

Information Content on the Shroud of Turin

by Robert A. Rucker, October 11, 2016

Abstract

People can see the image of a crucified man on the Shroud of Turin because the threads of the Shroud contain fibers that are discolored in a pattern that contains the information content that defines the appearance of a crucified man. This information could only have come from the body that was wrapped within the Shroud, because this information was only inherent to the body and not to its surroundings. After considering the five possible options for how information can travel from one location to another (radiation, waves in a medium, direct contact, a flow of particles through physical connections, and diffusion of molecules), it is concluded that the only credible option for how this information could have been communicated from the body to the Shroud is by radiation (photons and/or particles) emitted from within the body which was then absorbed onto the Shroud.

Introduction

Human bodies, whether living or dead, have never encoded a high resolution image of themselves onto any piece of cloth, with only one exception. In the Cathedral in the city of Turin in northwestern Italy, there is a burial cloth, or shroud, that contains an image of the body that it covered in death. To make this burial shroud even more fascinating, the image that can be seen on this cloth is a full size image of the front and back of a naked bearded man who was crucified exactly as the gospels in the New Testament say that Jesus of Nazareth was crucified. This might not be considered to be of much interest if the image was intentionally placed onto the cloth by a human agent such as an artist or a forger. But scientific studies on the Shroud indicate that an actual body of a dead crucified man was wrapped within the Shroud, and that in some way this body caused the front and back (dorsal) images and the blood that is on the Shroud. That the image is not the product of an artist or a forger is confirmed by the failure of all attempts to accurately recreate the image.

The scientific investigation of the Shroud started in 1898 when Secondo Pia took the first black-and-white photographs of the image on the Shroud and concluded, based on his photos, that the image on the Shroud must be a perfect negative (reverse) image. This meant that the image on the Shroud could not be the product of an artist or a forger. This is because no one prior to the invention of the photographic negative in the 19th century would have ever seen a negative image of a person. The discovery that the image is a negative intrigued other scientists. The first to scientifically study the Shroud was Dr. Yves Delage, an eminent scientist and professor of comparative anatomy at the Sorbonne University in Paris who was also the director of the Museum of Natural History in Paris. Though an avowed agnostic, after studying Secondo Pia's photographs between 1900 and 1902, Delage became thoroughly convinced that the body of a dead crucified man had been wrapped in the Shroud, and that this body caused the image that we can see today. On April 21 of 1902, Delage delivered what is now an historic presentation of his conclusions to the French Academy of Science. His presentation was titled

“The Image of Christ Visible on the Holy Shroud of Turin.” As a result of the anatomical flawlessness of the wounds and the blood, the image being a negative image, the lack of any sign of pigment forming the image, and the lack of any sign of decomposition of the body, Delage concluded: 1) that the image on the Shroud could not be the work of an artist or forger, 2) that the Shroud wrapped a real human body that had been crucified, 3) that by some unknown process the body had encoded an image of itself onto the inside of the Shroud, and 4) that the body wrapped in the Shroud can be identified as the historic Jesus of Nazareth. Delage concluded that “The man of the Shroud was the Christ” and later wrote to a friend that “I recognize Christ as a historical personage, and I see no reason why anyone should be scandalized that there still exists material traces of his earthly life.” (Ref. 1)

Subsequent studies over the next 75 years largely came to the same conclusion that the image and the blood on the Shroud must have been caused in some way by the dead body that was wrapped within it. They are not the product of an artist or a forger. This conclusion was confirmed by the Shroud of Turin Research Project (STURP) during their five days of non-destructive scientific tests on the Shroud in 1978. They concluded (Ref. 6) 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. ... 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 conclusion confirmed the results of the earlier researchers that the image and blood on the Shroud must have been caused by the body that was wrapped within it. There has now been 118 years of scientific research on the Shroud of Turin, making it the most scientifically researched ancient artifact in existence, and the majority conclusion is still that the body wrapped in the Shroud in some way caused the image on the Shroud (Ref. 1 to 5). This conclusion is confirmed by the attempts to produce the images by artistic or other methods, which have all failed to produce all of the characteristics of the images on the Shroud.

But this creates many questions. If the body that was wrapped within the Shroud caused the image, then how did this happen? To investigate this question, several issues will be discussed based on the concept of information:

- What is the nature of information, and how can it be stored and be moved from one location to another location?
- Why can we see an image of a crucified man on the Shroud of Turin?
- Where could the information have come from that is currently on the Shroud of Turin?
- What mechanism could have carried the necessary information to the Shroud and deposit it there?

Information is a Principle Component of Reality

Centuries ago, scientists considered only matter, space and time in their explanation of the physical universe. Gradually, scientists started to realize that energy is also an important

concept to include in their explanation of the physical universe. Energy consists of either matter in its relationship to space and time; or photons of electromagnetic energy traveling at the speed of light through space. In addition to matter, space, time, and energy, a new concept has arisen in the last half-century or so that is equally important in explaining our physical reality – the concept of information. The realization of the importance of information began in 1948, when Claude Shannon, a young mathematician with a background in cryptography and telephony, published a paper called “A Mathematical Theory of Communication” in a Bell Labs technical journal. Since then, progress has been so rapid in the field of computer technology and the resulting availability of information that our current era is now commonly called “the information age.” Recognition that information is essential to understand reality has gradually grown during this period. There are many examples.

Understanding the storage and transfer of information helps us to realize the nature and importance of information content. For example, a computer uses a long series of binary digits, each digit being either a one or a zero, to manipulate and store information related to documents, calculations, graphics, and pictures. These binary digits, or “bits”, are stored in a computer in three ways: 1) on a hard drive using the direction of magnetization of very small areas of a magnetic material coated on a rotating disk, 2) in a solid state device using the switching direction of transistors in an integrated circuit, and 3) on an optical disk using the direction of imperfections in the optical medium which can then be read by a laser. Optical disks are also used to store the information content that defines a song on a CD or defines a movie on a DVD or blu-ray disc. The information content that defines the appearance of a scene in front of a still camera or a video camera is stored as binary digits on a digital card. This information in the form of binary digits on a digital card can then be read into a computer so that the computer can translate the information content from the binary digits into a display of very small dots on the computer monitor which our brains interpret as a picture of the scene that the camera photographed. Also, the structures and functions of the components of all living organisms are based on the information content in the sequence of the guanine (G), adenine (A), thymine (T), and cytosine (C) molecules in their DNA strands.

Another example is our five senses (eyes, ears, nose, touch, and taste) which receive and process the information content that is communicated to us by our environment. When this information content is received by these receptors, it is translated into a form that can be transmitted to and understood by our brains. An example would be how one person can see another person. For example, as I look at my wife as she works in the kitchen (Figure 1), the windows in the kitchen let in light during the day and the overhead lights shine light into the kitchen during the evening. This light consists of photons of electromagnetic radiation of various wavelengths or energies. Photons are packets of energy that travel at the speed of light (186,000 miles per second = 3.00×10^8 meters per second) and have zero mass and zero charge. I can see my wife because some of the photons, as they travel at the speed of light in the kitchen, reflect off of her clothes and body in all directions including toward my eyes. The information content that defines what my wife looks like is carried by the reflected photons to my eyes. If she has a blue sweater on, then the photons with wavelengths corresponding to the color red and yellow are absorbed by the sweater and the photons with a wavelength corresponding to the color blue are reflected off of the sweater in all directions including toward my eyes. When the photons with a wavelength corresponding to the color blue reach my eyes, my eyes automatically

translate them into an appropriate electrical signal, which is then transmitted up my optic nerves to my brain. My brain has learned to interpret this electrical signal as the color blue. The number of photons received by my eyes communicates the various shades from black (no photons) to light (many photons). After the photons go through the lens of my eyes, they fall on the various light sensitive cells called rods and cones on the back of my eyes. Which rods and cones they fall on determines how my brain perceives the locations of the various components of my wife's appearance. The point of this is that all of the information content that defines the appearance of my wife (colors, shades, and locations) is transmitted to my eyes by reflected photons in their wavelength (or energy), intensity, and direction. My eyes translate the information content in the reflected photons to electrical signals which travel up my optic nerves to my brain. When my brain receives this information in the form of electrical signals, I then have a conscious experience of my wife's appearance. Thus, all the visual information that informs me about my surroundings comes to me by reflected photons, which is one form of radiation.



Figure 1. We can see another person because photons that reflect off of their cloths and body carry to our eyes the information content (colors, shades, and positions) that defines their appearance.

Information content from our environment is communicated to our other senses by means other than radiation. Information related to sound is communicated to our ears by way of compression waves in the air. Information related to smell is communicated to the nose by diffusion of molecules in the air. Information related to touch is perceived through direct contact usually with the hands. And information related to taste is communicated to us when various molecules from our food dissolve in our saliva and chemically react with the taste buds on our tongue. Considering all of our senses, it should be realized that most of the information content that is received from our environment is received through our eyes. And this information content

is communicated to our eyes by reflected photons. Thus, most of the information content that is received from our environment is received through radiation.

Like matter, space, time, and energy, information is a primary or foundational concept that is necessary to explain the physical universe. Information is necessary for every form of life to exist and for it to interact with its environment to continue its life. Without information, we would have no perception of the world around us. And without information, there would be no life in the universe.

Information on the Shroud of Turin

The Shroud of Turin is usually placed on display only a few times each century, and since 1578 has only been exhibited in the Cathedral in Turin, Italy. It is estimated that more than two million people saw the Shroud during its most recent exhibition in Turin from April 19 to June 24 of 2015. Many more millions of people have seen it during previous exhibitions. While the front and back (dorsal) images of the crucified man on the Shroud are easily discernible, they are also very light in appearance because the discoloration on the threads that make up the cloth is only on the topmost fibers of each thread. The question is how can people see an image of a crucified man on the Shroud? To answer this question, let us consider a simpler example. When you read a book or a newspaper, the information content is contained in the sequence of the letters and punctuation marks. But under a microscope, the information content in each letter and punctuation mark is defined by the pattern of very small dots on the page. For a picture printed by an ink jet printer, the information content that defines the appearance of the picture is contained in the pattern of very small black dots for a black and white picture or very small colored dots for a color picture. So the information content in a paragraph of text or in a picture is contained in the pattern of the dots on the page. The same can be said for the image on the Shroud, except that instead of the information content being contained in the pattern of dots on a page of paper, the information content is contained in the pattern of the discoloration of very short lengths of the top fibers in the threads that make up the linen cloth. So the information content that defines the appearance of a crucified man on the Shroud of Turin is contained in the pattern of discolored fibers on the Shroud (Figure 2).

It should be mentioned that while matter, space, time, and energy can all be quantified in the sense of being measured so as to assign a numerical value to them, it is usually difficult or impossible to do so for the quantity or quality of information. While the number of bits stored on a digital card can be specified by a number, a number can not be specified to represent the quality or nature of that information. And the number of bits stored on a digital card is not necessarily related to the quantity of actual information stored on the card. The same can be said for the sequence of the guanine (G), adenine (A), thymine (T), and cytosine (C) molecules in the DNA molecules. And for the information imbedded in the pattern of dots on a page, or imbedded in the pattern of discolored fibers on the Shroud, it would not be possible to assign a numerical value to quantify either the quantity or quality of the information. But this does not mean that there is no information present in the pattern of dots on a page or in the pattern of discolored fibers on the Shroud. The information content is still present even if we can't

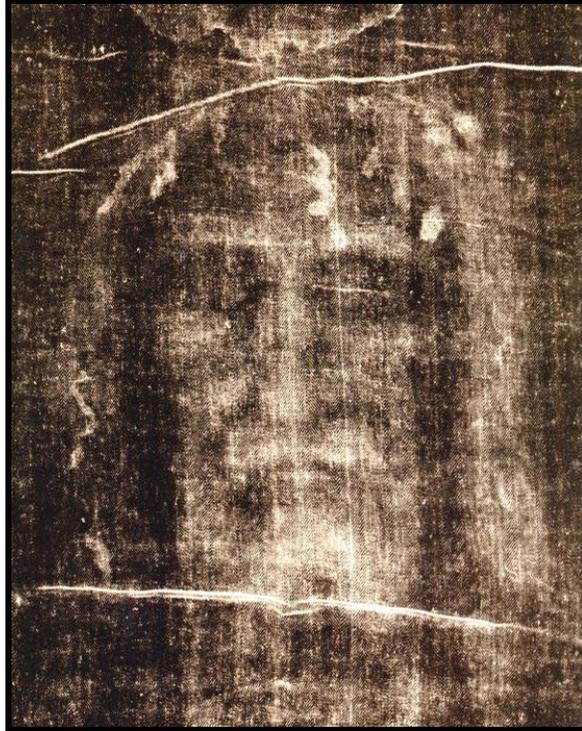


Figure 2. We can see the image of a crucified man on the Shroud of Turin because the pattern of discolored fibers on the top of the threads contains the information content that defines the appearance of the crucified man. This information content is carried to our eyes by reflected photons. (Photo courtesy of Barrie Schwartz, www.shroud.com)

quantify it, i.e. assign a numerical value to it. Consider an example. When I take a picture of my wife, print it on my printer, and then look at the picture to have a conscious experience of my wife's appearance, the information content that defines my wife's appearance has been contained in several different things:

- It was initially inherent to her body and clothes.
- Then it was contained in the energy, number, and direction of the photons reflected from her.
- Then it was contained in the electrons flowing in the electrical circuitry of the camera.
- Then it was stored on the digital card.
- Then it was downloaded to the hard drive of my computer.
- Then it was displayed in the pattern of dots on my monitor.
- Then it flowed through the electrical circuitry of the computer and printer.
- Then it was contained in the pattern of dots in the picture printed on my printer.
- Then it was contained in the photons reflected from the picture.

- Then it was contained in the electrical signals traveling up my optic nerves to my brain, which my brain interpreted so that I could consciously experience my wife's appearance by looking at the picture.

In this long sequence, the information content that defines my wife's appearance was carried by many different carriers, translated into many different forms, and stored in many different ways. And though the information content that defines my wife's appearance could not be quantified (have a numerical value assigned to it) at each step in this process, it was still present at each step in this process. So it is with the Shroud of Turin. Though we can't assign a number for the quantity or quality of the information content in the discolored fibers in the Shroud, we know that it is there because we can see the image of the crucified man when we look at it.

As discussed above, we can see the image of a crucified man on the Shroud because photons reflect off of the Shroud in all directions, including toward our eyes. These photons, by their wavelength, number, and direction, carry the information content that defines the image of the crucified man on the Shroud. This information content is carried on the photons from the Shroud to our eyes. Our eyes then translate this information content into electrical signals that travel up our optic nerves. Our brains have learned to interpret these electrical signals as an image of a crucified man. The point is that we can see an image of a crucified man on the Shroud because the pattern of discolored fibers on the surface of the cloth contains the information content that defines the appearance of the crucified man, and that this information content is carried to our eyes by reflected photons, i.e. radiation.

At this point, the nature of the front and back (dorsal) images on the Shroud needs to be clarified. These images of a crucified man consist of two components: blood marks and discolored fibers. The blood marks or stains on the Shroud are entirely consistent with the wounds suffered by Jesus of Nazareth, according to the gospels (Matthew, Mark, Luke, and John) in the New Testament, and assist our eyes and brains to recognize the front and back images as being that of a crucified man. But these blood marks are not the major component of the images. The major component of the images is the gradation of shading created by the pattern of discolored fibers in the images. A typical thread in the Shroud might contain about 100 or so fibers, each having a much smaller diameter than a human hair. It is only the top one or two layers of fibers in a thread that are discolored. The discoloration is always of the same straw yellow color so that darker sections of the image are caused by greater lengths and/or a larger number of fibers being discolored. And lighter sections of the image are caused by shorter lengths and/or a smaller number of fibers being discolored. In a discolored fiber, the discoloration is only around the circumference of the fiber so that the center of the fiber is not discolored. The thickness of the discolored layer in a fiber is less than 0.4 microns, which is less than a wavelength of light. And the discoloration on a fiber is not due to anything added to the fiber, but is due to a change in the covalent bonds of some of the carbon atoms that were already in the molecules that make up the linen fiber. It is the combination of these features that cause the pattern of discolored fibers that contains the information that defines the appearance of a crucified man that we can see.

It also needs to be recognized that this information in the pattern of discolored fibers that defines the appearance of the crucified man is specified in terms of the distance of the cloth from the body as the body was wrapped in the cloth. For example, a part of the body that was very close to the cloth as it was wrapped around the body, such as the tip of the nose or the top of the hand, created a darker coloration on the cloth. And a part of the body that was further from the cloth as it was wrapped around the body, such as the back of the knees or the section of the stomach next to the arms, created a lighter coloration on the cloth. The intensity of the coloration on the Shroud falls off approximately linearly with the distance of the cloth from the body, with no coloration being registered on the Shroud for cloth-to-body distances over about 3 to 4 cm. This feature is usually referred to as the Shroud containing 3D or topographical information content related to the cloth-to-body distance, and is what allows a 3D statue to be derived from the information content in the images on the 2D Shroud.

What is the Source of This Information?

Once we realize that the information content which defines the appearance of a crucified man is on the Shroud, the next logical question is where did it come from? It must have come from some place that contained such information. It could not have come from the limestone of the tomb for the limestone did not contain the information content that defines the appearance of a crucified man. The same can be said for the air in the tomb. And such information could not have arisen in the process of manufacturing the Shroud. That leaves only one possibility. The information content on the Shroud that defines the appearance of a crucified man must have come from the body that was wrapped within it. Only the body could have contained that information content. And that information content was inherent to the body.

Consider the men in the tomb performing the burial procedure. When they looked toward the body, they would have seen a crucified man because reflected photons would have carried from his body to their eyes the information content that defines the appearance of a crucified man. This means that the information content that defines the appearance of a crucified man was inherent to the body that was wrapped in the Shroud, just as the information content that defines the appearance of my wife is inherent to my wife. So the information content that defines the appearance of a crucified man that is on the Shroud must have come from the body that was wrapped within it.

How was this Information Communicated to the Shroud?

Information can be static, i.e. without moving from one location to another location, but it can also be moved from one location to another by various means. Information often moves from one location to another location merely by the nature of our environment, for example the information content defining how something looks moves between locations because photons reflect off of objects around us. Information can also be intentionally moved from one location to another location as the result of someone's decision. In English, the word "communication" refers to the movement of information from one location to another location. There are a limited

number of ways in which information can be moved, or communicated, from one location to another location:

1. The most common way that information is communicated is by radiation, specifically by emitted and reflected photons of electromagnetic radiation. Electronic equipment can cause photons to be emitted from an antenna to communicate sound and visual images to radios and televisions. Cell phones also emit photons to communicate information related to sound and visual images. Reflected photons also communicate information continuously all around us even when we are not aware of it. Reflected photons can carry information regarding how something looks in the following ways. A photon's wavelength (or energy) communicates color. A photon's intensity (number of photons) communicates shades of dark versus light. And a photon's direction communicates the location of something in the scene being observed. For example, in looking at my wife in the kitchen, if her arm is up, then photons reflect off of her raised arm in all directions including toward my eyes. Photons reflecting off of her raised arm toward my eyes will go through the lens of my eye and fall on different rods and cones at the back of my eye than if her arm were not raised. Depending on which rods and cones the photons fall on at the back of my eye will determine whether I perceive her arm as being up or down. So my perception of the location of any object within my field of view will depend on the direction of the photons as they enter the lens of my eye, for this determines which rods and cones the photons fall on. Though photons are by far the most common form of radiation that communicates information, other forms of radiation such as particles can also communicate information through their energy, intensity, and direction. In particular, protons and electrons can readily communicate information because their electric charge, either positive for protons or negative for electrons, makes them easily detectable. An example is the flow of electrons in a cathode ray tube such as an older style television communicating the information content necessary to create the sequence of pictures in a television program. Neutrons would not readily communicate information because they are not easily detected because they have no electric charge.
2. Information can also be communicated by waves in a medium. For example, sound consists of compression waves in the air. Various kinds of waves in the soil and rock of the earth can communicate the occurrence of an earthquake. High waves on the ocean can communicate the presence of a storm out at sea.
3. Information can also be communicated through direct contact, for example when you feel something with your hands. Reading Braille by touch is another example. The information content that is created by striking a key on a piano or manual typewriter is transferred by contact through the mechanism of the piano or manual typewriter until the desired result is achieved, either a musical tone that is played or a letter being typed on a piece of paper. Information can also be transferred by direct contact with a piece of paper in the process of printing or use of a pen or pencil.
4. Information can also be communicated by a flow of particles through physical connections. For example, all of our electronics is based on information being communicated by the flow of electrons through wires. And information is communicated in our bodies mostly by the flow of electrons along our nerve cells.

5. Information can also be communicated by the diffusion of molecules in air or a liquid, though the amount of information that can be communicated by this means is limited. For example, when your nose detects the smell of ammonia or the smell of a skunk, it only indicates to you its current or former presence, and perhaps some indication of how long ago it was present. And when your taste buds detect something sweet or sour, you can only detect its presence and perhaps have some indication of its strength.

The previous section concluded that the information content that defines the appearance of a crucified man that is on the surface of the Shroud was communicated to the Shroud from the body that was wrapped within it. The above five options for how information content can be communicated from one location to another must now be considered to determine how the information content that defines the appearance of a crucified man could have been communicated from the body to the cloth.

The image of the crucified man on the Shroud is only a front and back image; there are no side images. The front and back images are high resolution images. Based on this, we can reject the above option #5 (diffusion of molecules) because molecules diffusing in the air would not produce a sharp image and it would produce side images just as readily as a front and back image. And there were no physical connections such as wires between every point of the body and every point of the Shroud so that option #4 (physical connections) can also be rejected.

As it covered the body, the burial cloth would not have been touching the body at every point where the image is located. For example, the burial cloth would have touched the tip of the nose but it would not have been touching the upper lip just below the nose, yet there is an image at that point on the Shroud. There are many locations on the Shroud image which would not have been touching the body: beside the hands and arms, under the knees, under the small of the back, etc. Because of these air gaps between the body and the Shroud, the information content could not have been transferred at every point by direct contact between the body and the cloth so that option #3 (direct contact) can also be rejected. Another reason to reject option #3 (direct contact) is that the front and back images have approximately the same intensity, whereas all the weight of the body would have been on the back side of the body. On the front side of the body, only the weight of the cloth was pressing down onto the body. So the contact with the cloth would have been much greater on the back side than the front side. Rejection of option #3 (direct contact) includes any mechanism whereby anything on the surface of a statue or a real human body that is wrapped within the Shroud causes the image. This includes paint, ink, dye, chemicals, or bacteria that could be on a statue or a body.

The only options remaining for communicating the information content from the body to the Shroud of Turin are waves in a medium (option #2) and radiation (option #1). In considering option #2 (waves in a medium), it is helpful to first understand how waves move in a medium. A medium can be a solid such as the crust of the earth, or it can be a liquid such as water, or it can be a gas such as air. If the atoms in a medium are moving perpendicular to the direction of the wave in the medium, it is called a transverse wave. If the atoms in a medium are moving back and forth parallel to the direction of the wave in the medium, it is called a longitudinal wave. In some types of waves, the atoms move in a combination of these two motions. Thus, if the wave is moving horizontally through the medium, the atoms in the medium could be moving up and

down (transverse wave), or back and forth (longitudinal wave), or a combination of the two motions such as in a circle, depending on the medium. By such movement of the atoms, energy can be transported through the medium without causing any resulting net movement of the atoms because the atoms, after the wave is past, return to their initial positions. Both transverse and longitudinal waves can travel through solids such as seismic waves in the crust of the earth after an earthquake. The combination of transverse and longitudinal waves, with motion of the atoms in circles, can also travel through liquids if the liquid has an interface with a gas such as water waves on the surface of the ocean. But a gas such as air can only transport energy through longitudinal waves, where the atoms are moving back and forth parallel to the direction of the wave. Longitudinal waves can also be called compression waves. Transverse waves, where particles move up and down perpendicularly to their direction of the wave, can not propagate in a gas because of the relatively weak connection between atoms in a gas. In other words, gases are not rigid enough to allow transverse waves to propagate.

Since the medium in any gaps between the body and the Shroud would have been air, only longitudinal (compression) waves would have been possible. Longitudinal (compression) waves in air are known as sound. Sound is not something that is easily focused. It generally spreads out rapidly. In the option under consideration (option #2, waves in a medium), sound waves would have to be produced by the body that was wrapped in the Shroud, so that they would carry the information content that defines the appearance of a crucified man from the body to the Shroud across any air gaps between the body and the Shroud. The following problems are apparent in this scenario:

1. It is not clear how sufficient information could be carried from the body to the Shroud of Turin by sound. Perhaps in some way color could be carried by the frequency of the sound, and shade (dark vs. light) could be carried by how loud the sound was, but it is hard to conceive how the location of things on the body could be communicated accurately to the Shroud because sound spreads out so rapidly. So it is hard to conceive how sound could deliver the focused energy that would be necessary to transfer the information needed to create the high resolution images that are on the Shroud.
2. There is no evidence that sound can deliver the type of energy that can discolor linen. Even very loud sounds do not discolor fabrics.
3. There are no side images on the Shroud of Turin. Since sound spreads out so rapidly, if it could cause the front and the back images, it should also have left some effect on the left and right sides of the Shroud.
4. To cause sound to emanate from the body, the surface of the body would have to vibrate to cause the compression waves in the air to carry the necessary information content from the body to the Shroud. However, there is no known mechanism that could cause the body to vibrate in such a way.
5. The sound waves that must have carried the information content from the body to the cloth in this scenario, and that must have been created by the outer surface of the body vibrating, must have started by waves being created inside the body since some of the bones that were in the body are apparently visible on the Shroud. These waves must have been transmitted within the body to acquire this information content regarding the

presence of the bones in the body so that it could then be carried to the Shroud and be deposited there. And these waves must have been traveling in only vertically up and vertically down directions to maintain the sharp resolution that can be seen on the Shroud. That waves could be created and be transported within the body in this manner does not seem to be credible.

The existence of sonograms may be raised as a counterexample to the above line of reasoning. A sonogram is an image that is created of structures such as tendons, muscles, joints, vessels and organs that are internal to a human body. One example of a sonogram is the picture of a baby inside a pregnant mother. A sonogram picture is created by the use of ultrasound emitted by a probe. Ultrasound is sound waves with frequencies which are higher than those audible to humans. Pulses of these ultra-high frequency sound waves are emitted from a probe that is placed against the skin so that the sound waves are directed into the person's body. As each pulse of sound travels into the body, the various structures inside the body reflect the sound waves to varying degrees. The probe detects these reflected sound waves and in response sends a signal to the electronic equipment. The electronic equipment, based on the speed of sound in a human body and the time between the emitted pulse and the detected echo, is designed to electronically display an image on a screen that shows the inside of the human body. But the image on the Shroud did not result from electronic equipment's interpretation of the time between an emitted pulse from a probe and the probe's detection of the resulting echo. There was no probe, no electronic equipment, and no screen. And the image created by a sonogram is not a high resolution image as exists on the Shroud. So the example of a sonogram does not prove that sound waves alone can create a high resolution image on a piece of linen.

Thus, for all of the above reasons, option #2 (waves in a medium) should be rejected as the means by which the information content that defines the appearance of a crucified man was communicated from the body to the Shroud. Only option #1 (radiation) remains as a possibility. For purposes here, two forms of radiation will be considered. The two forms of radiation are differentiated by whether or not they have mass. Radiation can consist of particles that have mass such as electrons, protons, neutrons, or other sub-atomic particles. Electrons have a negative electrical charge, protons have a positive electrical charge, and neutrons have no electrical charge. These particles are usually found in atoms where they are constrained by the particles around them. But when these particles are released from the atoms so that they can move rapidly without being constrained by other particles, they are considered to be radiation.

Radiation can also consist of photons. Photons can be simply described as packets or bundles of electromagnetic energy that travel at the speed of light (186,000 miles per second = 3.00×10^8 meters per second in a vacuum). Photons are pure energy having no mass or charge, yet having characteristics of both particles and waves. This dual nature of photons simultaneously having characteristics of both a particle as well as a wave is usually referred to as wave-particle duality. Photons of electromagnetic energy, from low energy to high energy, include long waves, radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. This entire spectrum of photons from long waves up to gamma rays is called the electromagnetic spectrum. A photon in any of these categories is only different from a photon in any other category due to its energy, which is related to the frequency and wavelength of its electromagnetic wave. More specifically, the energy of a photon is given by $E = hv$, i.e. the

energy E of a photon is equal to h times ν , where h is Planck's constant ($6.6260755 \times 10^{-34}$ Joule second) and ν is the frequency of a photon in cycles/second. The frequency of a photon ν is related to the wavelength of the photon λ by the equation $C = \nu\lambda$, i.e. the speed of light C is equal to the frequency of the photon ν times the wavelength of the photon λ . These two equations can be manipulated to calculate the energy of a photon from the wavelength of the photon ($E = hC/\lambda$), or to calculate the wavelength from the energy ($\lambda = hC/E$). When our eyes see visible light, the photons that are interacting with our eyes have a wavelength of between about 700 nanometers (700×10^{-9} meters) at the red end of the visible light spectrum down to about 400 nanometers (400×10^{-9} meters) at the blue end of the spectrum. Since the energy of a photon is inversely proportional to the photon's wavelength ($E = hC/\lambda$), the photons at the red end of the visible light spectrum have a lower energy than those at the blue end of the spectrum. The main point is that visible light is only a very small fraction of the entire electromagnetic spectrum, and that just as photons of visible light can carry information content, i.e. reflected photons informing us of our surroundings, so photons of any energy in the entire electromagnetic spectrum can carry information.

Photons can carry information regarding color, shade (dark vs. light), and location in their wavelength (energy), intensity (number), and direction. The same is true of particles such as protons and electrons. That is, particles can also carry information content regarding color, shade, and location in their energy, number, and direction.

In the above consideration of option #2 (waves in a medium), five different issues were raised as to why sound waves in air could not communicate the information content that defines the appearance of a crucified man from the body to the Shroud. These same five issues will now be considered to determine whether radiation (option #1) could communicate the necessary information content from the body to the Shroud.

1. Radiation, including photons and particles, can carry information regarding color, shade, and location making it ideal for the communication of the information that defines the appearance of a crucified man from the body to the Shroud. And whether we realize it or not, radiation is the most common means of communicating information in our culture and surroundings.
2. Experiments have proven that photons of particular energies (ultraviolet light) and certain types of particles (protons) can cause discoloration of linen that is very similar in appearance to the discoloration found on the top fibers of the threads on the Shroud. (Ref. 7 and 8)
3. There are no side images on the Shroud of Turin. This feature of the Shroud can be consistent with radiation carrying the necessary information content from the body to the Shroud because each photon or particle, apart from scattering events, would travel in a straight line. Depending on the energy of the photon or particle, there may be some scattering of the photon or particle off of the atoms of air in any gaps between the body and the Shroud and thus some loss of resolution of the image could occur, but this tendency would not be as severe as with sound waves. The best example of photons moving in a straight line with little or no tendency to spread out is a laser beam, as used to point at items on a PowerPoint slide. While it is true that light spreads out from a

tungsten bulb, it is also true that this occurs because the photons are emitted from the tungsten filament in random directions. But once a photon is emitted from a tungsten filament, it only travels in a straight path until it scatters or is absorbed by an atom. If radiation carried the necessary information content from the body to the Shroud, and if this radiation were initially emitted in only vertical directions, i.e. only vertically up and vertically down, and if the energy of the photons or particles were such as to minimize scattering off of the air in the gaps, then a sharp image of the front of the man could be formed on the bottom of the cloth above him and a sharp image of the back of the man could be formed on the top of the cloth below him, with no side images on the inside of the burial cloth. This is exactly what we see on the Shroud. It should be noted that some hypothesize that this requirement for verticality in the image formation process involved the vertical collapse of the burial cloth instead of, or along with the vertical orientation of the radiation emitted by the body.

It is recognized that in general, the laws of physics require that photons be emitted with equal probability in all directions, such as when photons are emitted from a tungsten bulb. But under specialized conditions such as in a laser, photons can be emitted coherently, which means that all of the photons are initially emitted in the same direction with the same frequency with all photons in phase with each other so that there is no tendency for them to spread out. We should realize that the Shroud of Turin, where a dead body has created an image of itself on the burial cloth in which it was wrapped, must be the result of a totally unique cause. Specifically, the event which caused the encoding of the image on the Shroud must be outside or beyond our current understanding of the laws of physics. Experiments indicate that discoloration on a piece of linen that is similar to the discoloration on the Shroud can be caused by multiple pulses with an ArF excimer laser (Ref. 7) provided that the duration of the radiation pulses are about 12 nanoseconds (one nanosecond = 10^{-9} second = a billionth of a second). So the image encoding event in which the dead body emits radiation and forms an image of itself on the inside of the burial cloth in which it is wrapped can be an extremely short duration event, e.g. only a very small fraction of a second during which the phenomenon is outside or beyond the bound of our current understanding of the laws of physics. Always in the past, when a new phenomenon was encountered which was not covered by the laws of physics as then stated, science has been sufficiently flexible to modify the laws of physics to take into account the new phenomenon. But in this case, even if it is not possible at the present time to repeat this new phenomenon (the mechanism that causes the radiation emission from the body to encode the image on the cloth) in the laboratory, this impossibility should not imply in our thinking that the one-time occurrence of the phenomenon is not possible. The advantage of this approach is that it allows us to follow the scientific evidence where it leads, rather than forcing the scientific evidence to be reinterpreted to be consistent with our naturalistic presuppositions.

A presupposition is an assumption that is made before the investigation begins, and is thus not the result of the evidence that is found in the investigation. The potential problem with a presupposition is that it can rule out possible explanations before the investigation even begins, thus forcing the evidence to be misinterpreted in order to force it to be consistent with the presupposition. An example of this would be a detective investigating a murder scene who makes a presupposition, for political and career

purposes, that the murderer could not possibly be related to the mayor's office or the police department. This presupposition would automatically exclude certain individuals from even being considered as the murderer, and could thus force forensic evidence collected from the murder scene to be misinterpreted in order to reconcile the evidence with the presupposition that no one related to the mayor's office or the police department could be the murderer. In a scientific investigation, a naturalistic presupposition, often called a presupposition of naturalism, is an assumption made before the investigation begins that only explanations consistent with our current understanding of the laws of science will be considered. Though this presupposition is common in our culture, there are several problems with it in regards to the many mysteries related to the Shroud of Turin:

- Radiation being emitted from within the volume of a body which encodes an image of the body onto a piece of cloth, as has evidently occurred with the Shroud of Turin, is beyond our current understanding of the laws of physics. This contradicts a presupposition of naturalism.
- From the beginning of the scientific investigation of the Shroud in 1898, well over a century has elapsed. During this time, a large fraction of those researching the Shroud have been doing their research under the constraints of a presupposition of naturalism. And during this time, the mysteries of the Shroud have not been solved within these constraints. Perhaps it is time that we realize that the problem is overly constrained by such a presupposition, so that it is unlikely that the mysteries of the Shroud will be solved within the constraints of naturalism. We need to follow the scientific evidence where it leads so that the truth will be determined from the evidence, apart from presuppositions.
- Our current understanding of the laws of science has developed over many centuries. It is not reasonable for us to believe that they are now so perfectly known and stated that they can not change in the future. There will undoubtedly be new phenomena discovered that will require changes in our current understanding of the laws of science, even perhaps major changes. A dead body emitting radiation which creates an image of itself on a piece of cloth may be regarded as just such a "new phenomena."
- There are many areas of modern physics which appear to present intractable problems, which are not solved by our current laws of physics. This suggests that our current laws of physics are not perfect or complete.

Thus, we should allow for thinking "outside the box" of the constraints of our current understanding of the laws of science, so that we can follow the scientific evidence where it leads, specifically allowing vertically oriented radiation to be emitted from within the volume of the body of the man wrapped in the Shroud.

4. Is it possible for radiation to be emitted from the dead body that was wrapped in the Shroud of Turin? When we ask this question, we are not referring to the minute amount of radiation that is commonly emitted from every human body due to the radioactive decay of certain isotopes that are naturally present. We are referring to a very brief pulse of radiation that is intense enough to burn an image into linen. With this understanding of the question, and under normal conditions, we all agree that the answer to this question

is no, because we have no evidence that such a burst of radiation has ever been emitted from any other dead body. But we are very possibly not “under normal conditions” in this case. Based on the image on the Shroud being that of a naked man that was crucified exactly as the gospels in the New Testament say that Jesus was crucified, the most obvious question regarding his identification is whether this could be an image of Jesus of Nazareth, so the Biblical account should be considered. Jesus claimed (Mt. 26:63-64, 27:40-43, Luke 22:70, John 5:17-25, 10:36, 11:4, 19:7) and many others agreed (Mt. 4:3, 8:29, 16:16, 27:54, Mk. 1:1, 3:11, Luke 1:35, 4:41, John 1:34, 1:49, 3:18, 11:27, 19:7, 20:31, Acts 8:37, 9:20, Rom. 1:4, 2 Cor. 1:19, Heb.4:14, 1 John 5:5, 13) that Jesus was the “Son of God”, the Messiah foretold in the Hebrew Old Testament. The term “Son of God” is consistent with statements in the Old Testament regarding the deity of the Messiah (Ps. 110:1, Isaiah 9:6-7, 25:9, Jer. 23:5-6, Micah 5:2, Zech. 12:8-10) and is consistent with who his followers believed him to be (John 1:1 & 14, 14:9, 10:30-33). The word Messiah is a title which refers to the one anointed to be King (Dan. 9:25-26, Mt. 2:2, 27:42, Mk. 1:32, John 1:49, 12:13) during the future millennial kingdom (Dan. 2:34-35, 44, Luke 1:30-33, Rev. 20:2-7). The equivalent term, with the same meaning, in the Greek New Testament is the word “Christ” (John 1:41) which Jesus was called many times. So according to the Biblical account, and the use of these terms, Jesus was a totally unique individual. According to the Biblical account, he told his disciples many times that he would rise from the dead (Matt. 12:39-40, 16:4, 21, 17:23, 20:19, 26:32, 27:40, 63, Mark 8:31, 9:9, Luke 9:22, 24:6-7, John 2:19-22), though their expectations of the Messiah would not permit them to interpret his statements literally. And the empty tomb (Mt. 28:6, 12, Mk. 16:5-6, Luke 24:1-7, John 20:1-9) and the ten post-resurrection appearances (Mt. 28:9-10, 16-20, Luke 24:13-32, 36-49, John 20:11-21:25, Acts 1:3-12, 1 Cor. 15:3-7) are used to argue for the truth of Jesus’ resurrection. But if the Biblical account is to be taken at face value, so that Jesus was actually resurrected, then this would have been a totally unique event, and we would have no basis to rule out other totally unique events associated with it, such as radiation being emitted from within the volume of the body. Therefore, in this case, we conclude that we should allow for the possibility that radiation was emitted from the body while it was wrapped in the Shroud even though we may not know the specific mechanism involved. How Jesus’ body disappeared from within the Shroud while it was in the tomb, with the possibility of radiation being emitted at the same time, is discussed further in Ref. 9.

5. Since some of the bones that were in the body are apparently visible on the Shroud, the radiation must have been emitted from within the body to acquire this information from the bones so that it could then be carried to and deposited on the Shroud. This is not a problem for radiation, since radiation starting within the body could have been partially absorbed or scattered by the bones before the radiation exited from the body. And if the radiation was thus altered by the bones, the radiation could carry the information related to the presence of the bones from the body to the Shroud. And when the radiation was absorbed on the cloth, it would essentially deposit the information content regarding the presence of the bones onto the cloth.

In all of the above five considerations, it was found that radiation can explain how the information that defines the appearance of the crucified man could be communicated from the body to the Shroud. The other four concepts for transferring information (options #2 to #5:

waves in a medium, direct contact, physical connections, and diffusion of molecules) were all found to be inadequate. Only radiation (photons and/or particles) can carry the necessary information content from the body to the Shroud, and deposit it onto the cloth.

Radiation Explains Other Characteristics of the Shroud

It should also be added that the mechanism being advocated here, that of vertically oriented radiation emitted from within the body while it was wrapped in the Shroud, not only explains how the information content that defines the appearance of the crucified man can be communicated from the body to the Shroud but can also explain many other features of the image on the Shroud of Turin (Ref. 1 to 6), such as 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. This feature of the Shroud is consistent with the images being caused by (and information being transferred by) radiation emitted from within the volume of the body with the intensity of the radiation diminishing as it passes across the gap between the body and the cloth by one or a combination of the following: decay, absorption, or scattering.
- The image is not due to foreign materials such as particulates 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.
- The image is due to discoloration of only the top one or two fibers in a thread. In a discolored fiber, the discoloration extends around 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, so the thickness is less than a wavelength of light.
- Where one thread crosses over another thread, there is a white spot, or shadow, on the underlying thread as though the top thread has protected or shielded the underlying thread from something, e.g. photons or particles, which flowed 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 are encoded in the image.
- The intensity of the image is approximately the same on the front and back images, in spite of the fact that the weight of the body was entirely on the back side.
- 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. This indicates that the discoloration was not caused by a liquid.

- 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 that 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.

It should also be noted that some previous attempts to prove that radiation had nothing to do with formation of the image on the Shroud, upon review were found to be based on inadequate evidence (Ref. 10).

Conclusions

Among all of the billions of people that have ever lived, the Shroud of Turin is the only known occurrence of a body encoding an image of itself onto a piece of cloth. If we allow ourselves to follow the scientific evidence where it leads rather than being constrained by naturalistic presuppositions, then the evidence leads us to the following conclusions:

1. We can see the front and back images of a crucified man on the Shroud because the information content that defines the appearance of a crucified man is located in the pattern of discolored fibers on the tops of the threads in the image on the Shroud.
2. This information content in the pattern of discolored fibers in the Shroud could only have been transported to the Shroud from the body that was wrapped in the Shroud. It could not have come from the limestone of the tomb, or from the air in the tomb, or from the manufacturing process that made the Shroud.
3. Radiation consisting of particles and/or photons must have carried this information content from the body to the Shroud, across any air gaps between the two. The other possible mechanisms for communicating information content from one location to another location (waves in a medium, direct contact, a flow of particles through physical connections, and diffusion of molecules) must be rejected for the Shroud of Turin.
4. Since radiation must have deposited this information content on the Shroud in the pattern of the discolored fibers that make up the image on it, the process of depositing this information content onto the Shroud must have discolored the fibers, thus forming the image. So the image on the Shroud was caused by the radiation. In other words, the image is a radiation burn. The radiation not only delivered the necessary information to the Shroud, but also sufficient energy to cause the discoloration on the fibers, possible by a corona discharge.
5. The radiation must have been emitted from within the body in precise vertical directions, both vertically up and vertically down, to produce the high resolution front and back image without any side images, that also encoded the presence of bones near the surface of the body into the images on the Shroud.

Human bodies, whether living or dead, have never encoded a high resolution image of themselves onto any piece of cloth, with the Shroud of Turin being the only exception. The

uniqueness of this image on the Shroud indicates that it must have been formed by a unique process. This paper has argued that this unique process must have involved the release of vertically oriented radiation from within the dead body that was wrapped within the Shroud. Radiation is the only option that could carry the necessary information from the body to the Shroud, and deposit it on the cloth, in order to encode the image of the body onto the Shroud. Thus, the image encoding mechanism could not be a naturalistic process - defined as a process that is consistent with our current understanding of the laws of physics. A dead body emitting vertically collimated radiation from within the body is beyond our current understanding of the laws of physics. This is why all attempts to reproduce the image have failed in the past and will certainly fail in the future.

So how is the uniqueness of this event to be understood? Since the image of the man on the Shroud of Turin indicates that he was crucified exactly as the gospels in the New Testament say that Jesus was crucified, the most reasonable explanation, if we allow ourselves to not be constrained by naturalistic presuppositions, is that this unique image encoding event is the result of a unique individual (Jesus of Nazareth) going through a unique event, such as the disappearance of his body from within the Shroud as it lay in the tomb. Since this event must be outside of our current understanding of the laws of physics, we have no basis for rejecting the possibility of vertically collimated radiation being emitted from his dead body in such a unique event. How this unique event could have physically occurred is discussed in Ref. 9.

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