CONSERVATION AND PRESERVATION OF THE SHROUD OF TURIN

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The Shroud of Turin has long been an object of religious and historical controversy.[1] It is only comparatively recently that it has also become an object of scientific contention.[2, 3] These polemical matters more recently have been exacerbated by the C14 dating of a Shroud sample to the mid-14th century.[4, 5] A great deal of mass media coverage has exploited this hubris and accepted the Shroud simply as a painting.[5] This oversimplified conclusion ignores the large scientific base of observations arguing against the Shroud being a painting.[6, 7, 8, 9]

Although the problems in authentication of the Shroud have been thoroughly examined,[10] much of the confusion over the meaning of the scientific research resides in the layman's failure to understand what science can and cannot do about the problem of "authenticity". It has already been noted that scientific studies can only disauthenticate and never authenticate the Shroud of Turin.[7, 8]

The basis of scientific knowledge is the use of the "scientific method" usually attributed to Sir Francis Bacon,[11] To use this method one first gathers observations, makes a hypothesis of a cause and effect relationship between those observations, then tests that hypothesis by an experiment and draws a conclusion as to whether the hypothesis is satisfied. It is not generally appreciated that a positive conclusion does not "prove" the hypothesis. This is so for several logical reasons. There may simply have been an error in the measurements or the method employed in the testing. Repetitions of the experiment allow one to assess the random errors that affect the reproducibility or precision of the results. Similarly, control experiments permit one to evaluate the systemic errors (e.g., interferences) that affect the accuracy of one's conclusions. There is also the possibility that a more subtle and less obvious alternative hypothesis may exist which gives a deeper and more elegant explanation of the observations.

Thus the methods of science have some limitations. A hypothesis must be testable by an experiment or it is not science. Further, one must be aware that alternative hypotheses may exist and one must devise experiments to distinguish between them. Therefore scientific "truth" is always provisional and represents a constant approximation to acceptable logical belief based on a corpus of experiments that favor one explanation over another. It is logical consistency that counts.

There exists no scientifically acceptable experiment that can establish the identity of the man whose image appears on the Shroud of Turin; i.e., there is no

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experimental test for "Christness". Hence all the scientific experimentation that one can devise can only support the consistency of a historical identification or authentication of the cloth as Christ's burial shroud, but not "prove" it. However, a single experiment can be seen to be capable of disauthenticating such an identification.

The radiocarbon dating would appear to be such an experiment, despite the large body of data favoring authenticity. This would be so unless one could show obvious errors in the experiment or alternative hypotheses against such a conclusion. Recently several such explanations have been advanced, although few of them are appropriate for serious scientific consideration. For example, contamination of the sample has been suggested. This ignores the fact that radioactive decay follows an exponential law and the dates of concern are all less than one half-life of the radioisotope. Thus approximately one half of the total carbon in the sample would have to be substituted with present day carbon to produce the discrepancy between the observed 14th century date and the "expected" first century dating. Such a substitution is not consistent with the previous experimental observations already recorded and would be very unlikely.

However, a simple alternative hypothesis does exist. Prior to the carbon dating a very elaborate protocol for the testing was developed at a meeting of experts in Turin to deal with possible errors and alternative hypotheses that could arise in the testing.[12] Unfortunately, the protocol was not scrupulously followed in the actual sampling procedure. Only a single sample was taken and that was from an area of the Shroud known possibly to have undergone repair. If the sample represents a rewoven area, it might not be typical of the rest of the cloth. Some tentative evidence exists that indicates that this might be the case, but it can hardly be called conclusive. It should be noted that the recommended protocol would have detected this problem. Therefore, one is entitled to conclude that the radiocarbon dating of this possibly suspect single sample represents a precise date, but not necessarily an accurate date for the whole Shroud.

It is apparent that scientific investigations of the Shroud concerning the "authenticity" issue can hardly be less contentious than the historical studies. Fortunately, there does exist an area of scientific study of the cloth that should not be a polemical issue. Whether authentic or not this is an object of religious reverence and to many people a sacred symbol of their faith. Therefore efforts to conserve, and preserve the Shroud should be undertaken, and a long-term monitoring program should be developed.[13]

The Shroud having been woven from linen is composed of cellulose. A great deal is known about the preservation of cellulosic materials.[14, 15,16] While such experience is valuable in deciding on conservation measures for the Shroud, it is unfortunately insufficient. The images and marks on the cloth, and not the cloth itself, are what makes it worthy of preservation. Conservation of these cannot be undertaken until the chemical constitution of their chromophores is unequivocally established. This will require further scientific testing. Moreover, if the presently held identifications[8] are confirmed, one must note that very little is known about how one goes about conserving such structures, therefore an extensive

series of research studies will be required before one can confidently recommend an appropriate conservation/ preservation program.

For example, consider the "blood" images. Substantial evidence exists that they derive from the serum exudates from clotted wounds,[8, 17] therefore their red color has been attributed to their containing a mixture of protein bound bilirubin and methemoglobin as the chromophore.[8] Such a mixture is photosensitive. A decision would first have to be made as to whether this color should be preserved as is. If so, this would seriously affect the recommended conservation procedures with respect to atmospheric exposure and incident lighting conditions. These images are also slowly flaking off, due largely to mechanical disturbances of the cloth. What should be done about this? How long will it be before the cloth no longer contains recognizable blood images? What other conservation problems exist here?

A far more serious problem is represented by the "body" image, the source of the major interest in the Shroud of Turin. Considerable evidence exists that this has been chemically produced by an oxidation process involving the cellulosic structure of the surface of the cloth.[7, 8, 18, 19] It has been demonstrated that the variations in contrast of these body images are produced by a variation of the number of fibers discolored per unit area (a so-called areal density image) and not by the concentration variation of an applied pigment.[6, 7, 8] Therefore, each discolored thread is approaching chemical saturation in its color. It must be understood that as the non-image areas of the cloth oxidize with time, they will approach the same degree of color saturation and the image will then become indistinguishable from the background. It will take a very careful and continuous conservation program to allay this process and prevent the loss of the image on the cloth. Serious considerations should be given to archiving the Shroud with all the modern forms of image reproduction techniques as a security against such an event.

How long will it take for this image loss to occur? As the reaction in question involves the interaction of atmospheric oxygen with a solid surface, it clearly can be approximated as a pseudo-first order reaction. For such reactions the time for the reaction product (in this case the oxidized cellulose) to double in concentration will be given by the so-called half-time which is given by 0.7 / k, where k is the reaction rate. The reaction rate itself can be estimated from the Arrhenius equation: $k=Aexp(-E_a / RT)$, where T is the absolute temperature, R is the gas constant, E_a is the activation energy, and A is a constant dependent on the type of reaction. The literature values for A for this type of reaction[20, 21] range from about 10^{11} to 10^{23} sec^{-1}. Substituting various values of the activation energy into the Arrhenius equation gives a range of reaction rates from which a range of half-times can be calculated for various A and E_a combinations. Carrying out this exercise demonstrates an interesting result: somewhere in the range between 25 and 35 kcal / mole, the half-time goes from days to centuries (i.e., reflecting an exponential behavior) over a small range of a few kcals.

The values of E_a and A vary considerably from cloth to cloth and its environment. Photographs from the recent sample taking for the radiocarbon dating show that the color contrast between the covered and uncovered backing cloth (after sample removal) is approximately the same as that between the image

and non-image portions of the Shroud itself. As this is a known time period, some estimates of the Shroud's parameters can be made. An E_a estimate of 30 ± 3 kcal /mole would seem reasonable (a not untypical value for such linen cloths, e.g., see the data in reference 19).

At first sight this would suggest that we have another 500 years or so before we have to consider seriously the problem of image loss. This is a serious delusion! Unfortunately, cellulose oxidation processes are also readily catalyzed by a variety of environmental pollutants, e.g., dirt, sweat, acidic gases, basic gases, etc.[14, 15, 16] Such catalysts can readily lower the activation energy from 1 to 5 kcal/ mole and bring century-long half-times to matters of weeks.[14, 15, 16] (Ask any housewife who has seen a "dirty" linen napkin discolor in a matter of weeks). No one has really assessed the importance of such polluting materials already on the Shroud, although they have been readily observed on the sampling tapes.[7] Further, Turin is an industrial city which has had steadily increasing amounts of air pollution over the past few decades.

How serious are these problems? Could the quality of the Shroud's appearance seriously deteriorate within the next decade or so? It is not impossible and unfortunately there is some evidence that it is progressing right now. If we are remiss in undertaking conservation/preservation studies and measures on the Shroud of Turin, future generations will have every right to castigate us for failing to meet our responsibilities in these matters. History will not be kind to us! Mene Tekel Upharsin!

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