**THE SHROUD OF TURIN FROM THE VIEWPOINT OF THE PHYSICAL SCIENCES**


The study of the linen cloth known as the Turin Shroud can encompass such diverse aspects as its connections with artistic works produced through the centuries, the textile description of the cloth itself, the medical analysis of blood stains, the historical reconstruction of the possible paths that took it to France, the origin of the multiple wounds recognizable on it, the archaeological information contained in its image, the age of the cloth and the possible processes of image formation. Many researchers, specialized in each one of the sciences and techniques suitable for each study, have dealt in many occasions with those multiple aspects, presenting their conclusions with the full weight of evidence and the exacting rigor that is expected of work that is submitted to the critique of professionals of comparable standing. My appreciation and respect are happily given to so many honest and capable efforts, no matter where they have been carried out.

I am not fortunate enough to be counted among the reduced number of those who have had direct access to the Turin cloth or to samples taken from it for laboratory analysis; I do feel happy for having had the opportunity to speak directly with some of those who have performed such work, and I have read a large number of reports on the subject. As a physicist, I am especially interested in two problems which, whatever might be said of other questions, need to be treated and solved within the methodology and from the knowledge proper of the field of Physics: the radiocarbon dating of the Shroud by means of C 14, and the processes proposed to explain the formation and characteristics of the image found on the cloth. In this paper I will limit myself to these two points, and I will deal with them in a systematic way, always keeping in mind that we have to account for facts, and that the physical sciences are ultimately defined by the necessary check of any theory against the real and observable behavior of matter.

## I - RADIOCARBON DATING OF THE TURIN CLOTH

It is widely known that in 1988 spokesmen for three different laboratories jointly announced that the measurements of C 14 applied to samples from the Turin cloth indicated its age as corresponding to the 14th century, roughly the time period when historical information establishes its presence in France. The immediate reaction in the world press, and even in Church circles, was to consider that there was nothing more to be said, and that any connection of the cloth with the historical events of the crucifixion and burial of Christ, fourteen centuries earlier, had to be completely dismissed.

With just this one negative piece of data, even if clothed in the prestigious aura of modern nuclear science, all the work done before by dozens of experts in many fields was discarded as worthless. Their clear convergence towards an answer that points to the archaeological authenticity of the cloth was ignored or ridiculed. Without answering any of the obvious questions regarding the total lack of medical or historical knowledge in the Middle Ages that could justify the existence of an imprint that shocks and puzzles with the exactness of its anatomical, pathological and cultural details, and without proposing any credible method to explain the presence of the unique image found on the cloth, the inquiry was considered closed. At best, some lukewarm references were made to its symbolic value as a peculiar *icon*; at worst, it was taken as one more proof of the mindless credulity or interested opportunism of those who venerated the Shroud through the centuries.

As a physicist, I feel that the reaction was premature and exaggerated. It certainly isn't the first time, and it will not be the last, that a piece of discordant data causes perplexity during some time even in the most careful and respected kind of work. We might recall that a century ago

the age of the Sun, computed through the knowledge available at the time for processes of energy production, was totally incompatible with the age of the Earth inferred from Geology, which showed the presence of fossils at times much earlier than the age obtained for our star. The age inferred from Hubble's data for the Universe itself was also inferior to the age of rocks in our planet, and today we have faced a similar problem when the estimate of the age of the oldest stars in globular clusters seemed to predate the Big Bang. In each case it became necessary to re-calibrate the dating methods, or to enlarge the physical framework within which an explanation could be sought.

What nobody thought of doing was to discard or consider without value any of the scientific data that seemed to be in conflict. The same reaction was observed when particle physicists seemed to find a violation of the conservation law for mass and energy (a problem which led to the prediction and discovery of the neutrino), or in our own time, when the shortage of solar neutrinos is forcing a far reaching revision of our theories of the properties of elementary particles.

Science goes forward by facing problems, not denying them. Because he could go beyond *common sense*, Einstein gave us the Theory of Relativity. Quantum Mechanics, with its impressive successes, still defies all our ideas of reality and of the way matter *must* behave, to the point that respected authors of textbooks advise the students not to waste their efforts asking how things can really be so. In fact, we should always fear that the simplifying assumptions needed to solve many problems would give us the false impression that we have taken into account all the important factors.

In the case of radiocarbon dating by C14 it is well known that, not infrequently, unexplained and discordant values have been obtained (about 20% of the dates), and archaeologists will dismiss them when there is clear evidence for a particular object as due to a known culture or historical period. It isn't always possible to find a satisfactory explanation for the discrepancy, but one cannot dismiss other sources of evidence out of hand. It is worth noting in this regard that dating laboratories require from their clients all the available information about the source of the material to be dated, something really surprising from the viewpoint of scientific objectivity, and that seems to cast a suspicion over the expected reliability of the method in the views of its practitioners.

A single sample is never sufficient for experimental certainty, especially when dealing with material that is far from uniform in its present state, due to handling, repairs, storage under unknown conditions and so on. Since dating depends upon a measurement of radioactive atoms that form a minute percentage of the material, one needs to know the original abundance, the possible sources of contamination and their relative importance, the effectiveness of cleaning procedures, and the final amount to be actually measured as a function of age. It is not automatically certain that all those steps are always followed without errors.

A simple but extreme example will clarify these remarks. If a piece of a green branch is dated by the C14 method, it is obvious that we should get a zero age for the sample, since the tree is still alive when the branch is cut from it. If the C14 method indicates that the branch is thousands of years old, we will have to look for a reason for this erroneous date, but nobody will deny that the branch was alive just before the experiment. In this case, the most probable cause is the environment where the tree was growing: near a heavily used highway, most of the Carbon dioxide in the atmosphere will be from the exhausts of motor vehicles, which burn fossil fuels totally devoid of the original C14, thus leading to a lack of this radioactive element and to the inference of old age. The opposite effect can occur if modern carbon compounds were to contaminate the original sample.

The Turin cloth was analyzed utilizing *a single small piece from the edge* of the Shroud, where some repair work was done in recent times (during the last 4 centuries) and where there could easily be material that was added to the original cloth (**Please see the final note at the end of this paper**). It might be now impossible to tell for sure if this was the case: the sample is destroyed in the dating process, and nearby material might suggest contamination or the lack of it, but it cannot constitute a proof. There is an obvious need to obtain samples from several points in the cloth, from areas that are totally free of possible additions, far from the patches that cover the burns due to the 1532 fire as well as other earlier burns that are clearly identifiable.

Contact with other materials can also be a source of modern C14. One of the most important steps in preparing the samples for dating is the cleaning process, which should be done with organic and inorganic solvents that will not react with the cellulose in the linen fibers, but will remove or destroy anything that adheres to them. We can only suppose that this was correctly done in this case, and that no extraneous material was burned with the linen fibers to produce the $CO_2$ that went into the mass spectrometer.

This thorough cleaning cannot be automatically assumed: it needs to be checked even at the microscopic level. And there is, in principle, the possibility that some type of external contaminant might resist the solvents used, or that some chemical reaction might introduce modern C14 into the cellulose, in such a way that it becomes permanently part of it and it cannot be distinguished from the original material. Both sources of error have been suggested in the case of the Shroud, even if we cannot objectively judge the possible importance of those effects without direct access to the data of the researchers who have pointed them out[1]. But it is surprising that the original report in the magazine *Nature* states that the same C14 content was found in samples that were subjected to a very thorough cleaning and in others that were left in their original condition, in spite of the fact that the cloth is quite dirty after centuries of handling and exposure to smoke, water and various other contaminants[2].

It has been suggested that the linen plant concentrates the C14 isotope preferentially in the cellulose fibers that are used to make the thread for the linen cloth. If this were really so, all dates obtained for linen cloths would be in error; in fact, present day linen would appear to belong to a future date. I am not aware that this effect has ever been reported in the scientific literature. I have no knowledge either of any study that might identify different linen varieties and their possible differences in this selective process, nor of any study of the effects that the chemical composition of the soil or the environment might have; *as far as I know, ancient linen has been dated without a problem in other cases*.

Another factor, applicable only to the Turin cloth, could have an impact on the composition of the threads according to Dr. Jackson: the 1532 fire. Under conditions of lack of Oxygen and at temperatures of hundreds of degrees, the wood making the box suffers a chemical decomposition which liberates active products -especially Carbon Monoxide- capable of affecting the cellulose of the linen threads, thus adding extra C14 of modern origin to the sample to be dated. The theory is, in principle, plausible. To really establish its validity, it would be necessary to perform a carefully controlled series of experiments, preferably in independent laboratories, whose results should be published in refereed journals*; this has not been done, to my knowledge*. It does not appear too difficult to duplicate the conditions of the 1532 fire, and the final criterion for any scientific hypothesis is the experimental check.

After dealing with proposed explanations based upon natural and reproducible processes, we should also mention and examine other hypotheses which have recourse to something of an exceptional nature, not verifiable by any new experiment, and generally tied to a supposed method of image formation in some supernatural event. In some way, the ideas advanced suggest that *whatever unknown physical cause imprinted the image on the cloth, with some*

*type of energy, could also be responsible for a change at the atomic level that would enhance the contents of C14.*

The first logical reaction to this viewpoint is one of scepticism: it certainly seems rather odd that such supernatural event would lead to a change in the apparent date of the cloth to bring it *into coincidence with the century when the historical record is quite evident*. Is this by chance? If we think that the image on the Shroud is due to divine intervention, aimed at giving us a motive of belief in Christ's Resurrection, it seems totally illogical to weaken the value of the proof by casting doubts on its authenticity with a wrong age which is determined by scientific tests. On the other hand, if the excess C14 is due to some known or plausible physical process, what is its nature?

As the second part of this paper will show, it is common to attribute the image to some type of *radiation*. Current scientific knowledge does not accept any kind of electromagnetic radiation that will increase the number of neutrons in a C12 or C13 nucleus. If we assume an unknown process that will locally change atmospheric N14 into C14, there is no reason why the excess C14 would be chemically combined with the cellulose of the linen cloth; a simple superficial adherence would not suffice to change the nature of the samples which undergo a thorough cleaning.

Still less plausible is a hypothesis that has recourse to a supposed *weak dematerialization* of the human body at the moment of the resurrection[3], such that atomic nuclei would be unbound and the component particles would be free to interact introducing extra neutrons in the C12 present in the linen. The source of C14 in organic materials is the impact of cosmic rays upon the N14 of our atmosphere, not upon C12. Any reaction of 2 free neutrons with a C12 nucleus is rather unlikely, and their energy would need to be very accurately controlled.

From the viewpoint of the forces that hold the nucleus together, a very obvious objection can be formulated against any such *dematerialization* that pulls the particles apart. All nuclei heavier than H are the result of nuclear synthesis, with the liberation of energy from He to Fe. The total energy produced in the reactions that give rise to the C, N, O, Ca, that constitute 34% of the mass of a typical human body, is approximately 1% of the initial mass. This means that, beginning with pure H, the preparation of a 75 kg body requires that about 500 g of mass be changed into pure energy, according to the famous equation of Einstein, $E = mc^2$. This same amount of energy will be needed to undo the process and liberate the particles now bound in the heavy nuclei; this is the energy of a 10 Megaton nuclear bomb, about $50 \times 10^{15}$ joules. Nothing is said about the source of so much energy, or about the way to channel it exclusively into the splitting of body atoms, without destroying or drastically affecting all objects in the immediate surroundings. No reason is given for the behavior of the liberated particles to give the effect to be explained[4].

If the image is credited to low energy X-rays supposedly emitted during the weak dematerialization we have, once more, something quite unlikely in Physics. X-rays are produced in processes where an excess energy is liberated, not when energy must be supplied, as in the case at hand. In the second part of this study it will be shown that no radiation, transmitted through space according to physical laws, can explain the properties of the image. Nor is there any experimental basis to say that the radiation would have the exact wavelength to affect only the surface of the linen fibrils, without penetration, causing only the slight yellowish color of the image[5].

Summing up the present discussion: if we accept the radiocarbon results for the age of the cloth as obtained with professional expertise and honesty (even if there were well known methodological shortcomings) we must look for a plausible explanation for the disagreement with the age inferred from every other study of the Shroud. It will be very worthwhile to pursue the studies dealing with microorganisms or effects of the 1532 fire, all of which should

quantitatively establish the limits of such contamination and its effect upon the radiocarbon age. Other sources of C14 enrichment that have been proposed are quite unacceptable from the viewpoint of the physical processes involved and of their secondary effects (not to mention the philosophical or theological objections).

**NOTE: Please see the final appendix on Dr. Rogers' analysis of the dated cloth**.

## II - THE SHROUD IMAGE: PHYSICAL PROCESSES

Even if the Turin Shroud were of no interest for religious, historical or archaeological reasons, its very existence as *an object with a peculiar image* would stir our scientific curiosity. What explanation can be given to account for the formation of an image that is *the only one* of its kind known so far in the history of world art and technology, and that *we cannot reproduce* with all the knowledge available at the end of the 20th century? We cannot simply ignore something that we don't understand, but that quite clearly exists: we are not dealing with vague legends -like those regarding the Loch Ness monster- nor with something like UFOs, reported only by testimonies more or less consistent or trustworthy, but with no clear physical evidence. *This is an object, tangible and visible, to be studied in a lab.*

It cannot be considered an honest reaction to it to lump it together with so called *absurd relics*, to dismiss the whole list as unworthy of serious study, mentioning only the most obvious fakes or plainly ridiculous items, and concluding that this object deserves the same treatment. Whatever the merits or demerits of other relics, *they have no logical bearing* upon the fact that this image defies explanation: only the discovery of *other images comparable to it* would provide a basis for establishing its lack of special interest.

It is well known that only the Turin Shroud has been the object of scientific study for the last 100 years, with specialists in Medicine, Chemistry, Botany, Physics and Archaeology contributing to its detailed knowledge ever since Secondo Pia, in 1898, obtained the first photographs that startled the world with the discovery of the majestic face that nobody had suspected was hidden in the slight yellowish stains of that cloth. This interest, shown by serious scientists, is due to the uniqueness of the Shroud, without parallel in any museum or in any catalogue of strange objects, not only because of its possible origin and significance, but *because of the physical reality* that we observe.

Physics is the science that purports to provide an explanation and understanding of matter and its behavior. It is, therefore, proper of Physics to study this piece of linen cloth: perhaps in doing so we might find new knowledge, not only of a historical or theological interest, but *possibly of some new type of activity or property of matter itself*. The study should begin with an accurate and exhaustive listing of *all available data*, without omitting any, no matter how strange it might appear.

The image on the Turin Shroud, in a summary of its description, based on the multiple scientific studies that have been published through the years and have never been seriously challenged or disproved, has the following characteristics[6]:

- It is formed by a weak yellowish stain, visible clearly only from a distance of about 2 meters or more, that shows a double view -front and back- of a naked human body, covered with multiple wounds, that have also left blood stains on the cloth.
- There is no image of the top of the head nor of the sides of the body.
- The human figure, especially the face, is anatomically accurate, *without clear distortions*.
- There is a perfect congruence of the front and back images, obviously implying that a 3-dimensional body was wrapped in the cloth.

- The stains have *some* properties of a *photographic negative*: only when photographed in 1898 by Secondo Pia it became possible to really appreciate the information contained in the image.
- While in a photograph, be it positive or negative, *there is no correlation between density of the imprint and distance to the objec*t, the image on the cloth appears more intense in the areas where the *vertical distance to the body* would logically be shorter. This allows the use of a simple mathematical function to recover the 3-dimensional quality of the body (something that *cannot be done with any ordinary painting or photograph*, even if the "bas-relief" process is used in the darkroom).
- Fine detail, *down to millimeter size*, can be observed with contrast enhancing techniques. This is especially surprising in the case of a small coin visible on the right eyelid.
- There is *no added pigment, solid or with binding medium, on the surface* of the linen fibers, nor in their inside, even under microscopic examination. Nor is there any fluorescence that would imply the presence of foreign substances in the image areas.
- There is no change in the linen fibers themselves (no dehydration or chemical alteration *of the cellulose*). The color seems to reside exclusively in a thin layer covering the fibrils that make up each linen fiber, as if some surface impurity were affected by the image process, which did not change the cellulose itself. Next to a colored thread, one can find another thread without image color, implying that the threads reacted differently to the image-producing stimulus. The color layer can be dissolved with diimide.
- There is *no image under dried blood crusts*: the image seems to have been formed after the crusts, unless the crust pulls the color layer when disturbed.
- The spectral signature of the yellowish image stains is similar (*but not identical*) to that of the burns caused on the cloth by the 1532 fire.
- The image was *not affected* by the high temperature or the water from the 1532 fire.
- Of *possible interest*: there *seem to be* images of teeth and bone structures in the face, as well as indications of the finger bones all the way to the wrist, and of a hidden thumb[7].

It is now necessary to account for *all these characteristics* in terms of a suitable image formation process. We will review the proposed answers to discuss their respective strengths.

## POSSIBLE EXPLANATIONS OR HYPOTHESES

To systematically cover the different solutions proposed as possible, it will be methodologically helpful to describe *mutually exclusive* hypotheses. First of all, we should discuss the image formation methods where the cause and effect is known, so that the image might, *in principle*, be duplicated in a modern experiment:

- The image could be the *artificial* result of some artist's work, done in the 14th century or before, by means of some suitable technique of painting, primitive photography, or scorching of the cloth.

- If this hypothesis is unsatisfactory, the image might be due to a simple contact of a corpse with the cloth, *without extraneous human intervention*, so that with the passage of time the substances transferred to the cloth would produce de stains that are now visible.

If we find that those known processes fail to explain the image, it will be necessary to propose some new phenomenon, *not reproducible at will*, where the corpse directly affects the cloth:

- *Without contact*, by means of corpuscular or electromagnetic radiation of some kind.
- *With simultaneous or successive contact*, joined with some kind of heat energy or equivalent that will directly alter the color of the cloth or enhance a chemical coloring process.

These two possibilities might imply *some new cause*, unknown to science, if there is no reason to attribute to a *normal human corpse* the capability of producing those effects and if

those effects cannot be reproduced in a laboratory. The need for such cause is not something that science never faces: the very existence of the Universe and the initial choice of parameters cannot be explained within the confines of scientific methodology, which only deals with the development of matter *from given initial conditions and the activity of known forces* according to proven laws. But the Universe exists, and its coming into existence, and its initial parameters, require some explanation beyond physics.

If strict logic requires us to discard explanations of an *artificial or known natural* type for the Turin image, it will be necessary to *keep an open mind* to the possibility of some supernatural event related to it. But even in this case, it would be useful to search for some *indication of the process* which could explain the image that we observe.

**II a - CAN THE TURIN IMAGE BE DUE TO HUMAN TECHNIQUES?**

It is still frequent to find, especially in popular reports, the assertion that the image of the Shroud is a medieval *painting*. This explanation is just absurd on the part of anybody who might claim to have objectively studied the Shroud. Without going into detailed arguments of a cultural nature[8] (*even if they are important and irrefutable*) the fact that there is *no pigment* of any kind absorbed by the fibers of the linen cloth, nor any colorant powder among them, *even when examined under the microscope*, renders such a hypothesis simply untenable. Neither oils, nor tempera or watercolors, nor any solid powder have been used on the cloth. Even sceptics with regard to the authenticity of the Shroud confess that the image is not a painting[9].

When the cloth underwent the high temperatures of the 1532 fire, sufficient to melt part of the metal box, there was *no change in the image*, nor was it diluted or washed out by the water thrown upon the burning relic, *as would be expected if the image were composed of organic pigments or binders.* It is clear that we cannot speak of a painting without some colorant material and some vehicle to apply it to the cloth. Whoever claims that this is the proper explanation should *produce a similar image with identical properties*, even under the microscope. Nobody has succeeded in doing so.

It is worth adding that when capable artists have tried to copy the Shroud (of course, using paints that are clearly identifiable) they have only produced very poor imitations, which bear no comparison in the degree of anatomical detail, freedom of distortions and -most obviously- their total lack of a three-dimensional quality under electronic reconstruction.

Since the Turin image is practically *invisible when observed in close-up*, no painter would have been able to work directly on the cloth. And no medieval painter could have foreseen the effect of using photography five centuries later *to discover the effect of something painted as a negative*. We should remember the surprise and impact of the discovery in 1898 of the positive image, unsuspected and of a marvellous beauty, but hidden until then.

In an effort to explain how some kind of artistic method could have produced the 3-dimensional effect of the Turin image, other solutions have been offered:

Nickell managed to superficially imitate the effect by using a cotton wad, loaded with a dry brown powder, to produce a *rubbing* on a cloth applied to a suitable *bas relief*, just as one can produce an image of a coin or a tombstone by using graphite powder on a flexible paper applied to it. There was no attempt on his part to obtain the permanence, fine detail or spectral reflectivity that we find in the Shroud image, *nor was the cloth submitted to a microscopic exam* to detect the powder caught in the linen fibers. Clearly the whole affair managed only to achieve the notoriety typical of popular magazines or other mass media without any scientific standing: looking at the results *from far away*, with the naked eye, it is similar to what one sees in the Turin cloth[10].

More surprising and arbitrary still are some imitations of the Shroud based on presumed photographic processes, totally lacking any historical support, which are attributed to unknown artists of the 14th century. It has been proposed that Leonardo da Vinci invented photography and produced in the Shroud a self portrait, without paying attention to the fact that the Turin image is well documented a century before da Vinci was born (1452), and that no evidence whatsoever exists of any photograph until the mid-19th century.

From a physical viewpoint it is enough to point out that any photographic process, ancient or modern, *requires sensitizing the material with some liquid coating*, that will remain on the cloth, and penetrate its fibers: the image will not reside *exclusively* on the very surface of each dry linen fibril. None of those supposed reproductions has been subjected to fire and water, *nor do they show any 3-D properties*, just as modern photographs don't, even when made with the best lenses and sensitive emulsions. It is impossible to obtain 3-dimensionality in a single image, obtained from a single viewpoint, when only the varying *reflectivity* of the subject is the cause of the play of light and dark, without any relationship to its *distance* to the camera. The hypothesis also ignores the fact that there is no image visible when the blood crusts are lifted in the image areas of the Turin cloth: the crusts would have to be present before the image was formed or would have to be painted on destroying the color underneath. Once more, there is a total disregard for scientific logic in comparing the object to be explained and the results of the supposed process.

Among all the proposed methods to duplicate the Turin image, the one which seems closest to achieving success is the *scorching* of the linen cloth by contact with a suitably hot metallic relief. If the temperature, pressure, degree of relief and time of contact are *carefully adjusted*, it is possible to obtain –as has been done with *small objects*- a superficial burn, more intense where the contact is closer, so that a negative image is produced and a 3-D positive can be later made photographically. But a more careful analysis of the method immediately brings to our attention a multitude of problems.

First, we need to accept the existence of a *totally unknown artist*, who, with an expertise and genius never surpassed, was able in the 1300s to produce a life-size relief, anatomically correct and with perfect correspondence of front and back. We then need to explain how this person, without access to *any medical or archaeological knowledge*, exactly reproduced the types of wounds of a Roman *flagrum* and of nails and spear proper of a Roman execution, even to the point of making the wounds through the wrists, *where nobody would accept them at that time*. Then, the cloth would be required to briefly touch, *with the same pressure*, both sides of the metal relief. Nowhere could the contact be long enough to cause a burn *even through a single thread*, but different tones had to be produced so as to give the 3-dimensional effect. The temperature and time had to be exactly controlled to avoid the *changes in the blood stains* if the blood -*both vital and post mortem flows, venous and arterial*, on the exact points where it would be expected from a crucified victim- was already in place, or the blood would be added on top of the image, that should still be present underneath.

Without contact, no detail would be imprinted; even with careful control, it is practically impossible that something as small as an inscription in a little coin (from Pilate!) would be registered. The physical constraints, even without the cultural and medical requirements, unknown in the Middle Ages, render the whole enterprise impossible in practice in our own time. No wonder that *an image of a whole human body imprinted by this method has never been presented for inspection*, even if popular accounts of similar images of a *small medal* make the whole problem appear to be solved. Naturally, such “proofs” are never subjected to a scientific evaluation, even without discussing a deeper analysis of spectral reflectance or simply the degree of detail of the image.

No other alternative methods have been presented to explain the Turin image, either in a detailed proposal in a scientific paper or with a physical sample showing that the process actually works. *The Shroud image cannot be attributed to any known technology*[11].

## II b - NON-ARTIFICIAL EXPLANATIONS: KNOWN PROCESSES

The alternative artificial-natural has forced us to critically look for some way to produce the Turin image without recourse to human technology. And the first answer, which seemed obvious already a century ago, involves the *contact of a real human corpse with the cloth*, so that the resulting stains will automatically show an image of the entire body surface. Since the cloth is a single piece, which wrapped the body from head to toe, front and back, the double image is to be expected, with perfect correspondence of both imprints. Such contact is also logically required to explain the presence of blood stains, while *the blood itself should prevent an image from forming* where it covers the cloth.

People who deny the authenticity of the Shroud as related to the death of Christ have come to propose, especially after the C14 dating, that a *medieval corpse* was used to present to the faithful a fraudulent relic. We have then, at the very least, an admission that is most important: *the cloth did envelop a human body which was subjected to all the tortures described in the Gospels, and it is not a picture*. The physical sciences, *by themselves*, cannot establish the identity of the person wrapped in that cloth, but they should critically analyze the suggested means for the image and stains to be as we actually observe them.

At first sight it seems plausible that the *fluids*, liquids or gases, coming out of a corpse that was covered with sweat and blood, and possibly reacting with the resins and spices used in the typical oriental burial, would cause stains on the cloth, more diffuse or clearly defined according to the body-cloth distance. If the cloth was simply laid on top of the corpse, instead of being tucked in at the sides, it would be logical as well that there would be no lateral image. And it would seem that the stain would appear just as a slight coloration, visible from a distance, but without identifiable pigment in the fibers. All these properties are, without a doubt, very suggestive when we check them against the description of the Turin Shroud.

Because this hypothesis is basically believable and because of its ability to explain many of the characteristics of the Shroud, this *vaporography* -first suggested by Dr. Vignon in 1902- is still favored by many people[12]. We should carefully review all its presuppositions and implications.

If the image is due to a contact between cloth and body, it would be expected that the dorsal image, with the *full weight of the body* resting on the cloth, should be more clearly marked and stronger than the frontal imprint, due only to the weight of the cloth over the corpse. This is not the case: there is no visible difference in intensity or detail between both sides, leading some commentators to assert that the body was levitating over the Shroud when the image was formed. As it will be shown later, there is no cogent reason to have recourse to this solution.

When the linen threads are observed under the microscope, *no penetration* of any fluid into the fibers is visible, as would be expected due to diffusion or capillary effects in the case of a gas or a liquid in contact with the cloth. As has been indicated before, the color resides only on the very *surface* of each individual fibril with a maximum depth of about 3 fibrils of each thread.

If we assume a direct contact in all the image areas, there would be a clear distortion of the body surfaces when the cloth is laid flat, especially in the face: a cloth that follows the contours of the head so as to mark the cheeks, the sides of the forehead, the neck under the chin, must then produce an image *much wider than the frontal view*. This is not the case. The

top of the head is also missing between the frontal and dorsal images, in spite of the fact that the Shroud is a single continuous piece wrapped over the whole body. There is no lateral image, but we do see blood stains, especially on the left elbow, which require a lateral contact with the cloth.

The stains themselves *if due to organic materials*, would likely have been affected by the 1532 fire at least in the immediate vicinity of rather strong burns, and would have a spectral *reflectance* proper of those organic compounds. This is not observed. No diffusion process, occurring *in all directions* (isotropically) between cloth and body, can *by itself* produce the fine detail that is evident in the image (again, especially in the case of the coin over the right eye.)

Centuries of archaeological work have brought to our museums many human remains from many cultures, with burial cloths in contact with corpses covered with sundry agents meant to avoid decay, or, on the contrary, with stains that show the effects of the decomposing flesh. Nothing remotely similar to the Turin image has ever been reported, *nor has any laboratory experiment* succeeded in reproducing by contact anything comparable.

I must confess that, before studying the Turin Shroud, I was implicitly accepting its image as the result of this natural process, and the main reason leading me to develop an interest in the cloth was its archaeological value as a source of historical information regarding the crucifixion. It is still true that this aspect, independently of the way the image was formed, is most important for me, but as a physicist I am more and more impressed by something for which I can find no satisfactory answer within the framework of the normal activity of material forces. And if these forces are not sufficient, perhaps the study of the Shroud will lead us to obtain some new knowledge.

## II c - HYPOTHETICAL NON-ARTIFICIAL PROCESSES OF AN UNKNOWN NATURE

Accepted methodology to solve any scientific problem requires that *new causes be sought* when those already known reveal themselves incapable of providing the necessary solution: this is the way science has advanced through the centuries. We have reached in our analysis of the Shroud image an impasse where new ideas are needed, and those that have been already advanced by several authors should be discussed, however briefly. Rather than to exhaustively trace the development and authorship of each theory, our principal task will be to search their logical consequences, to find the one that can best explain the actual image.

Especially after the research done in 1978, it is frequent to find the idea of *radiation* presented as the key concept to explain the existence of an image that does not contain any pigment, natural or artificial. Even if *no mechanism is suggested* to show how this radiation would arise from a recent corpse, in a dark and cold cave, it is assumed that such a physical agent, acting upon the cloth, would be sufficient to explain the *properties* of the image.

In the physical sciences, the word “radiation” refers to any type of matter-energy that is emitted from a source, and that can reach other objects *not in contact with it*. It can be corpuscular radiation, consisting of particles given off by radioactive materials, or extremely thin gases in the solar wind, or high energy nuclei from a stellar explosion. In all cases the flow of particles is isotropic unless there is some special factor (for instance, a magnetic field) that will channel the emission in a preferred direction. Its penetrating power and its effect upon a target will depend upon the type of particle and its energy: from alpha particles (He nuclei) emitted by Radium and unable to penetrate a piece of paper, to neutrinos from the center of the Sun or a supernova explosion, which can go through light-years of solid lead without practically any chance of interaction.

When we deal with low energy and massive particles, with very limited penetrating power, the attenuation due to *absorption* in air is sufficient to suggest that the effect of this radiation upon some target which reacts to it will be an inverse function of the distance to the source. If this were the cause for an image, the density of the stain produced in an absorber would allow the distance to be inferred, thus leading to a 3-dimensional reconstruction. But to have a finely detailed image, the radiation would have to be emitted in *parallel beams* (collimated) closely perpendicular to the emitting body and the receptor to avoid geometrical distortions.

No known particle has been proposed as the *logical* candidate to produce the Shroud image, nor is there any *a priori* reason why a particular kind should be emitted, or for its behavior to be as described. No data are available, to my knowledge, that would show that any corpuscular radiation would cause a superficial color in cellulose fibers, *without any penetration into the threads,* unless the type of particle and its energy were very carefully chosen and adjusted.

Perhaps a thermal effect could be attributed to electrons in sparks produced in some type of "corona discharge" (proposed by Dr. Giulio Fanti and others) or static phenomena, if they act in such proximity to the cloth that it is equivalent to contact: in this case, we no longer speak of *radiation* in the strict sense. Without some new factor involved to control the directionality of the emission, there is no reason to explain the lack of an image on the sides of the body or the top of the head, nor for the identical density of the image of the back, under the pressure of body weight, and the frontal view.

As a *complete* explanation, this hypothesis does not carry us very far towards a solution, even if it does propose a process which does not require any fluid to penetrate the fibers by diffusion, nor a pigment to adhere to the threads. In many respects it is equivalent to the scorching by a hot relief that was discussed earlier, but instead of postulating an improbable technology, it introduces the idea of a *mysterious phenomenon* outside our physical understanding: there is no logical reason to expect *a corpse* to become very highly charged electrically when left to itself in an ancient tomb, or to suppose that it will uniformly cause a discharge of the right energy and directionality to produce an undistorted and detailed image on a cloth that is not electrically conductive nor attached to some grounding conductor.

Almost everything positive that is said about corpuscular radiation can be applied also to electromagnetic radiation, emitted as waves that move at the speed of light with energy proportional to their frequency. They will show an intensity decreasing with the square of the distance from the source if the radiation is isotropic, and, if they have the right energy, they will affect the cellulose without leaving anything on it, except a superficial scorching or dehydration (especially in the case of UV radiation).

Its negative aspects are also similar: no reason is apparent to expect a definite direction of the beams, nor the lack of lateral images or the identical intensity for front and back imprints. And while a beam of low energy particles can be appreciably absorbed by travelling through a few centimeters of normal air, visible or UV radiation (in general) is not so affected, unless we deal with a very specific wavelength of UV (vacuum UV) or X-rays.

More generally: *any radiation*, as understood in Physics, will occur either as an *isotropic* flow, emitted equally in 3-dimensional space (Lambertian) or in parallel beams along a specific direction (*collimated*, more or less perfectly). In the first case, we have an attenuation proportional to the distance squared, but the beam cannot produce a detailed image corresponding to the sources. In the second, each ray will mark a specific point for each source, but the intensity does not change as a function of distance. This can be made quite clear observing the different behavior of common light sources: if an ordinary light bulb illuminates a piece of paper, the brightness of the paper will depend upon the distance from the bulb, but I will have no image of the filament (or filaments, if several bulbs are used): the

propagation is approximately isotropic. If I use several laser pointers forming an array in the shape of a circle, I will have a similar circle of bright points on a screen, but the intensity remains practically the same regardless of whether the distance is one meter or two, since the beams are collimated. Physical laws cannot *simultaneously* explain the retention of detail, by parallel beams, and the loss of intensity with distance in isotropic propagation.

A simple experiment, performed in my photo lab, will clearly show the dilemma. We can make some geometrical figures of different sizes using some fluorescent tape, frequently used to indicate electrical switches in a darkroom. Some triangles, circles and squares, of dimensions of the order of one centimeter, are excited to glow by exposure to ordinary light; then, under a safelight, a piece of photo paper is placed over the tape, with a heavy glass plate on top to assure good contact. An exposure of a few seconds is given, and the paper, after development, will show in negative form the crisp black shapes against the white background. There was no propagation of light through space, and there is no loss of intensity or detail.

When we repeat the process inserting a thin glass plate between the luminous tape and the photo paper, the image shows immediately that the shapes are no longer so well defined, nor is the image quite as black or the background perfectly white: light has travelled in all directions. Increasing the spacing between tape and sensitive material, by adding extra glass plates, the amount of detail and the degree of contrast rapidly diminish, so that by the time the distance from tape to photo paper reaches 10mm, *no recognizable shape* appears after development. Such a short distance is enough to lose all information about details on scales of centimeters, even if we can still recognize the general form of the array of light sources. Increasing the distance a bit more will give us a uniform grayish exposure, without any hint of what or where the sources were[13].

Applying these observations to the Turin Shroud, it becomes impossible to explain that there is fine detail, at levels much smaller than one centimeter, in parts of the body that must have been at some centimeters from the cloth, as inferred from the loss of intensity of the imprint. Logically, one cannot call *radiation* something that does not follow its laws.

When the original work of Drs. Jackson and Jumper described the 3-dimensional character of the Turin image, a very close correlation could be established between the intensity of the color stain on the cloth and the *vertical distance* measured in the laboratory between a similar cloth and a human volunteer, covered by it while laying on a horizontal table. But there was no correspondence, either in density or in shape (without distortions) if the distances were measured perpendicularly to the body or to the cloth at each point: *only vertical distances* (along the terrestrial gravitational field) are able to produce a three dimensional effect. This fact leads Dr. Jackson to infer that gravity was a deciding factor to determine the characteristics of the image: something totally unexpected when dealing with radiation of any kind, even perfectly collimated. Neither atomic particles nor electromagnetic energy are appreciably affected in their paths by the surface gravity of the Earth. This idea will be developed later on[14] (and proposals of a different directionality will be mentioned).

An interesting part of the electromagnetic spectrum is that covered by the name of *soft X rays*, meaning X rays of fairly long wavelength and low energy. In a proposal of a *weak dematerialization* of the human body at the moment of the resurrection, it has been suggested that such radiation could have been produced. The x-rays would then be responsible for producing the visible image, either by directly scorching the surface of the linen fibers or by exciting some of the elements present in the body, which would then re-emit the energy at different wavelengths. But there is no physical reason why X-rays should be produced in a supposed process that *requires energy* to be supplied, instead of providing it. Less likely still is the *fine adjustment of the energy* given off, needed to produce only a surface change in the linen (without any penetration in the threads) and to show the perfect directionality and correct

energy of the x-rays needed to give simultaneously fine detail (through collimation) and the 3-dimensional effect (by absorption along the path through air)

Both Dr. Jackson and Dr. Alan Whanger have remarked that in photographs of the image with enhanced contrast it is possible to see a *suggestion* of bone structures in the areas of the face and hands: nose and orbital bones and teeth seem to appear in the face in a way reminiscent of medical X-ray images, and also the hidden thumb under the palm of the left hand. But this is not a phenomenon due to the *absorption* of radiation coming through those structures, as is the case with a dental X-ray, where the teeth act as opaque barriers to the radiation, thus producing a weak imprint on the negative, and a corresponding dark image in a positive. In the Turin image they seem to be *sources*, which are seen as white points in the positive.

Everything said up to this point leads to the important conclusion that *no radiation of any type*, *even if miraculously produced*, has the proper characteristics of propagation and energy to explain everything we observe in the Turin image. With a phrase borrowed from ancient astronomers, we still don't have a hypothesis that will *save the phenomena* at least in a coherent description with a given source; still less can we give *a reason for its existence*. But we can, at least, establish the limits for any acceptable solution to account for all the data:

*- We must reject any explanation due to organic fluids, absorbed into the cloth by contact.*
*- We reject also an image formed by true radiation, without contact, be it particles or waves.*
*- We possibly need to find a process where terrestrial gravity is a deciding factor.*
*- The image formation process must naturally lead to an image without distortion.*
*- There must appear a logical reason for the lack of images on the top of the head and body sides. And also for the presence of colored threads next to uncolored ones.*
*- The same image density must be plausible for the front and back views.*
*- Perhaps: The hypothesis should allow the imprint of internal bone structures*.

The Turin image clearly corresponds to a crucified man, but among the thousands of victims of that brutal execution there is no other case of a similar imprint (and one would not expect in ordinary burials, especially in a Jewish context, any interest in keeping as something precious a burial cloth, more or less stained). In the one case of the Shroud all the detailed studies of the *information* content of the cloth and its traditional veneration *point* to a direct link with Christ as the Crucified wrapped in this cloth, *whose body was not found in the tomb*. Thus it appears that the existence of this unique image should be in some way related to the *unique event* of Christ's Resurrection.

This event is historically established by the testimony of reliable witnesses, who gave their lives for their testimony in historical times; without this basis, the very existence and spread of Christianity is inexplicable.

We are then entitled to *suggest* that the special transformation that places the risen body *outside the framework of space and time* (as expressed in the new *Catechism of the Catholic Church*[15]) and that occurs *without any external energy source*, might be the reason why the image exists, but that its imprinting did not cause any destruction of the atoms in the body or in its surroundings.

*We will not be able in this case to establish as a cause something that can be reproduced in our laboratories*: the resurrection, just like the creation of the Universe, goes beyond physical laws and experimental reproducibility. We will not be able either to give a *cogent reason or strict proof* of why the image was formed exactly as we observe it: at best, we might say, as Newton did for gravitation[16], that it appears as it would be expected to appear IF the formation process were as described.

The only alternative left, if this methodology fails or is rejected, would be to acknowledge that we have no idea of how to give a physical explanation and we should simply have a direct recourse to a miracle whose specific details remain hidden in the supernatural activity of the Omnipotent Creator.

## II d - A NEW HYPOTHESIS: PHYSICS AND THEOLOGY

The key point underlined by the 3-dimensional reconstruction of Drs. Jackson and Jumper is the presence of a *dependence* of the image intensity with respect to the *vertical* cloth-body distance. This verticality has no other physical meaning than the direction of the Earth's gravity field, and it leads naturally to search for a process where gravity plays a role. But the effect of gravity upon bodies on the Earth's surface is simply to produce a force which accelerates them downwards, towards the center of the planet: left to themselves in the gravity field, bodies fall down

The cloth that covered the corpse of the crucified Christ was resting on the body, more or less close to it, with contact at the salient points, and loose over other areas, even if *possibly* tucked in at the sides. At the moment when the body *ceases to be present in the space-time* environment of ordinary material existence, the top layer of the cloth loses its support and falls under gravity, flattening itself in the process, bulging at the sides and looking more and more like two parallel surfaces, the bottom one on the stone floor of the tomb and the top one finally resting flat on it. Nothing has disturbed the proper location of bloodstains, so that even the most minute clots remain in perfect anatomical accuracy as they were applied to the cloth by direct contact.

But *being in space is a physical reality*, where every bit of the material world is in interaction with everything else, in a complex web of forces and fields. It is thus *plausible* to think that the subtraction of a body from its environment *will disturb its surroundings*, however minutely, and this interaction cannot be totally instantaneous: *all physical changes require time and involve some energy exchange*. Thus the cloth must fall during a finite time through the rapidly diminishing resistance of the vanishing body, and be affected by the increasing friction with the air that takes its place. It is impossible to quantify those factors, since they cannot be subjected to experimental check in the lab, but we might suppose, as a starting point, that a time of the order of one second is likely, during which the cloth falls about 5 cm.

If we now admit as plausible that the energy associated with the existence in a physical environment (such a minute amount that it has never been measured) might be released in some way from the different points of the entire body, *the cloth will be affected by it in succession at different depths*. This could provide a *source* of extra energy for the image to be imprinted, very lightly, and with different intensity -as a function of time and the remaining effect of the body- as the cloth goes through the space from which the body is disappearing.

We would have an image without distortion, stronger where the cloth is in contact with the body at the very beginning of the process, weaker at later moments, and possibly due also to internal bone structures, with a *relationship to density* to be expected if each body particle is a source. This would apply to the finger bones, extending all the way to the wrist, to the teeth on both jaws, to the nasal bones; it is less likely for deeper body parts if the time involved is very short. This would *clearly apply to the frontal image*, since the cloth that falls through the evanescent body is the section on top of it. On the back we should also have an imprint of the *outer surfaces*, but we should not expect the back image to show a strong 3-D effect.

In the physical sense this is not a *radiation*, *transmitted through space*, but more like a static discharge, *by successive contact*, and the problem of isotropic or collimated propagation disappears. There is no artificial destruction of the body or a need for an external energy

supply to specifically act upon the body atoms and nothing else. The falling scenario naturally explains the lack of side images, as well as the displacement of blood stains (elbow and side of the face) from their origin to a new location on the image. And there is a reason for the mysterious X-ray effects (due to deep sources) that could show the left thumb through the palm and the teeth under the lips.

Finally, this postulated energy could also affect objects *in the immediate vicinity of the body*, like coins over the eyes, which could become points of discharge to leave an imprint on the cloth. The blood stains and clots would shield the cloth from the very weak *static*, thus explaining that no image is found under the blood.

This is, in a very schematic and speculative way, the hypothesis that best seems to *save the phenomena* without adding anything to the basic theological datum of the resurrection, while it tries to be as conservative as possible from the viewpoint of physics. Much more detailed work will be necessary to compare the totality of what is present on the Turin cloth with the logical consequences of the proposed process: only thus will it be possible to refine the model or to entirely discard it if it appears incompatible with some established data. Even at this stage of an elementary outline, it seems necessary to point out some questions that require a careful study and that could possibly be answered if new studies of the cloth itself are allowed:

- If we are dealing with a miraculous event, outside of the normal behavior of matter, why is some time required for it, instead of expecting an instantaneous change?
- If the coin over the right eyelid, which was not pulled out of the physical environment, was able to mark the cloth, what can we really give as a reason? Would something similar be expected from other nearby objects?[17]
- Is there a relationship, possibly quantifiable, between the density of body parts and the intensity of the image for areas at the same expected distance from the cloth?
- If the image was formed from the inside of the cloth volume, so that the blood shielded the linen fibers, is there any minute change in the blood itself that would indicate the effect of some energy?
- Why is the image -coloration of the linen fibers- found only on the inside surfaces of the cloth? It might seem more logical to find it through the thickness of the weave, under the effect of a three dimensional material that is undergoing a physical change simultaneously while the cloth is immersed in it during the fall.

It is obvious that a lot of work remains to be done and a detailed analysis of each and all logical consequences of each step has to be carried out. It should be possible, at least, to simulate the behavior of a falling cloth, similar to the Shroud, with some kind of support that is rapidly withdrawn, to see what shape the cloth develops. But *there is no physical law that can be directly invoked to find the answers,* and there is no possible laboratory experiment that will bring this study under the strict control of scientific methodology: *we have no way to put a piece of matter out of space and time to check the effects of the process on its surroundings*. The basic idea is received from theology, not from the sciences of matter, even if it cannot contradict the well established facts of science. It is more *qualitative and descriptive* than we can accept for any scientific work, but it should not lead us into any conflict.

This can be said also of other realities: intelligent life -abstract thought, consciousness and freedom- cannot be explained by any of the four forces recognized by Physics, but its existence cannot be denied, and it does not contradict any scientific data. If science cannot explain the very process by which science is developed, we can't expect that it will give a satisfactory explanation of a supernatural event.

## CONCLUSIONS

The total weight of multiple studies, medical, archaeological, chemical and physical, clearly indicate a direct connection between the Turin cloth and the Passion, Death and Resurrection of Christ. There is no other explanatory hypothesis for the existence of this cloth, for the information that is contained in it and for the very fact that it has been carefully kept and venerated through the centuries. The undeniable fact that nobody has been able to duplicate the image, or to even explain it satisfactorily by any known process, is also reason enough to conclude that *only a unique event in history seems acceptable as its cause.*

Experts in burial customs of the Jewish people, or medical specialists discussing blood flows as due to more or less plausible ways of handling a corpse, may disagree when interpreting details that are inferred from the Shroud. But even if customs and ritual prescriptions may be inapplicable in a given case, the laws of Physics do not allow exceptions due to any human concern. That is why the kernel of any discussion of this unique object should be to test it against physical, chemical and medical criteria, at least to suggest possible processes that may resolve discrepancies and lead to positive ideas.

Against the impressive evidence of reasoned studies validating the authenticity of the Shroud, there is one, *and only one*, discordant piece of data: the C14 dating performed in 1988. There are serious reasons to suspect that not all factors, capable of leading to error, were adequately taken into account, besides very serious methodological lapses: all this has been discussed by several authors, without implying a lack of objectivity or any fraud in the dating process itself. It is impossible to say more until a new series of experiments, performed with due scientific exactness and controls, once for all settles the question of this dating enigma. And we should not try to explain the mystery by some kind of hypothesis that is both without a physical basis and theologically inconsistent, by supposing a supernatural event that changes the C14 content in a purely *ad hoc* manner and leads to error by weakening the historical acceptability of the relic. (See the FINAL NOTE at the end, for recent views on this matter).

From a physical viewpoint, the main problem resides in finding a suitable and likely process to produce the body image that renders the Turin cloth a unique object of study. *No artificial method is compatible with what the cloth shows nor is the image totally explainable by any known or plausible effect of the contact of a human corpse with the linen cloth used to wrap it in the tomb*. We are thus led to suggest that a supernatural event was crucial in producing the image we see. The obvious event is the one attested to by the Apostles: the Resurrection of Christ.

Even within this explanatory *model* (in the scientific use of this word, denoting a specific viewpoint) it is unacceptable to attribute the image to any kind of *dematerialization* that literally destroys the human body; it cannot be explained either by any *radiation* understood according to the physical meaning of the word, which denotes a behavior according to known laws. But we can have a hypothesis that is *qualitatively coherent* with the data if we propose that the cloth fell vertically through a body that ceases to be in any spatial location, in such a way that the cloth is in *successive contact* with different levels of the body structures.

The Catholic Church has never declared (and it never will) the Turin Shroud to be authentic, nor has it said anything about the information obtained from it or about the origin and explanation of the image: *nothing in this problem involves our faith, and religious leanings should not enter into the discussion*. We deal with a physical object, archaeologically of the utmost interest, *that should be studied as such*. But we cannot close our eyes to its theological implications, positive or negative. And there is no need to apologize to any science if the objective study of all the data forces us to conclude that something unknown within the ensemble of normal physical processes has to be invoked to explain the image. This, then, can be accepted as a *confirmatory reason* to accept the testimony of those who gave their lives to attest to the fact that Christ rose from the dead, by God's power, never to die again.

When looked at in this perspective, the Turin Shroud appears, most obviously, first of all as a shocking complement to the Gospel narratives of Christ's Passion. But it also points to a marvellous new fact: the transformation of a human body into something which, being true matter and truly human, exists forever outside of the limits of space and time.

NOTES

1. Dr. GARZA-VALDES, in his paper *Scientific Analysis of the Shroud of Turin. A Progress Report* (continuing work presented in a previous manuscript kept in the files of the Holy Shroud Guild, Bronx, N.Y. since 1993) mentions detailed experiments carried out on fibers of the Turin Shroud, that show a coating of microbial origin, impervious to chemical cleaning and contributing up to 60% of the total carbonaceous content. But his claims have been strongly contested by other scientists.

2. References to Dr. KOUZNETSOV's work have been published in the *Newsletter of the British Society for the Turin Shroud*, no. 36, Dec./Jan. 1993/94. I have not been able to obtain the original text, and his credibility as a scientist has been called into question for several reasons.

3. This theory is presented in a booklet meant for private distribution, *Silent Witness: The Turin Shroud as Parable*, by Thaddeus J. TRENN (Victoria College, University of Toronto) dated on Christmas 1996. It is said to be the penultimate version of an article requested by the *Journal of Interdisciplinary Studies,* for publication in 1997.

4. The discussion of dematerialization as presented here is also applicable to the proposals of E. LINDNER (who has suggested the partial *annihilation* of protons in the atoms of the corpse) and of J.B. RINAUD (suggesting the disintegration of Deuterium nuclei to liberate neutrons that will enhance the amount of C14). There is no physical reason offered why this would happen, nor why the correct number of particles should be produced to give a medieval date, nor why the particles would have the correct energy to affect the cloth to produce an image. In *Linteum* (CES, Avda. Reino de Valencia, 53 - 16, 46005 Valencia, Spain), nos. 2, 7 & 8, there is a description of these hypotheses, with references to the original work.

5. Besides the remarks presented from the viewpoint of Physics, it might be also worthwhile to indicate the theological inconsistency of any dematerialization proposal. The concept of Man as a *rational animal* requires the existence of the body, necessarily made of matter, of atoms, to have a real human being: we are not spirits incarcerated in matter and waiting to be liberated from it. The Gospels are quite definite insisting upon the reality of Christ's risen body, his flesh and bones, his wounds, his ability to be touched and to partake of a meal with his disciples. It is meaningless to speak of *resurrection* if we say that it is just a spirit -which could never have died- that *recovers* life. Thus it is illogical to say that in the resurrection the body is destroyed at its most basic level.

6. Dr. JACKSON's articles can be checked for multiple details and references, especially *Does the Shroud of Turin Show us the Resurrection*?, in the book *La Sindone de Turin -Estudios y Aportaciones*, Centro Español de Sindonologia, Valencia 1998, pp. 217-239.

7. Drs. JOHN JACKSON and ALAN WHANGER have presented their studies of images similar to X-ray plates in a symposium held in Madrid on No. 20, 1996. Dr. Whanger has also described his work in several publications of Duke University, N.C.

8. The paper by Dr. J.J. DOMINGUEZ, *Estudio Médico de la Sindone*, in the book already cited as reference in note no. 6, pp. 85-125, presents a very detailed study of the medical and anatomical exactness of the imprint found on the Shroud, containing information totally impossible to explain within the context of the Middle Ages.

9. Dr. McCRONE is the only scientist who claims to have detected the presence of paint, iron oxide, in some small samples of the linen from Turin: this he interprets as being a pigment held in some unspecified organic medium. But this minute amount of iron is found equally distributed through image areas and clean cloth, and it appears as microscopic particles, totally beyond the technology of the Middle Ages. On the other hand, it is well known that the process of preparing linen for spinning (retting) leads to the deposit of iron that, practically always, is present in spring water; the iron found in blood cells, when the blood has dried and been rubbed repeatedly through the centuries, must also

have covered the whole Shroud. Less convincing still is the argument for a medieval painting drawn from a minute cinnabar crystal: it is well known that many painted copies of the Shroud were produced, and that it was a common practice to put the finished painting in contact with the original to make it more venerable as a relic.

10. NICKELL published his theory under the title *The Turin Shroud: Fake? Fact? Photograph?* in the monthly magazine *Popular Photography* 85, 5, 1979, pp. 97-99, 146-147.

11. Given the sensationalistic approach with which, time and again, these *solutions* to the Shroud mystery are presented to the public, it would be very desirable that some independent Foundation or individual, wanting to put the matter to a final test, would present a challenge to be met by anyone who claims to have an answer. A substantial prize could be offered to anybody who, with the technology and knowledge of the Middle Ages, would present in a reasonable time (for instance, 5 years) a duplicate of the Turin image, corresponding to all the characteristics found in the original. We could even allow the use of any modern technology. But, to stop attention seekers from wasting the time of qualified scientists, a penalty of 10% of the prize should be assessed if the work presented for evaluation does not succeed in its purpose, when judged by a multidisciplinary panel of medical doctors, chemists and physicists, experts in their own fields and well informed about the Shroud.

12. Presented in 1902 to the French Academy of Science by Pierre Delage, a friend of Vignon.

13. The original paper, *La Sábana Santa desde el punto de vista de la Física*, in the book referenced under note no. 6, has a page of photo reproductions of these results (p. 192). The largest circles shown (16mm in diameter) are almost identical in size to the coin upon the right eyelid (a *lepton*, minted by Pilate, 15 mm across).

14. Dr. John Jackson remarked on these facts during an oral presentation held in Madrid on Nov. 20, 1996, before a group of Shroud researchers, commenting a previous paper of his (1990) that is also described in his monograph (reference in note no. 6).

15. See no. 645 and the other sections dealing with the historical fact of the real, physical, resurrection of Christ.

16. Newton presented his Law of Universal Gravitation with utmost prudence, saying that *everything occurs as if masses attract each other...* because he could not give a reason for the existence of the attraction, nor an explanation for the transmission of the force.

17. Even if the coin image has, as a strong argument in its favor, the fact that it was first described with *a spelling error that nobody knew existed*, and that led to the prediction of its existence, later confirmed in 4 units of several coin collections, there are still researchers of the Shroud who attribute the image and its interpretation to just chance play of light and shadow. *This is, in my view, asking too much from chance.* A new prediction confirmed is taken as a good reason in favour of a scientific theory.

**Emmanuel M. Carreira, S.J, Ph.D.**

Universidad Comillas - 28049 Madrid

Having presented, as accurately as possible, what I consider as well established from the viewpoint of the physical sciences, I would now like to add some ideas based upon my studies on the Philosophy of Nature, or the Metaphysics of Matter.

What follows will not directly affect the reasons given to discard or accept some views, but it might provide some new insight to better understand the full meaning of the concept of bodily resurrection. Only in these arguments have I presented something of my own: everything else is just the systematized discussion of data and ideas of researchers whose work I admire and

respect. I hope that such logical analysis and the critical assessment of each proposal has a value that is independent of the reception that these last pages might elicit.

If any of these ideas, presently far from any possible experimental check, can lead to something closer to the truth, I will be quite satisfied and sufficiently rewarded.

## APPENDICES

### A - PHYSICS AND META-PHYSICS: SOME POSSIBLE LINKS

*Faced with a unique object, the Turin image, we were forced to seek a reason for it in a unique event: the Resurrection of Christ*. This is still compatible with a further question: is the image the pure result of a *miracle* that divine Omnipotence directly performs upon the cloth to give us a motive to believe the glorious transformation of Christ's body? Are its properties explicitly determined by the *purpose* of pointing directly to the Person of the risen Christ? Or, rather, is the very nature of the resurrection such that it should lead, *as its proper consequence*, to alter the material surroundings in a way that can explain something beyond known physical processes? Should we expect that a similar image would be produced in any other case of a hypothetical glorious resurrection?

If we answer with a direct appeal to a miracle, exclusively related to the apologetic value of the image in the case of Christ, there is no hope left of getting any further with our explanations. But if we can offer some plausible reasons to say that the very concept of resurrection leads us to expect the liberation of some energy, detectable in principle, *then our understanding of matter itself should be richer, and the nature of the image will no longer be the result of a "fiat" without any connection with the structure and parameters of the material world*.

In the previous discussion we looked for a reason to expect a minimal release of energy in the case of a resurrection, and the only logical basis to think of it was found in the statement (from theology) that the risen body is given a new way of existing, outside of the framework of space and time: an existence that is *real, but not experimentally detectable*. Developing this idea, we can ask the obvious question: what is lost by the body when it ceases to be localized? Equivalently: *what is the nature of localization?*

To answer properly, we should analyze the modern concept of matter. This word, in contemporary Physics, covers -in different ways- everything that is described in more detail with terms like *particles*, *energy*, *fields*, *space*, *time*. Specifically, space and time are correlative with matter in its common meaning, and they have no applicability until there is matter, after the zero point of the Big Bang of modern Cosmology. There was no previous empty space, nor previous time. When the Universe began to exist it was endowed with a given localization in a *space* that is only the abstract ensemble of real and possible localizations of physically detectable matter.

*But a given location is real, not an abstraction*. All motion is a real change, and there can be no real change with respect to a simple abstraction. It is true that in Physics only *relative changes* of a body with respect to another, used as a reference, *can be detected and have verifiable effects*, but this is not the whole story: if we want to make all localizations and motions just a set of fixed or changing relations, *we are led, necessarily, to an infinite process or to a vicious circle*.

Any real relation is established between things that really exist, and whose properties are the basis for the relation, be it quantitative (of the type *one is twice as big as another*) or qualitative (*one is of a different shape than the other*). The relation presupposes the reality of the properties that are compared, and *the relation cannot change as long as the objects are*

*the way they are*. Because of this, it is a truism in Philosophy that any relative change *presupposes (logically) an absolute change at least in one of the terms of the relation.*

Nobody really disputes this in any area of knowledge, from Mathematics[18] and Logic to Physics, but this obvious requirement is forgotten when we speak about localization. It is common to speak of it in a way that implies that nothing is localized by itself, but everything is localized by something else in its surroundings; that nothing really moves, but everything is moving with respect to some point of reference. Einstein was careful to stress the fact that even if only relative motions are important in Physics, this does not logically imply the denial of absolute motion[19]. The same warning should apply to any statement about localization, since motion is a local change[20].

If real localization *implies something absolute*, this should be of an accidental nature, not detectable by any physical effect aside from those attributable to the four known forces or interactions. But being part of the total web of matter, it should, basically, have something in common with known energy forms. And since all types of energy are mutually interchangeable, even with mass itself, this *localizing energy* -perhaps comparable to the potential energy of a field- must be capable of some interaction, directly or indirectly, at least in some circumstances. Thus we are led to expect that if a body were to lose its localization, so as to be no longer in any space, its *spatial charge* would be given off and that it might affect its physical environment in some minimal way.

*There is presently no experimental confirmation of these ideas*. But since nothing is created or destroyed in any physical process, if the localizing *energy* is lost, something else must appear in its place. What should it be, or what effects are to be expected from it, we simply don't know: no laboratory experiment succeeds in making something cease to exist in space (even if an analogous state is sometimes assumed for matter falling into a black hole) and there are no other cases known of a glorious resurrection, so that we might establish rules or laws for its effects.

The only positive value of these remarks would be to reduce the supernatural intervention in the case of the resurrection to its *minimal level*: to change a human body into a body which, while *remaining a true material structure*, begins to exist *in the manner proper to a spirit*, free from the bounds of space and time, by a gift of divine Omnipotence. We don't have to ask for a miracle *meant to produce an image* on the linen cloth, with details of the process and physical effects to be determined arbitrarily, but we will say, instead, that the effects on the cloth are a *natural* consequence of this transformation. It also seems acceptable, in this view, that a nearby object -like a coin on an eyelid- might have a momentary role in the changes that occur in the surroundings.

Applying the same kind of reasoning, we can accept that the physical processes occurring in the material world as a consequence of a resurrection, will require a finite time, instead of being strictly instantaneous. It also seems logical that the degree in which the surroundings are affected will show some kind of proportional relationship to the amount and density of matter involved. All these statements would have to be accepted as arbitrary data in any other hypothesis. But they appear as *plausible inferences* if the *localizing charge* is given off as some weak energy, just capable of minutely changing the outer surfaces of the linen fibers, *thus marking the cloth with an image as the natural byproduct of the supernatural resurrection event*. The equivalent energy involved would be of the order of a microgram of mass, or even less.

In this suggestion, Physics, Metaphysics and Theology come together to provide some explanation for something that eludes our complete understanding. We can only say again that if another body, wrapped in a similar linen shroud, were to undergo a glorious resurrection, we should expect a similar image to be produced. In this sense, the hypothesis is

more successful in *saving the phenomena* than any other proposed explanation, just as the elliptical orbits proposed by Kepler for the planets were better than the cycles and epicycles of Ptolemy or Copernicus, but neither they nor Kepler could give a physical reason why the planets should move one way or another. Newton himself could not give a reason either: he prudently expressed his Law of Gravitation saying that *everything occurs as if... This is all we can say at this point: the image found on the Turin Shroud has properties as if it were produced in the proposed way*.

ADDITIONAL NOTES

18. To find a change in the relation **a/b** = **c** an absolute change has to be accepted in the value of **a**, **b**, or both. Otherwise the ratio will always be **c.**
19. "*The totality of physical phenomena is of such character that it gives no basis for the introduction of the concept of 'absolute motion'; or shorter, but less precise: There is no absolute motion".* Found in the book *Out of my Later Years,* 1950.
20. In the textbook *Metafísica de la Materia*, 2nd. ed.,Univ. Pontificia Comillas, Madrid 2001, I present a more detailed treatment of the theories suggested in the history of Philosophy to save the objective reality of localization.

## B - SUMMARY

Aside from the Gospel narratives, there are several relics traditionally related to Christ's Passion, and one -especially mysterious- that is likely the sheet that wrapped Christ's body in the tomb until the moment of the resurrection. This is the Turin Shroud, the most extensively studied archaeological object in all antiquity.

There are on this cloth the expected bloodstains from a Roman scourging and crucifixion, as well as the unexpected puncture wounds of a thorny head covering and a side wound from a spear thrust after death. From those and other anatomical considerations proper of forensic medicine, one can say that the only reasonable explanation of the blood markings is the use of the cloth to wrap a body of a person who suffered all the tortures described in the Gospel for the Passion of Christ, and no other known candidate can believably be suggested.

The fact that the cloth was kept and considered worth of veneration, when we know the obsessive concern of Jews for legal impurity, even from just touching the outside of a tomb, leads us to think that something extraordinary happened that made the Shroud no longer the burial cloth of a dead person, but rather a precious relic of a living Master. Details of the way Peter and John saw the linens on the morning of the Passover Sunday are also indicative that something very strange made them believe that the empty tomb was not the result of an improbable theft (by whom?) but rather of a mysterious disappearance of their beloved Lord.

Still, whatever we see in the Turin Shroud, even considering it as the real burial cloth of Christ, shows only a dead body. But the unique feature found in this relic is the full size image, front and back, of the entire body, so that not only the bloodstains but the full anatomy is clearly visible, especially in high contrast photographs, where the imprint on the cloth has the tones reversed as if we were working with a photographic negative.

This image defies explanation, and nobody has succeeded in reproducing anything like it even with the most modern technology. There is simultaneously amazing detail and a dependence of intensity from cloth-to-body distance that allows a three-dimensional reconstruction, something impossible with any known photographic or painting technique. Hypothesis based on the diffusion of gases from the body to the cloth cannot explain detail and simple contact cannot explain either the 3-D effect or the lack of serious anatomical distortions. Supposed unknown radiation (that really nobody can logically suggest should be present) would have to be emitted either isotropically or in collimated beams, explaining either the 3-D effect or the detail, but not both by any single process

Drs. Fanti and Whanger have proposed a “corona discharge” phenomenon, where no properly called radiation saves a varying distance from body to cloth, but rather in an almost direct contact could affect the linen. No reason is given to expect the high voltages required for this effect to occur; still less, for the fact that the corona discharge would take place only along vertical paths (there is no side image). Dr. Jackson, using still the word “radiation”, suggests a vacuum UV that is rapidly attenuated in air, thus allowing for the change in intensity of the image as function of distance. And instead of a collimation of emitted beams, he proposes that -at the moment of the resurrection- the body became “mechanically transparent” in such a way that the cloth fell through the body and was affected by the UV at different levels, but by *successive contact* or nearly so. No reason is advanced to indicate that such emission of UV should take place, but if it did appear, it would affect the linen in the way we actually observe.

Dr. Rogers by chemical tests determined that the color that forms the image (a very weak straw color) resides only in an extremely thin layer on the outside fibrils of each linen thread. This color can be dissolved with diimide and leaves perfectly white cellulose. A similar color can be obtained by Maillard reactions when polysaccharides are affected by reactants containing amine groups that are to be expected in gases from a corpse, even without real corruption. He did admit that this process by itself could not explain the detail we observe in the image.

Without entering into chemical or physical debates as to the merits of each proposed mechanism, it might be a positive step *to find a reason why some kind of energy should be associated with the resurrection* and how it might contribute to the formation of the image. The only thing that comes to mind is the *change* from being in the physical environment of space and time to a new existence without those parameters. If space and time properties are real, they must imply something physical in the object that is affected by that physical framework. Therefore it is plausible to expect that leaving that way of existing will imply, to use a simple language, the “shedding” by the body of whatever anchored matter into this normal universe. This should be some unknown type of energy that, like any other, could in some way affect its surroundings in some minimal way.

The energy should be similar in its superficial effects to the corona discharge, but probably acting just by successive contact, that would be expected –following Dr. Jackson- if the body ceases to be in space and thus presents no resistance to the weight of the covering. If the process is not instantaneous (no physical process occurs in zero time) then the cloth can fall a small distance while the energy is still available, and its presence would facilitate the chemical reactions that produce the surface color but without altering the cellulose of the threads. This would also apply to images of non-body objects that are very close to the body itself.

No special treatment of the cloth is required to explain the image: any set of stains, whatever their origin, can be photographed and will produce a reversed image on a photo-sensitive material. True photographic images are made by an optical system projecting an image of something external that has varying degrees of reflectivity, like a painting or a drawing or just a simple arrangement of different objects.

We are still very far from a total explanation of the Turin image, impressively beautiful with its qualities of majesty, pain and peace portrayed in the tortured face better than in any work of art. It is doubtful that a similar image might ever be produced with complete correspondence to the original. It might be the only visible trace of the unique event that is the transformation of a human corpse into the living body that will no longer be subject to death.

## C - A POSSIBLE SYNTHESIS OF PROPOSED IMAGE FORMATION PROCESSES

After many years of discussions and hypotheses regarding the Shroud image, it seems that no single explanation is satisfactory to cover its main properties. Since it is a unique object (at least in the sense that we have no other known instance of a similar image on a burial cloth) and that up to now no successful effort to duplicate it has been presented for a scientific appraisal, perhaps a combination of ideas from different viewpoints might give a plausible scenario for a first *qualitative* description of a suitable process. This might be, at least, worth a further analysis to clarify points that could be debatable or even incorrect. And in any case, what is presented here is not science in the strict sense (something that could be tested experimentally) even if it tries to avoid any science fiction or arbitrary –"ad hoc"- presuppositions. Subject to possible refinements, I will begin with a basic list of the image properties that I propose we need to consider:

1.- The image of a human body, front and back, exists as a slightly darker yellowish color in the surface of linen threads (the upmost fibrils) composing the cloth. There is no added pigment of any kind, and the color does not affect even the entire thickness of a thread. The color can be dissolved chemically (using diimide) and the cellulose then appears white and unaffected. Side-by side- threads show different levels of color.

2.- The image shows simultaneously a surprising level of detail and the encoding of 3-D information relating color density to plausible cloth-to-body distances, especially in the case of the frontal image.

3.- The image of the body shows a rigidity -"rigor mortis"- that seems to preclude contact of the backside with a flat cloth laid simply upon a horizontal hard surface, especially under the bent knees.

Further development of these 3 points would logically imply:

1A- According to Ray Rogers, the color could be due to a reaction of body vapors (containing amino groups) with a surface layer of typical sizing polysaccharides used when preparing the threads for weaving. These would be unevenly found in different batches of thread, and would migrate to the outermost surface of the cloth when washed and left to dry after bleaching. Such Maillard reactions are to be expected, and they are affected by temperature (extra energy). The unevenness of the sizing would lead to bands of different intensity and even to threads side-by-side having quite different colors: *identical cellulose in the threads cannot explain that fact.*

2A.- Detail can be explained in only two ways: by the emission of radiation (particle or electromagnetic) in collimated (parallel) beams, or by contact of the cloth with the body. There is no reason to expect any collimated emission from the body (particles or waves), mostly in a vertical direction (up and down). A *simultaneous* contact with the entire body (front and back) is quite unlikely and it would produce obvious distortions. And the 3-D properties of the image are incompatible with a simultaneous contact of the body with the cloth. The absence of side images is an added reason to say that the cloth was not wrapped around, in contact with the body, at the moment of image formation.

Encoding of 3-D information could be explained by the collimated emission of some specific radiation that would be strongly absorbed by air, thus providing the body-cloth distance. But, as said above, there is no reason to expect the collimated beams or the very specific vacuum UV that is properly absorbed in air.

3A.- In order to have contact of the bottom half of the shroud with the rigid bent legs it was suggested that large amounts of some material were placed under the cloth, adapting it to the body shape, either as plants (Fanti) or as bales of spices (aloes and myrrh bought by Nicodemus). Neither option is reasonable: Jewish practice did not allow for any foreign living

thing being in the tomb, and it is hardly a way of honoring a beloved deceased to put armfuls of ordinary wild shrubs or sacks of powders under the body. Why would anybody want to have the cloth touch the back of the corpse?

The partial hypotheses proposed to give a reason why the image is as described are, in a very elementary description, reduced to three:

A.- The color is due to a Maillard reaction (Rogers). He admitted that gas diffusion *alone* cannot explain detail.

B.- Some kind of energy –associated with the unique event of the Resurrection- was the trigger that produced the image, either as a "corona discharge" (High voltages in near contact, Fanti) or as a series of vacuum UV beams (Jackson) occurring only in the vertical direction (no need for Maillard reactions). The source of energy: a miracle that would produce the image. But some plausible energy favoring Maillard reactions might be involved without miracles.

C.- The image was formed while the upper cloth was falling through the "mechanically transparent" body at the moment of the Resurrection (also proposed by Jackson).

The recourse to a miracle *to directly produce the image* (miracles are free acts of an intelligent God who produces them for a reason) leaves the entire discussion outside the realm of physical logic. It would be simpler to say that the miracle occurs directly upon the cloth, and there would be no reason to look for a previous miraculous step. If that seems satisfactory, we would just stop here. But perhaps we can advance a bit more if we use some basic ideas from Philosophy and Theology, regarding the concept of space and the Resurrection. Those who want to speak only of experimentally verifiable concepts (excluding even God from their mental schemes) should not waste their time reading any further.

Let us begin with the idea of space. In Physics, the concept of matter includes particles, energy, the physical vacuum, space and time: everything that in some way can be affected by the four interactions that we observe (gravitational, electromagnetic, strong and weak nuclear). All physical activity occurs within the framework of space and time, and it implies some energy exchange and some time interval. Motion means a change of distance relationships, and it is only relative motion that can be observed and that has detectable physical effects. But every relative change requires an absolute change in at least one of the terms of the relation: as long as the terms remain the same, their relation is the same. This is not discussed in Physics when dealing with position, and even in Philosophy it is common to say that changes in location do not imply any real change in the bodies that move. This is clearly illogical, and Einstein himself had to admit that -due to the fact that we only *perceive* relative motions- we can say, *less accurately*, that there *is* no absolute motion. But if nothing moves absolutely, there can be no relative motion either. Things can be inferred even if they cannot be detected directly.

Thus we should admit that there is a real "something" that anchors a particle in a specific spot in physical space. Let us refer to it as a "spatial charge", so far undetected by experiment, but logically required, just as the "color charge" is not directly detectable but it is still accepted to distinguish the different quarks and their ability to cause specific reactions. Such property should imply some kind of energy that must be capable of showing itself under the proper circumstances.

We now enter the field of Christian Theology. We distinguish the raising of the dead back to ordinary life (a re-vivification, like that of Lazarus) from a Resurrection that changes human existence, placing the entire human reality, body and soul, outside of the framework of space and time (see the *Catechism of the Catholic Church*, no. 645). This is what we profess with respect to Christ, as the very foundation of the Christian Faith: a totally new concept that was

hard to accept even for the Apostles, but that was imposed on them by the evidence of seeing Christ alive, while able to be visibly present to them or not, at will, and without any physical constraint. For this conviction they gave their lives; upon it rests the development of Christianity for 2000 years.

When each particle of matter of the human body ceases to be in space and time, first, it must physically change *in some way*, losing whatever that "spatial charge" is, as some kind of unspecified minimal energy, and the change will occur in a non-zero time interval. The body will then be immune with respect to physical forces that always work within space and time: it will disappear from between the two layers of cloth in the tomb, leaving them flat where they were, as described in the Gospel of John.

The volume previously occupied by the body will retain, perhaps for a minimal time, a distribution of energy corresponding to each body particle in its proper position. The electromagnetic repulsion, that causes the apparent impenetrability of matter in our experience, will no longer act to support the upper layer of cloth, and the linen will fall through that space, being affected *in succession* by the different levels of residual energy that correspond to body structures and that will be weaker as a function of time and, consequently, of depth. This extra energy will reinforce the Maillard reactions that produced the color, thus encoding 3-D information but retaining detail, because at each moment the effect occurs by a *successive* contact of each body point with the cloth.

It is logical now to consider a second effect of the disappearance of the body. A partial vacuum will result, even if the cloth is porous and the entire volume contained some air. Atmospheric pressure will tend to fill the vacuum producing a collapse of both cloth layers towards the center, flattening the cloth and driving it sideways from the body volume. Thus no image is formed for the sides or the top of the head, but the bottom layer goes up, sucked against the back to fill the vacuum. While the top layer falls under both gravity and atmospheric pressure, the bottom rises against gravity, thus moving more slowly and a shorter distance. Consequently, the top image has more pronounced 3-D properties. Nothing similar occurs with the Sudarium, "rolled up apart in its proper place", that has no image. Neither cloth was disturbed or moved from where it was by any human intruder, but the Shroud is now flat, without the obvious bulk of the body underneath, and this fact leads John and Peter to their realization that there was no robbery but the fulfillment of Christ's prediction of his Resurrection: "He saw and believed", says John, with a typical phrase that in his Gospel is only used for a reaction toward Christ's claims.

In this scenario, the image is a *natural byproduct* of the physical change from being in space and time to the new way of existence. There is no miracle *directly aimed at producing it*, and there is no "ad hoc" process to cause a specific form of energy to act on the cloth by being emitted in a peculiar way. One could say that if a similar Resurrection were to take place under the same circumstances, a similar image would be expected.

Other suppositions based on ideas of particle emission (protons from a disintegrating body) or the effect of lasers on linen cannot be justified by any logical consequence of what Science, Philosophy or Theology have to offer, even if they could simply claim that they involve possible direct ways of acting for God's Omnipotence. Yes, they can be admitted as a complicated way to obtain some effects, but "Ockham's razor" (the simplest explanation must be preferred) would favor the minimal intervention of the divine power.

Of course –as clearly stated before- we cannot test this hypothesis in the laboratory: we do not know how to exclude even the most minute bit of matter from its space-time environment. While the idea of a black hole is expressed sometimes by saying that whatever falls into it becomes unobservable because it is outside the space and time accessible to our instruments, its gravitational pull is still there, attracting new matter into the bottomless pit of

gravitational collapse. It says nothing useful to visualize or to understand the new way of existing that our Theology claims for a risen body.

What am I trying to contribute with this "Synthesis"? Only some possible additions to ideas proposed by others -not to discard those previous suggestions- but to develop them in a coherent whole. I have introduced the idea of *successive* contact, implicit in Jackson's "mechanical transparency", but not mentioned explicitly by him. I have added the source of a kind of equivalent "corona discharge" without high arbitrary voltages by suggesting that the "spatial charge" contributes a minimum energy to the Maillard reactions. I have looked for a reason to have the bottom cloth touch the back, attributing it to "suction" -atmospheric pressure filling a vacuum- instead of piles of shrubs or packets of aloes and myrrh. In every case I have considered as very valuable the basic contributions of many people through many years of deep thought about the Turin Shroud.

I don't claim to have solved the mystery to everybody's satisfaction, or even to my own! I would rather ask that every weak point of this presentation be clearly underlined and if a better scenario is proposed, I will be most happy to accept it. I am sure that we can all learn from each other, even if it is quite probable that we will never find a totally correct and convincing explanation of the marvelous relic that attracts our reverent attention: the image "not made by human hands" that shows so powerfully the Passion of Our Lord and that possibly points also towards his Resurrection.

Emmanuel M. Carreira, S.J., PhD – June 16, 2010

Universidad Pontificia Comillas (Madrid) - Vatican Observatory

## FURTHER SCIENTIFIC STUDY OF THE TURIN SHROUD: POSSIBLE IMPROVEMENTS FROM THE VIEWPOINT OF PHYSICS

Practically all of us, no matter how long we have been interested in the study of the Shroud, feel hampered by having to speak from second hand –or third or more!- knowledge, that not always seems totally substantiated by acceptance in a peer-reviewed scientific paper. Most of the suggestions that are presented in this elementary discussion deal with data that are presented as already obtained by reputable scientists, and if that is the case and the data are universally accepted as having the required quality and extent, there would be no need to repeat whatever was done. Still, for the sake of completeness, a general outline of the different steps to obtain information is presented for the consideration of those who want to leave no stone unturned –as physicists- in our effort to really make the Shroud a serious object of study, free from any stigma of prejudice or amateurish approach.

While the Turin Shroud, as a physical object, is simply a piece of cloth that at first sight seems rather unremarkable, its properties should be studied for a number of reasons and with different methods, first to determine its composition and age, and then to infer a plausible way to relate its use -as the envelope of a human body- to the varied stains found in it. The most demanding analysis will be required to find a plausible way to explain the unique image found in it, without resorting to a totally "arbitrary" miracle with no connection to the expected logical behavior of matter. All these objectives should be attained in a non-destructive way, with minimal contact with, or disturbance of, the cloth itself, even if the detailed study of some sample fibers might be clearly desirable.

The composition of the cloth – animal or vegetal fibers, linen or cotton- should be determined in detail, at different points of the large cloth. This would be a first step needed to establish the usefulness of any given sample as representative of the original cloth or a possible later addition due to repairs. Spectral reflectance can be applied at every point without damage to the material, and it should include visible, infra-red and ultraviolet wavelengths, as well as

polarized light and even X-ray transmission properties. Microscopic observations, both of the surface and of individual fibers, should be used as well, with the data obtained being clearly specified with margins of error and the identification of the instruments used.

A second step would describe weaving patterns and the way the threads have been spun. This will not have any bearing on physical parameters as such, but it will allow us to place the fabric in a cultural context (place and time), at least with a degree of probability acceptable in archaeological studies. The lack of uniformity (bands), the presence of added strips or indications of the removal of samples through the centuries should also be established, and the properties of any possibly extraneous material clearly indicated.

Third, and most important, determination: the characteristics of stains found all over the Shroud. Aside from general "dirt" from exposure to different environments during centuries, the cloth clearly shows patterns that suggest water flows, dark areas rich in carbon deposits (burns) and other more limited and clearly not uniformly localized sets of reddish stains. Their spectral reflectivity should allow assigning the causes for each type of stain, and a possible later step –with chemical reactions- would be the definite tool to identify the sources.

The unique "stain" that the Shroud presents is a very obvious -even if faint and imprecise- double image of a human body, front and back, where the sides of the body and the top of the head are missing. The reddish marks mentioned above are found only within the areas embraced by this human image, thus implying that they correspond to surface features of the skin. Their patterns should also allow us to infer a plausible cause for their existence and distribution.

The body image by itself appears as a very diffuse and light straw color, not much darker that the common color of an old piece of cloth, such that the image cannot truly be appreciated in a close inspection: only at a distance of meters does our eye obtain enough information to detect the general shape. To see any kind of detail we need high contrast photography, and this should be done with traditional black & white films that cover –with the suitable filters and developers- the infra-red, visible (orthochromatic and panchromatic emulsions) and ultraviolet wavelengths.

New digital cameras should also be used, but they require a clear knowledge of their spectral sensitivity and the possible effects of adjusting contrast and resolving power. This applies also to scanning techniques that will give us a practically identical reproduction of the cloth, (in visible light) but that cannot substitute for it in terms of contrast and spectral response. We might take into account the fact that we might miss "seeing the forest, because of the trees": the highest resolution scanning of a printed page will give us a meaningless pattern of dots of different colors, not an image. This is also true of photographic film when we reach the level of silver grain sizes.

The image itself must be studied from the viewpoint of its correspondence to a human body, with or without noticeable distortions (that should be specified if present) as compared with the proportions, shapes and sizes of corresponding sections of the body in a typical photograph. Some comparison with features that vary with age and race could also be made, with limits of error and possible statistical frequency of each: there is no doubt that most adult males without obvious medical conditions will show a general coincidence of most anatomical traits. This will be an area where anthropologists must be the experts, not physicists who simply obtain the images and measurements.

Medical doctors, forensic doctors especially, should interpret the image, as done when called to testify in court regarding some evidence for a crime. The presence or absence of rigidity ("rigor mortis"), of superficial or deep wounds, of liquid or clotted blood, of serum haloes, can

be deduced from the image as presented in the different wavelengths. This work should then be carried to completion with chemical tests when they can be performed on sample fibers.

It has been reported that dry blood crusts in the image area –when removed by friction or the application of an adhesive tape- leave behind clean, colorless cloth. It has been pointed out that this could be explained in one of two ways: either the blood prevented the image from forming, or the crust pulled off the slight color when it was removed by the tape. It would be rather important to determine the correct answer.

The color itself in the image areas does not penetrate to the reverse of the cloth, so that no general image is visible from the back (except perhaps for some evidence of image for the hair and some facial areas). A multiple photographic and microscopic exam should be sufficient to establish without a doubt whether this is the case everywhere or not, and also if the color penetrates the threads to any extent. The presence or absence of pigments –colored powders or liquids that would penetrate the threads by capillarity- is a crucial piece of information that should be established once for all without any possible ambiguity. A series of microscopic photographs and comparison pictures made in a laboratory with comparable cloths and colors should make it clear once for all if the body image can be described as a painting or not. Other images (flowers?) might have different properties *if present* (not evident, even if identified (as wild thorny species!!) by botanic experts.

This would also apply to supposed methods of obtaining it by scorching or some kind of photography that always involves an “emulsion” applied to a receptive surface. And this leads us to the most unusual properties of the image as found in the Shroud: its “negative” representation of light and dark areas (tonal inversion), its three-dimensional encoding of relief, and its ability to show unexpected levels of detail.

The inverted tonal rendering was the reason for the impact of Secondo Pia’s photographs in 1898: for the first time, it was possible to clearly see a human figure, shown with an impressive majesty and peace together with evident suffering that nobody could have guessed from previous observations with the naked eye. The orthochromatic plates used by Pia, (not sensitive to red wavelengths: they were visually developed under red safelights) increased the contrast between the yellowish image and the cloth itself, thus making it overwhelming in a way that only after the invention of photography could be achieved. It became clear that no forger could have anticipated that effect in the Middle Ages, and any hypothesis of an inventor of photography at that time is sheer science fiction.

The impact was so great that Pia was accused of forging his pictures, something that is an obvious nonsense: what could he have photographed to obtain that image? Up to this time, no other similar image has been found in the history of archaeology, but new photographic materials and techniques have again and again reproduced the effect: it can be said that nothing else but a real imprint with inverted tones can account for the results, even if –surprisingly- the better rendition of all colors with panchromatic emulsions *lessens the contrast and the strength of the resulting image.*

Once more, different photo materials should be used now in order to obtain all the possible information and not just a conventionally acceptable image. Digital cameras, *with known spectral response of their CCD or CMOS sensors* and the suitable light sources and filters, could add to our study of shadings and detail that otherwise we might be missing.

The discovery by Jackson and Jumper almost 40 years ago of the relationship of image tone to vertical distance between a similar cloth and a horizontal body draped with it, allowed the recovery of the third dimension, producing a quite acceptable relief when transferred to a sculpture. This is impossible to achieve with any normal photograph or painting, where the tone is not related to distance, but depends upon the reflectivity of the subject. This

immediately implies that the image could not have been produced by *simultaneous contact* with a corpse: there would be no third dimension to affect the density of color (and there would be obvious distortions when the cloth is flattened). It also excludes any image produced by optical means (as in photography) or by any painter, in any art school or period.

Dr. Fanti and his associates have reached the conclusion that the best fit between color density and body-cloth distance is obtained if the measurements do not follow the vertical, but a perpendicular to the cloth. This point should be definitely clarified in order for a plausible mechanism for image formation to be well established, even if the detail way a cloth rests upon the body might be difficult to determine. It also seems from the published images that the three-dimensionality is less obvious for the bottom part of the Shroud (the dorsal image) and this, again, might constrain possible formation hypotheses: the body rested upon the bottom half of the Shroud, but the image is not stronger due to body weight.

The third property of the image is the most controversial: it shows detail, at levels not clearly established. There is no problem in seeing the features of a human face, with eyes, nose, lips in their expected places and with sizes that anthropologists judge correct. The overall shape of the head (in the frontal image) appears rather rectangular, but bands of darker weave are an obvious artifact of the cloth itself, that tend to limit the true outlines of the sides. We must accept that there is no definite “edge” to the face, as there would be in a true photograph or a painting: this renders rather doubtful any argument trying to relate artworks –oriental icons- to the image of the Shroud, and we find in those icons triangular faces with a single point for the beard, while others are more rectangular and with a double point.

It is also doubtful –at best- that changes of tone between the eyebrows should be the reason for similar marks in ancient art: they were present in pre-Christian paintings and statues and they appear in icons of angels, saints, even the Christ Child. I haven’t found any evidence of supposed “phylactery boxes” or amulets between the eyebrows (leaving aside the question of their use or logical presence on the forehead of a crucified Jew).

Other images that seem to suggest internal body structures (especially teeth or facial bones) must be clearly distinguished of irregularities in the threads of the cloth; this is also necessary when talking about finger bones and even shadings that might correspond to internal organs. Medical experts undoubtedly have the trained eyes to distinguish shapes that lay people cannot see –even in an X-ray image—but all those “images” need a quantitative description in terms of changes of tone, contrast, margins of error in the position and size of the supposed organs. If the images are well established, it would be most interesting to see if a relation is found between image tone and the density of the body part, teeth, bone or organ. This would be useful for the hypothesis mentioned at the end.

Of all the controversial images with incredibly fine detail, the best known and discussed is the small disk-like bump on top of the right eye. It was discovered by Fr. Filas, S.J of Chicago in enlargements of high contrast images taken by Enrie in 1931. The image is not visible in more recent, detailed, but *less contrasted images*, either in color or in panchromatic black and white film. For many people, this proves that they are not real, but only visual illusions. To this argument I am inclined to say, first, that you lose information when the image is less contrasted. Second –and methodologically most compelling- that in science I accept as real an observation of a *predicted but totally unexpected feature.* What could convince me that an image of a coin is on the eyelid? Only the actual finding of a coin with the exact details observed in that image, including an “impossible” orthographic error (C instead of K in *Kaisaros*) and the equally “impossible” placing of the inscription around the diviner’s staff. This is what was found, in coin collections where nobody had ever noticed the errors. What other proof can be required? Against the facts, arguments have no value.

The fine detail can only be attributed to direct contact or to some radiation emitted in perfectly collimated –parallel- beams. Both hypotheses are incompatible with the rendition of three-dimensional information, which requires a distance and an isotropic emission of the active elements (particles or waves). This constrains all the possible explanations for the image as an exclusively physical or chemical process. To develop a possible scenario to explain the image, several ideas might be combined into a plausible multi-faceted proposal, but this view (attached in **Appendix C** as a matter for discussion) will probably not lead to detailed experimental checks to be performed by physicists.

**FINAL NOTES**

**A -** Recent work by Dr. Ray Rogers has established that the color that produces the image is almost certainly due to impurities on the surface of the original linen threads, chemically altered by some reactions, still unspecified. Quote from Dr. Rogers' e-mail: "Linen fibers from authentic scorches on the cloth are colored all of the way through their diameter. The heat scorched the entire fiber. Image fibers show the color on their surface *only*. The image color can be reduced chemically (diimide and sodium borohydride), leaving colorless, lustrous linen fibers. It is still possible to see places on the sampling tapes from 1978 where image color was stripped off of image fibers. The thin, colored layer is still stuck to the adhesive of the tape. These colored "ghosts" still show all of the chemical properties of the complete image fibers. The image color is not a result of any changes in the cellulose of the linen fibers. The cellulose of the image fibers is still colorless ". A message from Dr. Rogers is summarized here:

"I did a search of the message base with the two key words Maillard and diimide. My motivation was the thought that Ray Rogers was too good a scientist not to have commented on Ben's specific question. The first "hit" was message #3216 which you can all reference -- but on the offhand chance that you don't have the time or predilection here's a quote of the key passages:

"Later we found that the image color resided only on the outer surfaces of image fibers: the flax fiber was not colored at all. The layer of image color was often pulled off of the fibers by the adhesive of our sampling tapes in 1978. The layer is approximately one wavelength of visible light thick (200-600 nanometers), and it is amorphous. It can be specifically reduced with diimide, leaving a colorless flax fiber behind. Diimide reduction confirmed the presence of double bonds.

The problem became, what could produce a color in a thin layer without affecting the structure of the cellulose?

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

There are many more details, but the bottom line is that the only logical reaction I could find that could produce the proper chaotic conjugated structure (image color) at normal temperatures was the Maillard series of reactions. This, of course, required -NH2 groups as well as reducing saccharides. And where is the most logical place to get amines in the vicinity of a shroud? A decomposing body should be an excellent source. That is why I am so glad to welcome you.

My interpretation of the situation is that, given reducing saccharides on a cloth and a decomposing body, Maillard products will form. If the reactants are really present, there is no alternative. The presence of Maillard products on the Shroud would prove it was an authentic shroud, a fact that has not been proved. Maillard reactions would also agree with the spectra and chemistry."

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Ray specifically mentions diimide and says that the Maillard reaction agrees with the spectra and chemistry. Q.E.D.

Other hits were #2916 (a response to a comment of mine) #651 which alludes to the Maillard reactions in beer and the properties of diimide as in the Adler work.

This constitutes all the messages that had both search terms. I think it is more than enough to show that Ray Rogers was fully cognizant of the Adler work and had concluded that a Maillard reaction had a satisfactory chemistry. Unless there are other prestigious chemists that disagree on some scientific basis I regard the matter as settled. The chemistry of a Maillard reaction fits the available optical and chemical characteristics reported in the STURP work. Best regards, Ray Schneider

**D -** The chemical analysis of threads from the piece used for the C14 dating indicates that they come from a part that was later reworked to repair the original cloth. The sample sent to the three laboratories was correctly dated, but it is not representative of the Shroud itself. The mystery of the age discrepancy is solved: new samples, carefully chosen with the proper tests to make sure that they belong to the main cloth, should be submitted for testing with the well known safeguards of a “double blind” methodology. See www.shroud.com/pdfs/rogers2.pdf. **Here is a summary written by Dr. Rogers:**

Dear Giulio and Researchers: Giulio asks: "How is your hypothesis about the 16-th reweaving to be considered? Is Flury- Lemberg’s statement credible?"

If part of the Shroud were woven out of gold wire, the fact it was different from the rest of the cloth would be obvious. The situation is almost that bad, and Fury-Lemberg's claims are al! based on visual examination. The chemical properties of the area from which the radiocarbon sample was cut were not considered or tested, and the ultraviolet photographs from 1978 were not consulted. The radiocarbon area is outstandingly different from the rest of the cloth. That is a fact: it has nothing to do with whether or not certain terminology applies or what Flury-Lemberg either knows or does not know about Medieval textile technology. No assumptions about technology need be made to prove that the area in question is anomalous. Without adequate testing, she was fooled. That lack of careful characterization of the sample has made a laughing stock of the Shroud. Most of the world has all of the "proof' it needs to label the Shroud as a Medieval hoax, and her book certainly seems to confirm those beliefs.

Chemical tests prove that the Iow-fluorescence part of the Shroud in the area where the radiocarbon sample was cut had the following characteristics:

1) It did not fluoresce; i.e., its chemical composition was different. There is absolutely no question about that statement.

2) The yarn was coated with a gum that contained both dyes and mordents (common technology through millennia for dyeing linen). It had been colored for a purpose. Most of the added color appears on the outer surface of the yarn in that area. Photomicrographs document this fact. None of the main part of the cloth had any of the same gum-dye-mordant coating.

3) The linen had been bleached by a different technique than the main part of the cloth: it shows very little lignin at growth nodes.

4) The lignin in the anomalous area gives the microchemical test for vanillin, a component of lignin that decreases with time. The lignin in the main part of the Shroud does not give the test (nor does lignin from Dead Sea Scroll wrappings). The anomalous area has a different age than the Shroud.

5) As Raes observed, there is cotton in the yarn of the anomalous part of the cloth. It is easy to find inside the segments of yarn. The only cotton that is found on the main part of the cloth is a superficial impurity.

6) SEM analyses by Adler proved that fibers from the anomalous area have twice (2X) the concentration of aluminum as other areas. Aluminum is used as a mordant for the ancient Madder root dye that exists in the anomalous area. Microscopic views, documented with photomicrographs, prove the presence of Madder dye on hydrous aluminum oxide mordant.

7) Madder root dye is largely alizarin and purpurin. These can easily be detected in the anomalous area. No other area of the Shroud is coated with Madder root dye. Alizarin has been used for over a century as an acid-base indicator in chemistry: its properties are known in detail, and its presence in the area has been documented with photomicrographs.

8) The hydrous-aluminum-oxide mordant is instantly soluble in hydrochloric acid. The color of fibers from the anomalous area changes instantly when treated with the acid, and the colors obtained depend on the pH of the solution (as expected from the dyes),

9) The gum coating on the outside of the yarn is soluble in water. It can be observed under a microscope, and the soluble gum is redeposited when the water is allowed to evaporate. The gum is not a biogenic polymer, and it does not give any test for proteins. The gum quickly hydrolyzes in acid, and it hydrolyzes somewhat more slowly in sodium hydroxide solution. It gives the color test with iodine that is common to plant gums like gum Arabic (bright yellow). There is nothing like that on the rest of the cloth. Such gums were items of commerce for millennia, it was not a natural impurity on linen, and it was used to stain/dye the yarn. Photomicrographs are available to document these observations.

10) Careful microscopic viewing of yarn segments from the Raes sample showed a unique, end-to-end splice (photomicrograph available). The main part of the cloth was woven using overlaps of yarn when one batch of yarn ran out and another was added to continue weaving. Photographs of the Shroud show the method, and historical documents discuss it. The "bands of different color" seen in the Shroud correspond to areas that were woven from different batches of yarn. The bands also show different concentrations of lignin (each batch of yarn was bleached separately).

I invite anyone with competence in chemistry to view samples that show the extent of the compositional differences between the anomalous (low-fluorescence, different chemical composition) area and

authentic Shroud fibers. I can supply some samples: Turin can supply more. I challenge the custodians of the Shroud to have a competent chemist perform a few simple chemical tests on retained samples of the radiocarbon area. These differences are obvious, and they cannot be waved away by an "appeal to authority." I seriously doubt Flury-Lemberg's credentials to make pronouncements on the chemical properties of the radiocarbon sample.

Raymond N. Rogers Fellow, University of California, Los Alamos National Laboratory Los Alamos, NM, USA

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**Please note: This proves directly that the sample used for the C14 dating was NOT representative of the main cloth. This is totally independent of other possible uses of the chemical test to obtain an age by vanillin or any other process. The *different density* of main cloth and C14 sample also indicate their different composition: typical values for shroud cloth and comparable linen cloths is of the order of 25 milligrams per square centimeter, while the sample tested gives 42 milligrams. This clearly points to additional material present in it.**

Emmanuel M. Carreira, S.J.