body, and carried that information to the cloth where it was deposited. Since radiation is the only option for communicating such information to the cloth (Ref. 15), the most reasonable explanation is that radiation was emitted from within the body. This information regarding the bones could have been communicated to the Shroud either by radiation that was emitted behind the bones being



altered probably in intensity as it passed vertically through the bones, or by the bones vertically emitting more radiation than the surrounding material.

- The front and back images on the Shroud have good resolution, with the resolution estimated to be about 5 mm or less. There are no images of the side of the body or the top of the head. To encode good resolution images on the Shroud, there must be a one-to-one correspondence between each point on the surface of the body and each point on the cloth, so that each point on the surface of the body affects only one point on the Shroud and each point on the Shroud is affected by only one point on the surface of the body. The best explanation for how this could have been accomplished is that radiation was emitted within the body, and that this radiation was emitted initially in a vertical direction – vertically up and vertically down. This is shown in the left figure below. And with the radiation only emitted in vertically up and vertically down directions, no image of the side of the body or the top of the head would be formed, which is consistent with the images on the Shroud.



As shown in the right figure above, if radiation is emitted randomly in all directions from every point in the body, then each point on the cloth would receive radiation from many points in the body so that no image could be resolved on the cloth. The reason for this is that there is no lens between the body and the cloth to focus the radiation coming from the body. Consider how our eyes function. When we view the scene in front of us, our eyes can produce a high resolution image of the scene on the retina at the back of the eye because each eye contains a lens. Even though photons are being reflected in all different directions from every point in the scene in front of us, so that photons are entering our eyes from many different points in the scene in front of us, the presence of the lens in each eye is able to focus those photons onto the retina so that a high resolution image can be formed. If there were no lens in the eye, no image of the scene in front of us could be formed on the retina. Similarly, for the Shroud, since there was no lens between the body and the cloth, no image of the body could be formed on the cloth if radiation were released in random directions from every point within the body. This can only be accomplished if the radiation emitted from every point in the body was initially released in a vertical direction – collimated vertically up and vertically down. It should be pointed out that even if the radiation were initially emitted in perfectly vertical directions, some degree of scattering of that radiation would be expected as the radiation passed through the body, through the air in the body-to-

cloth gap, and through the Shroud. Such scattering would decrease the resolution of the image that was formed on the Shroud. This may be the explanation why the image of the face on the outside of the cloth appears to have a lower resolution than the image of the face on the inside of the cloth. As the radiation penetrated through the cloth from the inside surface to the outside surface of the cloth, it would have gone through additional scattering events which would have reduced the resolution of the image produced on the outside of the cloth.

8. Only the top 1 or 2 layers of fibers in a thread are discolored, the depth of the discoloration is less than 0.4 microns – less than a wavelength of light, and this thickness of discoloration is circumferential around the outside of the fiber. The most likely cause of this type of discoloration was probably a static discharge, also called a corona discharge, from the tops of the fibers – essentially a “lightning rod” effect, which caused a flow of electrons and the resultant heating of the tops of the fibers thus explaining the location and the thinness of the discoloration. This needs an energy source such as radiation. Charge particles and perhaps ultraviolet light could cause such a static discharge.
9. The image is a negative (reverse) image that contains 3D or topographic information content related to the distance of the cloth from the body. The 3D effect is due to the intensity of the image being approximately inversely proportional to the vertical distance of the cloth from the body, but in such a way that no image was formed when the cloth was more than about 3 or 4 cm from the body. This can be explained by radiation that went from the body to the cloth, with intensity decreasing as it passed through the air gap between the body and the cloth due to absorption, scattering, and/or decay, until it was not strong enough to cause any discoloration. This implies that the discoloration mechanism has a threshold energy, i.e. at least a certain amount of energy must be applied to the discoloration mechanism or it will not cause discoloration at all. An example of a threshold energy level is the ionization potential in the photoelectric effect, where the photon must have at least a certain amount of energy to knock an electron out of its orbit. Examples of threshold mechanisms that could have caused discoloration on the Shroud include a photo-chemical process as suggested by Di Lazzaro (Ref. 6 to 14) or a corona discharge as suggested by Fanti (Ref. 1 to 3).
10. Microscopic analysis of the Shroud shows that threads/fibers that are discolored in some way prevent threads/fibers below them from being discolored. Two possible reasons for this are as follows:
  - If the discoloration on the fibers is due to a photo-chemical process, then this “shadow” on the lower threads or fibers indicates that something flowed from the body to the cloth that was blocked by the upper threads or fibers, and that this flow was essentially vertical. The best explanation for this would be that radiation was emitted from within the body in a vertical direction - vertically up and vertically down. This radiation traveled essentially vertically through the body, then vertically across the air gap between the body and the cloth, and was then absorbed onto the Shroud. When this radiation hit the upper threads or fibers, it was absorbed, and so could not affect the threads or fibers underneath, thus creating a shadow.

- If the discoloration is due to a “lightning rod effect”, i.e. a corona discharge, then the electrical discharge would take place from the highest portions of the threads/fibers and not from the underlying threads/fibers, thus creating the “shadow” effect. But this process would be the result of radiation from the body hitting the cloth, so again radiation must be emitted by the body.
11. The front and back images have nearly the same intensity in spite of the fact that the front of the body only had the weight of the cloth on it whereas the back of the body had the entire weight of the body on it. If for example, the discoloration on the cloth were proportional to the degree of contact between the body and the cloth, then the back (dorsal) image should be significantly darker than the front image. But if the image formation was due to radiation emitted from within the body, and it was emitted vertically up and vertically down, then both images should be equally dark. Some have observed that the back image appears to be somewhat lighter than the front image. This could possibly be explained by particle radiation that has a different electrical charge going in opposite vertical directions. Protons have a positive one electrical charge (+1) and electrons have a negative one electrical charge (-1). Perhaps one went vertically up and the other went vertically down due to the presence of electrical and/or magnetic fields. Such fields would not affect radiation that has no electrical charge such as neutrons or photons of ultraviolet light.
  12. The discoloration on the fibers is not due to any pigment, but is due to some of the carbon atoms in the cellulose molecule having altered covalent bonds in the molecular structure. The covalent bonds of carbon in the cellulose molecule could only have been altered by time, chemical interaction, or radiation. But time could not create the image of a crucified man. The discolored sections of the fibers show no evidence of capillarity (soaking up of a liquid), so the discoloration cannot be due to a chemical reaction involving a liquid such as acid. Thus, the only remaining possible cause is radiation.
  13. The image consists of altered covalent bonds of carbon in the cellulose molecule. Energy must have been deposited on the Shroud to cause this alteration in the covalent bonds of carbon. In 1978, STURP found that the image was not visible in back lighting. From this, they concluded that the image was not caused by any substance (matter, atoms) deposited onto the Shroud. The transfer of energy without the transfer of substance (matter, atoms) is only accomplished by radiation.
  14. Experiments have shown that discoloration on individual fibers similar to that on the Shroud can be caused by proton irradiation (Ref. 4 and 5) or by a pulse of ultraviolet light (Ref. 6 to 14). At this point in the scientific investigation, it is best to retain both options. And both options are consistent with the hypothesis that radiation was emitted from within the body that was wrapped within the Shroud.
  15. Neutrons emitted from within the body (Ref. 16) can explain the three mysteries related to the C<sup>14</sup> dating:
    - In 1988, the Shroud was C<sup>14</sup> dated to 1260 ± 31 AD (uncorrected), which translates to a two sigma (95% probability) range of 1260 to 1390 AD when corrected for the changing

$C^{14}$  production in the upper atmosphere. If radiation was emitted from within the body, and neutrons were included in this radiation, then a small fraction of these neutrons would have been absorbed in the trace amount of  $N^{14}$  that was naturally in the Shroud to form new  $C^{14}$  atoms in the Shroud ( $N^{14} + \text{neutron} \rightarrow C^{14} + \text{proton}$ ). This new  $C^{14}$  would have been indistinguishable from the remaining  $C^{14}$  that was brought into the flax plant while it was alive, thus shifting the  $C^{14}$  date in the positive direction. If  $3.0 \times 10^{18}$  neutrons were released from within the body, then the  $C^{14}$  date for the sample from the bottom corner of the Shroud would have been shifted from about 33 AD to 1260 AD. Of course the three dating laboratories and those that did the statistical analysis of the experimental results (Ref. 17), not suspecting that the Shroud had experienced a neutron absorption event, simply reported the average value for the  $C^{14}$  date ( $1260 \pm 31$  AD, uncorrected).

- The average  $C^{14}$  dates reported by the three laboratories did not agree well with each other. Statistical analysis of this has indicated that the spread of these average values have less than a 5% chance of being consistent with each other given the stated measurement uncertainty. This indicates that these differences were probably caused by something. When these average values from the three laboratories are plotted as a function of the distance of the sample from the end of the Shroud, a slope or gradient in the data is apparent. The slope of the  $C^{14}$  date for the Shroud as reported by the three dating laboratories for the sample location is about 40 years/cm (Ref. 18). If neutrons were homogeneously (uniformly) emitted from within the body, then the natural shape of the neutron distribution in the tomb will cause this 40 years/cm slope of the  $C^{14}$  date that was experimentally determined by the dating laboratories. The natural shape of the neutron distribution in the tomb was calculated by the MCNP (Monte Carlo n-Particle) nuclear analysis computer code. As shown in Slide 34 of Ref. 16, this natural neutron distribution is similar to a cosine shape shifted toward the center of the body mass.
- The Sudarium of Oviedo, which ancient tradition indicates is the face cloth of Jesus, was  $C^{14}$  dated to about 700 AD. If  $3.0 \times 10^{18}$  neutrons are released from within the body, and if Jesus' face cloth, after being removed from Jesus' face, was placed on the right shelf in the tomb just in front of the back shelf, then enough new  $C^{14}$  would have been produced in the face cloth to shift the date from about 33 AD to 700 AD (Slides 39 and 45 of Ref. 16).

The only hypothesis that has been suggested that can explain the above three mysteries related to  $C^{14}$  dating is neutrons emitted homogeneously (uniformly) from within the body that was wrapped within the Shroud. The invisible reweave hypothesis was conceived to explain the first mystery (the 1260 date for the Shroud). For the invisible reweave hypothesis to explain the second mystery (the slope of about 40 years/cm), a second assumption must be made regarding the fraction of the old cloth that was replaced with new cloth as a function of the distance from the end of the cloth. The invisible reweave hypothesis does not explain the third mystery of why the Sudarium of Oviedo was  $C^{14}$  dated to 700 AD.

16. The color of old dried blood is very dark brown or black, but the blood on the Shroud has a reddish hue. Why is this? Experiments have shown that dried blood retains a reddish color if it has been exposed to neutrons (Ref. 19). There may be other explanations for the reddish hue of the dried blood on the Shroud, but neutrons emitted from within the body that were then absorbed in the blood appears to be a possible explanation.
  
17. When the body of the crucified man was wrapped into the Shroud, the body would have had some holes in the skin through which blood could have continued to drain for some time, such as the feet and the side wound. But most of the blood would have dried on the body, such as from the scourge marks and the blood that had run down his arms and forehead. Dried blood will not soak into cloth, and in fact requires some effort to wash off of the skin. The mystery is how this dried blood was removed from the body and moved to the Shroud, even where the two would not have been in contact. After the blood had transferred to the cloth, it appears to have re-dried in place while apparently maintaining the pristine appearance that it had while on the body, including blood serum rings around the blood exudate. And this must have happened while the body was wrapped inside the Shroud. The hypothesis of radiation emitted from within the body includes a possible explanation for this mystery. Radiation carries momentum with it so that, by a transfer of momentum, it can exert force on an object. The term for this is “radiation pressure”. A very brief intense burst of vertically collimated radiation emitted within the body, as it exited the body, could possibly lift the dried blood off of the body, heat it to a liquid state, accelerate it vertically away from the body, and thrust it onto and into the Shroud, where it then re-dried. This would allow the blood serum ring to extend beyond the area of the blood exudate due to the capillarity (tendency to soak up liquids) of the linen. This is an area for future experimentation and research.

Another aspect of the blood marks on the Shroud is that the linen fibers are not discolored under the blood. This means that the mechanism that discolored the fibers on the Shroud did so after the blood was transported from the body to the cloth. The blood was evidently transported from the body to the cloth first, and then the discoloration mechanism discolored the fibers in the images on the Shroud except under the blood. So we have two distinguishable events; first the transport of the blood from the body to the cloth, and afterwards the encoding of the images onto the cloth. The amount of time between these two events must have been at least enough to allow the blood to be transported from the body to the cloth, which would have been a small fraction of a second. And each of these events (transport of blood and encoding of the images) could have been accomplished by a burst of vertically collimated radiation. For example, in considering the two types of radiation discussed above (charged particles and ultraviolet light), perhaps one was primarily responsible for transport of the blood and the other was primarily responsible for encoding the image, i.e. perhaps a burst of ultraviolet light was primarily responsible for transport of the blood and a burst of charged particles was primarily responsible for encoding of the images.

Some researchers have noted that the front image looks as though it was projected onto the Shroud with the Shroud configured more in a raised smooth curve or plain than draped over the body. The above scenario of first one type of radiation transporting the blood from the

body to the cloth followed by another type of radiation then causing the discoloration of the image, provides a possible mechanism for this. If the radiation pressure of the initial burst of radiation were intense enough, it could momentarily lift the weight of the top cloth to form it into more of a raised smooth curve or plain. Then, if the second burst of radiation occurred at just that moment, the discoloration mechanism would encode the front image onto the top cloth as it momentarily was in this smoothed curve or plain configuration. Admittedly, this scenario is very speculative, but it is worth mentioning it as a logical possibility. This issue does not arise for the back cloth because it can simple be assumed that the back cloth is resting on a fairly level surface on the shelf in the tomb.

### Working Hypothesis for Radiation Emission

If we choose to not be restricted by the constraints of naturalism, but instead choose to follow the evidence on the Shroud where it leads, then we find that there are multiple evidences (as discussed in the previous section) which indicate that radiation was probably released from the dead body that was wrapped in the Shroud. But there are many questions related to the possibility of radiation being emitted from the body that are difficult to answer definitively because we have no experimental data for what kind of radiation could or would be emitted in such a unique event. In spite of this difficulty, the many evidences for radiation being emitted from the body motivate us to develop the most reasonable working hypothesis for radiation emission from the body. Such a working hypothesis should be useful to suggest experiments that could be performed to test the hypothesis. The following is this working hypothesis:

When: The best explanation for the evidence on the Shroud is that radiation was released by the dead body that was wrapped in the Shroud. As such, this event is outside of our current understanding of the laws of science. There are also historical reports, recorded in the gospels of the New Testament (John 20:1-10), that the body of Jesus disappeared from within the Shroud. If this was a real historical event that was being accurately reported by the observers, then this event would also be outside of our current understanding of the laws of science. Under this assumption that the historical documents attest to a real historical event, it is most reasonable to associate these two unique phenomena together, so that the radiation was released from Jesus' body in the process of his body disappearing from within the Shroud. This assumption implies that the radiation was released only over the period of time during which the body was disappearing. But how long did it take for the body to disappear? To answer this question, evidence from both scripture and the Shroud needs to be considered. According to the Bible, the future resurrection of the righteous will occur "in the twinkling of an eye" (1 Cor. 15:52). And Jesus' resurrection is the "first fruits", i.e. first occurrence, of the believer's future resurrection (1 Cor. 15:20, 23, Ref. 20) so that Jesus' resurrection should have taken the same amount of time as the future resurrection of the righteous. Therefore, Jesus' resurrection including the disappearance of his body should have taken place "in the twinkling of an eye". This phrase means that Jesus' resurrection should have occurred in a very short period of time, probably in a very small fraction of a second, and not in minutes or hours or days. So it is reasonable to assume that the body disappeared over a time period of between  $1.0 \times 10^{-9}$  second and 1.0 second. Anywhere in this range could

be called “in the twinkling of an eye”, and yet would still be long in comparison to the time that it would take electromagnetic radiation such as ultraviolet light to exit the body. The radiation must go through the remaining fraction of the body, including the bones near the surface of the body, as the body disappears, so that the information that defines the body’s appearance could be picked up by the radiation and be communicated by that radiation from the body to the cloth. This information must be communicated from the body to the cloth in order for it to control the discoloration mechanism so that it can form the image of the crucified man including the bones on the cloth (Ref. 15). Electromagnetic radiation, such as photons of ultraviolet light, travels at the speed of light ( $3.0 \times 10^8$  meters per second or about 186,000 miles per second), so that it would traverse a body thickness of 20 cm in only  $0.2 \text{ m} / 3.0 \times 10^8 \text{ m/s} = 6.7 \times 10^{-10}$  seconds. Particle radiation such as protons and electrons travels much slower. But even if protons or neutrons are not emitted with any additional energy but are simply left behind with a kinetic energy in equilibrium with their surroundings, i.e. at a thermal energy [0.0253 eV (electron volts)], their speed at the peak of the energy distribution would be 2200 m/s (meters per second) (Ref. 21), which is equal to 7218 feet per second. At this speed, it would take at most  $0.2 \text{ m} / 2200 \text{ m/s} \sim 0.0001$  second for the protons or neutrons to get out of the body if they are travelling vertically. So even at this relatively slow speed, a body disappearance time of 0.001 to 1.0 second would be slow relative to the time that it would take for the radiation to exit the body, thus allowing the information content of the body’s appearance to be transferred to the cloth.

- Where: If, as in #1 above, it is assumed that radiation was released by the process of the disappearance of the body, then it is reasonable to expect that an equal amount of radiation was released for each gram of body material that disappeared. With this recognition, and assuming that the body was approximately a uniform density ( $\text{gram/cm}^3$ ), then it follows that the radiation would be emitted approximately homogeneously (uniformly) from within the body.
- What: Regarding what kind of radiation would be emitted in the process of the disappearance of the body, it is probably best to initially consider the simple constituent parts of the atoms that made up the body (neutrons, protons, and electrons) and electromagnetic radiation (photons) such as ultraviolet light. The much more complex option would be to consider all of the other particles that are currently known in the standard model of particle physics. And of course the particle emission may have involved particles that we know nothing about.
- Why: Under the assumption that it was Jesus’ body that was wrapped in the shroud, and that the observers accurately reported (John 20:1-10) that his body had disappeared from within the Shroud, then why would radiation be emitted in the disappearance of Jesus’ body? By what mechanism would the radiation be emitted? We have no experimental data related to the disappearing of human bodies, except the Shroud, so that these questions cannot be answered to our total satisfaction, except to note that the disappearance of Jesus’ body is best understood not as a disintegration of the atoms of the body but as a transition of the atoms of the body into an alternate dimensionality, as explained in Ref. 22. The concept of a transition into an alternate dimensionality is

consistent with various hypotheses in string theory developed in an attempt to solve problems in modern physics. In this way Jesus' body would continue to exist in the alternate dimensionality after the disappearance of the body from within the Shroud in the tomb. This most easily allows for the reports of Jesus' post-resurrection appearances because the body never ceases to exist. And if Jesus' body disappeared by a transition into an alternate dimensionality, then there is no basis to argue that radiation could not be released in the process, though we don't know the mechanism by which the radiation would be released. Our ignorance about how a particular event could have happened is not a proof the event could not have happened. What is possible needs to be determined from what has happened. As Spock, in his irrefutable logic, said to Captain Kirk: "That which has happened is possible" (Star Trek – Original Series, Third Season, episode 77, "The Savage Curtain").

How: Particles such as neutrons, protons, and electrons could have been emitted from the atoms as they transitioned into an alternate dimensionality. They also could have been merely left behind, having only the kinetic energy due to their being in thermal equilibrium with the surrounding material. Also, these particles could be secondary particles created by decay from other particles or they could result from basic energy differences between our dimensionality and the alternate dimensionality. Of course, electromagnetic radiation (photons) could also have been emitted by the process of the body disappearing. Because the front and back images on the Shroud have good resolution, and because there are no side images, there must be a verticality relationship between the body and the cloth which facilitates the vertical point-by-point communication of the information content that defines the body's appearance. This information must be communicated from the body to the cloth to form the image of the crucified man on the cloth (Ref. 15). Two explanations have been offered for this verticality:

1. The radiation that could have formed the image (protons, electrons, and electromagnetic radiation) was emitted in vertically up and vertically down directions. Neutrons, because they have no charge, are very penetrating. This means that if they were involved in forming the image on the inside of the cloth, then the same image intensity would be formed all the way through the cloth as well as on the outside of the cloth. The evidence from the Shroud contradicts this, which proves that neutrons were not a significant contributor to the formation of the image on the Shroud. So the neutrons could have been emitted in vertically up and/or down directions or they could have been emitted uniformly in all directions. The nuclear analysis computer calculations presented at the 2014 Shroud conference in St. Louis (Ref. 16) to solve the C<sup>14</sup> dating problem for the Shroud were based on the neutrons being emitted uniformly in all directions.
2. The cloth moved vertically (the upper cloth moving vertically down and the lower cloth moving vertically up) under the forces of gravity and air pressure difference after the disappearance of the body. This is the "cloth collapse" hypothesis where the burial cloth collapses into the "radiant region" of the body during and/or after the



body's disappearance. Radiation encountered by the cloth in this radiant region then causes the discoloration on the cloth.

The first of these two options is believed to be more likely correct, and so is selected for further consideration in what follows. Unresolved issues with the cloth collapse hypothesis will be discussed at a later time. In reference to the above working hypothesis, the following questions might arise:

1. The proposed hypothesis is that radiation was emitted from within a dead body that was wrapped within the Shroud, and that this radiation caused the images of the front and back of the crucified man that can be seen on the Shroud. For this hypothesis to be real science, you have to know how the radiation was emitted within the body, what type of radiation it was, and what the energy level was. You then have to be able to repeat the process in a laboratory under controlled conditions so that a dead body emits radiation that encodes a good resolution front and back image of itself onto a piece of cloth. If you can't do that, then this is not science.

Response: This is a common objection to the approach taken in this paper to the investigation of the Shroud, and arises due to certain false assumptions. The first assumption is that experimental science is the only type of science that exists. But various types of science can be discussed, with forensic science being used for the study in this paper. In forensic science, one follows the evidence where it leads without necessarily knowing or even being able to investigate the root cause. A detective investigating a murder scene uses this approach. The second assumption is that of naturalism – that our current understanding of science is totally correct and absolute, so that nothing new can ever be discovered that can change our current laws of science, so that it is only legitimate to use our current understanding of science to explain all things including the image, date, and blood on the Shroud. But the history of science and the basic unsolved problems at the very foundation of physics argue strongly against this assumption. And since truth ought to be the goal of science, we must be willing to follow the evidence where it leads, even to the point of questioning our own basic assumptions. As a result, we need to foster an attitude of humility, curiosity, and willingness to “think outside the box” created by the constraints of naturalism. There are several good reasons to believe that this approach will be necessary to solve the mysteries related to the image, date, and blood on the Shroud. These issues are considered further in the introduction.

2. The time period over which the radiation is emitted is referred to as 0.00000001 to 1.0 second at one extreme for photons of electromagnetic radiation, down to 0.001 to 1.0 second at the other extreme for thermal particles. Are these the time intervals for a single burst of radiation or could there be multiple bursts of radiation?

Response: The above discussion, for simplicity, assumes that the disappearance of the body, and the resulting radiation burst, occurs linearly over the stated time period. This means that the density ( $\text{g}/\text{cm}^3$ ) of the body linearly decreases over this time period so that the radiation occurs in a single burst with a constant intensity over the entire stated time period. But admittedly, there could have been multiple shorter bursts of radiation over these time periods

so that the disappearance of the body could have occurred in more of a step-wise time dependence over these time periods. This would result in multiple shorter bursts of radiation over these time periods.

3. You assume that the radiation is emitted homogeneously from within the body. Since you are also assuming that the radiation emission is caused by the disappearance of the body, this implies that you are assuming that the material within the body is also disappearing uniformly across the entire volume of the body. Is this the only option?

Response: This assumption was made for simplicity of the consideration, and for simplicity in computer calculations. We don't know the time or spatial dependence of the disappearance of the body or the resulting radiation emission, so we must remain flexible on these issues. Just as one very speculative example, the disappearance of the body could have resulted from a horizontal "activation plane" sweeping up and down through the body with the radiation being emitted perpendicular to the activation plane, and in the direction of motion of the activation plane, as it sweeps through the body. This would result in multiple radiation bursts within the above stated time intervals with all of the radiation oriented either vertically up or vertically down, thus causing the front and back images. This is just one example of a process that could produce an image consistent with the evidence on the Shroud.

4. If protons were a significant contributor to image formation, can we ignore electrons?

Response: Probably not. Electrons would probably also be involved. This is because there would have been an equal number of electrons and protons in the atoms in the body. If we are assuming that in the disappearance of the body, a very small fraction of the atoms broke apart releasing their constituent parts (neutrons, protons, and electrons), then an equal number of electrons and protons would be released. Under this assumption, the number of neutrons released would be about 18% less than the number of protons (slide 13 of Ref. 16).

5. In this hypothesis with a single burst of radiation, would both the protons and electrons go vertically up and vertically down after being emitted from the body?

Response: This is uncertain. Under the right conditions, such as the right electrostatic and magnetic fields being present, the electrons and protons might go in opposite directions because the electric charge of a proton (+1) is opposite to the electric charge of an electron (-1). For a single burst of radiation, this might explain why the discoloration of the back (dorsal) image is slightly lighter than the front image. In dealing with electric charge, it is well known that opposite charges attract and like charges repel. If an equal number of protons and electrons were travelling in the same direction after the disappearance of the body, then there would be a strong attraction between them so that, depending on the speed of the particles, there may have been a significant recombination into neutral hydrogen atoms, each of which contains one proton and one electron. Under this scenario, the opposite charges would cancel each other out. However, this scenario seems unlikely.

6. An objection to charged particles such as protons and electrons being a major contributor to the image formation is that an electric charge would build up on the cloth that would prevent additional charged particles from reaching the cloth, or could at least divert charged particles that did reach the cloth thus preventing an image with a good resolution. A sharp image can be obtained with electrons in a television tube because there is a return path for the electrons so that a charge buildup does not occur, but there is no return path to prevent charge buildup on the Shroud.

Response: It is not clear that any charge buildup would be sufficient to prevent additional charged particles from reaching the cloth, or even to prevent an image with a good resolution from forming. Perhaps this is a good area for future calculations and experiments. It is also not clear that there is no return path for the electric charge to return from the cloth to the body during the short time interval of the disappearance of the body. At least four options exist:

- The cloth was undoubtedly touching the body at many points. Charge could have flowed along the cloth from points where the cloth was not touching the body to points that were touching the body, and then could have flowed into the body thus dissipating the charge buildup on the cloth.
- If the image is formed by a corona discharge (Ref. 1 to 3), then there could be a return path for the electric charge to flow from the cloth to the body on ionized air molecules that form across the air gaps between the cloth and the body. This would be essentially a “lightning rod effect”. In a thunder storm, the bottom of the clouds become negatively charged and the top of the lightning rod becomes positively charged. If the charge difference is sufficient, a channel of ionized air, called a “leader”, develops between the lightning rod and the bottom of the cloud and when sufficiently developed, a lightning strike will proceed along the channel of ionized air from the cloud to the lightning rod. High speed photography shows that most lightning strikes consist of from 3 to 30 electrical discharges going in both directions between the cloud and the lightning rod. This process results in extreme heating of the tip of the lightning rod. In the case of the Shroud, the high points along the top one or two layers of fibers in a thread would also experience a significant heating effect from the electrical discharge. Perhaps this heating of the high points along the fibers could have caused the discoloration of the outer layer of the fibers, resulting in a circumferential discoloration of the fiber to less than a thickness of 0.4 microns – less than a wavelength of light. The flow of electrons could also have directly caused the discoloration. The fact that the high points along the fibers are discolored is evidence that an electric discharge has occurred between the cloth and the body and/or the air, so that a return path functioned to limit the charge buildup on the cloth.
- Perhaps both the protons and electrons flowed together onto the upper and lower cloth so that there was no net charge buildup because the positive charge of the protons cancelled the negative charge of the electrons. But this would then prevent a corona discharge from occurring. Evidence on the Shroud indicates that the high points along the fibers are discolored, which argues for the option in the above bullet. It also argues for the protons

and electrons, if both were emitted from the body, going in opposite directions – one vertically up and the other vertically down, so that a charge buildup would occur on each cloth, so that a corona discharge could occur to discolor fibers on both the front and back (dorsal) images.

- The discoloration could have occurred on the fibers before a sufficient charge had built up on the cloth to prevent additional charged particles from hitting it.

7. Can the above working hypothesis explain the 3D effect on the cloth?

Response: Yes. According to the hypothesis, the radiation is initially emitted approximately homogeneously from within the volume of the body. The radiation that could cause the image (protons, electrons, and electromagnetic radiation) would be initially emitted vertically up or down. After it exits the body, this radiation must travel across the air gap between the body and the cloth. During the time that this radiation would be traveling across the air gap, the intensity of the radiation could be diminishing due to decay, absorption, and/or scattering, so that less discoloration is caused by larger body-to-cloth gaps. This will result in the 3D effect on the cloth. The Shroud indicates that there is no discoloration of the fibers for body-to-cloth gaps over about 3 or 4 cm.

8. In the discussion on the “How” of your working hypothesis, you say “The particles such as neutrons, protons, and electrons could have been emitted from the atoms as they transitioned into the alternate dimensionality. They also ... could result from basic energy differences between our dimensionality and the alternate dimensionality.” Could you explain?

Response: In reference to the first part of the quotation, the explanation and justification for the body transitioning into an alternate dimensionality is given in Ref. 22. In reference to the second part of the quotation, at one time atoms were thought to be the smallest indivisible unit of matter. Then it was discovered that atoms are composed of neutrons, protons, and electrons. For a long time, these were thought to be the smallest indivisible units of matter. Then it was discovered that each neutron is composed of one up quark and two down quarks, and each proton is composed of two up quarks and one down quark. There are only four forces in nature: gravity, electromagnetism, the weak nuclear force, and the strong nuclear force. The three quarks in each neutron or proton are held together by the strong nuclear force, which is accomplished by the continual exchange of particles called gluons between the quarks. The "standard model of particle physics" identifies six types of quarks, each type of quark distinguished by a characteristic known as its "flavor". The six types of quarks, i.e. their six flavors, are: up, down, strange, charm, top, and bottom. These quarks are currently understood to be fundamental particles, which means that they cannot be further divided into smaller particles. But as a result of this historical sequence, it might be suspected that quarks are also composed of smaller components just like atoms and then neutrons and protons were found to be composed of smaller components. The advocates of "string theory" believe that everything including quarks are composed of much, much smaller one-dimensional lengths of vibrating energy called "strings", and that all the characteristics (mass, charge, spin, etc.) of the sub-atomic particles that make up atoms and

thus make up all of our physical reality, results from the different possible vibration modes of the strings of which they are composed.

Thus, if a 170 pound man made a transition into an alternate dimensionality where all the atoms including all of their neutrons, protons, and electrons transitioned into an alternate dimensionality but with the total mass-energy of each particle reduced by an average fraction of  $1.5 \times 10^{-10}$ , then it is probable that this would initially be left in our dimensionality in the form of energy (perhaps vibrating strings, with the lost mass converted to energy according to  $E = MC^2$ ) which then very quickly would form into a wide variety of particles in our dimensionality, including photons and various flavors of quarks. The quarks would very quickly form into a variety of sub-atomic particles which would interact and decay until ultimately forming the most stable combinations of quarks, which are neutrons and protons. This would all happen so quickly that it would be imperceptible. So, in an approximate sense, any energy not ultimately converted into neutrons and protons would be converted into photons such as ultraviolet light. I say "in an approximate sense" because there could be a host of other particles that are created and survive long enough to be of significance. The neutrons that are absorbed in  $N^{14}$  in the linen to create  $C^{14}$  may be secondary neutrons (created by decay or interaction of other particles with matter) rather than primary neutrons (created more or less directly from the energy left behind). We can't be sure what kind of radiation, whether particles or photons, were the most significant contributor to the discoloration on the linen. It may have even been radiation that we know nothing about at this time.

9. The most common image formation hypotheses promoted by Shroud researchers are a corona discharge, a photo-chemical process due to ultraviolet light, and a cloth collapse. How do the concepts discussed in this paper relate to these hypotheses?

Response: Radiation being emitted from the body which provides the energy for the discoloration mechanism and which carries the required information to the cloth does not require the discoloration mechanism to be either a corona discharge or a photo-chemical process or a cloth collapse. It could be associated with any of these. But the above discussion has taken a corona discharge as the most likely discoloration mechanism because there does appear to be secondary images of the face and hands on the outside of the top half of the Shroud as it would have covered the body. If these secondary images are proven to not be present, and only appear to be present due to issues with human perception and expectations, then a photo-chemical process would become more of an option. The cloth collapse hypothesis is judged to be less likely, but the details of this consideration are beyond the scope of this paper.

### Image Formation

The first observers to enter the tomb after Jesus' crucifixion and burial (John 20:1-10) claimed that the body that had been wrapped within the Shroud had disappeared from within the Shroud. If this is understood as a simple statement of eye-witness testimony, then it is an important clue as to how the image was formed. This event, which would have been outside of

our current understanding of the laws of science, could have caused radiation to be emitted from within the body, consistent with the 17 arguments given above for radiation being emitted from within the body. Though there may be other methods, there appears to be two methods that radiation (charged particles or photons) could have caused the discoloration that makes up the images on the Shroud:

1. The first option is where the energy of the radiation breaks the molecular bonds of an atom or group of atoms thus leaving an unbound electron in the outer carbon shell (orbit of electrons) which can then recombine with the surrounding atoms such as oxygen that results in a change in the covalent bonds of the carbon atoms. In this option, the discoloration is caused along the entire path length as deep as the radiation penetrates into the cloth as long as the energy of the radiation is sufficient. The problem with this scenario is where the discoloration occurs. Since it appears that there is a real secondary image on the outside of the cloth where the image of the face is located, if this first option was the cause, then the discoloration should appear across the thickness of the cloth rather than just on the inside and outside surfaces, because the radiation must penetrate through the cloth to discolor it on the outside. The proposed photo-chemical process based on ultraviolet light (Ref. 6 to 14) is of this type. So if there is a secondary image on the outside of the Shroud, and if the ultraviolet light is causing it by a photo-chemical process, then the ultraviolet light should have caused discoloration across the thickness of the cloth, which is contrary to the evidence on the Shroud.
2. The second option is where the radiation knocks outer shell electrons out of the atoms in the air and the cloth through which it passes. This creates a positive charge distribution across the thickness of the cloth which then moves (electrically conducts) across the thickness of the cloth to collect on the highest sections of the fibers on both the inside and the outside surfaces of the cloth in response to the cloud of electrons in the air both on the inside and outside of the cloth. When sufficient charge difference is built up between these positively charged high sections of the fibers and the surrounding electrons in the air as they move toward the cloth by electrical attraction, a static discharge will occur between the high sections of the fibers and the surrounding cloud of electrons. This will cause a very significant electrical flow resulting in significant heating. One or both of these (electron flow or heating) may cause the change in the covalent bonding of the carbon atoms in the cellulose molecule, and thus result in the discoloration. This is probably how the protons in Rinaudo's experiments (Ref. 4) caused discoloration. This second option assumes that the energy of the radiation will be deposited across the thickness of the cloth, though as normally occurs it will deposit more energy on the inside of the cloth and diminish in intensity as it penetrates through the cloth. This is why the image is stronger on the inside of the cloth than on the outside of the cloth. So this second option results in discoloration only on the inside and outside surfaces of the cloth, i.e. it is only a surface effect, which is consistent with the nature of the discoloration on the Shroud. This second option is called a corona discharge in many references (Ref. 1 to 3) and can be compared to lighting that passes between a charged cloud and an oppositely charged tip of a lightning rod, resulting in tremendous electron flow and heating of the tip of the lightning rod.

So in this image formation hypothesis (#2 above), there would be a corona discharge from both the inside surface and from the outside surface as a result of the radiation going through the cloth. These electrical discharges could cause discoloration on both the inside and the outside surfaces of the cloth. As the radiation went through the cloth, its intensity would diminish and scattering events from off of atoms in the linen would tend to divert the radiation from an exactly vertical direction, which would decrease the resolution of the resulting image on the outside surface. Both of these predictions can be seen in the image of the face on the outside of the cloth: it is weaker in intensity than the image on the inside of the cloth, and it has a lower resolution.

## Conclusions

In scientifically investigating the Shroud of Turin, we ought to strive to follow the evidence where it leads and not be constrained by a presupposition of naturalism. Based on this methodology, the evidence indicates the following. Three things are necessary for formation of the image on the Shroud: a discoloration mechanism, energy, and information. The discoloration mechanism must discolor the highest parts of the top one or two layers of fibers with a straw-yellow color that is circumferential around the outside of the fibers, is less than 0.4 microns thick, and results from a change in the covalent bonding of carbon atoms in the cellulose molecule. The energy is needed for the discoloration mechanism to function, i.e. to cause the change in the covalent bonding of the carbon atoms. And information is necessary to guide the discoloration mechanism so that front and back images with good resolution are properly encoded onto the cloth. The content of this information must define the shape of the crucified man that was wrapped within the Shroud. This information must be based on the vertical distance of the body-to-cloth gap. This information must also include the location of bones near the surface of the body. And this information must be communicated to and deposited on the cloth. This can only be done by radiation that is emitted within the body, that passes through the air gap between the body and the cloth and is altered by this passage, thus communicating the vertical distance of the gap to the cloth. To properly encode good resolution images onto the cloth, there must be a one-to-one correspondence between each point on the surface of the body and each point on the cloth. This can only be accomplished if the radiation is emitted from within the body in exact vertically up and vertically down directions. So the role of radiation in image formation is two-fold: 1) to provide the energy that is required for the functioning of the discoloration mechanism, and 2) to carry the necessary information from the body to the cloth required to encode the images.

Seventeen reasons were given that radiation emitted from within the body is the most likely explanation for the image: 1) all other causes for the image have been disproven, 2) the color of the image and lack of fluorescence under UV light implies that it is a “cold” scorch due to radiation, 3) the front and back images are on the inside of the Shroud so the radiation must have come from the body, 4) the uniqueness of the image implies a unique cause, 5) information must have been carried from the body to the cloth by radiation, 6) bones are encoded into the images, 7) the front and back images have good resolution, but there are no side images, 8) a corona discharge is the best explanation for multiple bizarre characteristics of the image, 9) there is 3D or topographic information in the 2D image, 10) upper fibers shield lower fibers from discoloration, 11) the front and back images have a similar intensity, 12) the

discoloration is due to altered covalent bonds of carbon, 13) the image is due to the transfer of energy without substance so that it could only be radiation, 14) there is experimental evidence for protons and UV causing similar discoloration, 15) neutrons emitted from the body explains the C<sup>14</sup> dating, 16) the blood on the Shroud has a reddish color that could be explained by neutron absorption, and 17) radiation could possibly explain how the dried blood on the body was thrust off the body, liquefied, and transferred onto and into the Shroud.

To guide future research, a working hypothesis for radiation emission was developed. In this hypothesis, radiation is emitted by the process which causes the disappearance of the body, so that the radiation is emitted homogeneously throughout the body, and the radiation ceases once the body has fully disappeared. The radiation is initially emitted in a vertical direction, being collimated vertically up and vertically down. For simplicity, the radiation should initially be considered to be the components of the atoms (neutrons, protons, and electrons) and photons primarily in the ultraviolet energy range. Finally, an image formation hypothesis was stated based on vertically collimated radiation emitted from within the body potentially causing corona discharges on the top portions of fibers on the inside and outside of the cloth, consistent with dimmer less resolved images of the face and hands on the outside of the cloth, and darker more resolved images being present on the inside of the cloth.

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