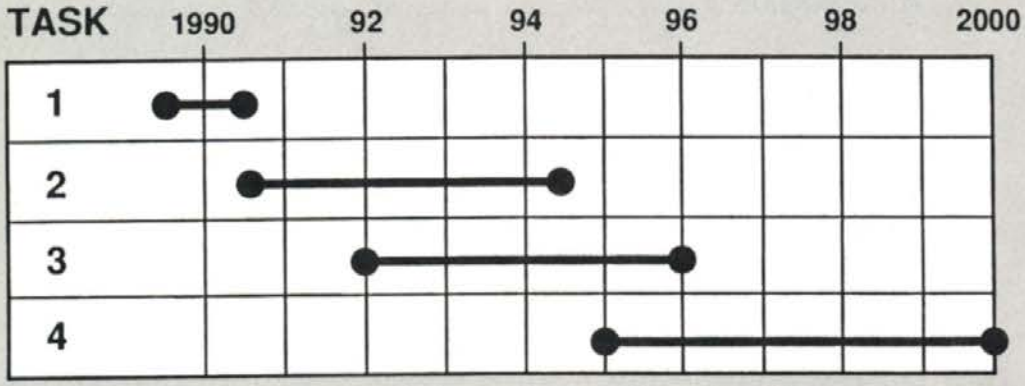

Fig. 1. Timetable for tasks relating to issues of conservation.

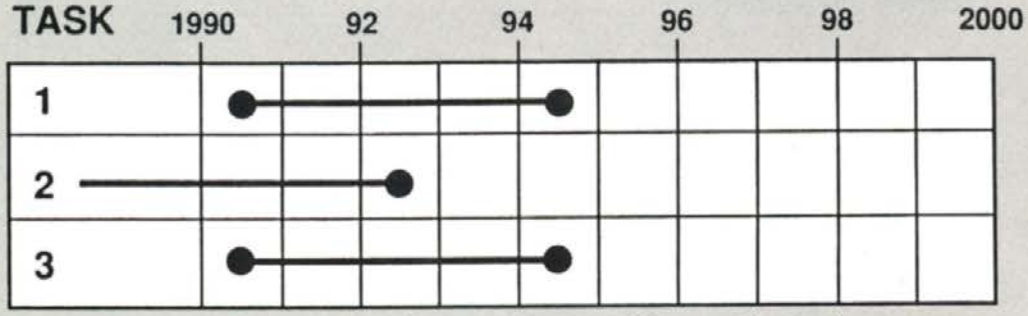

Fig. 2. Timetable for tasks relating to issues of image formation.

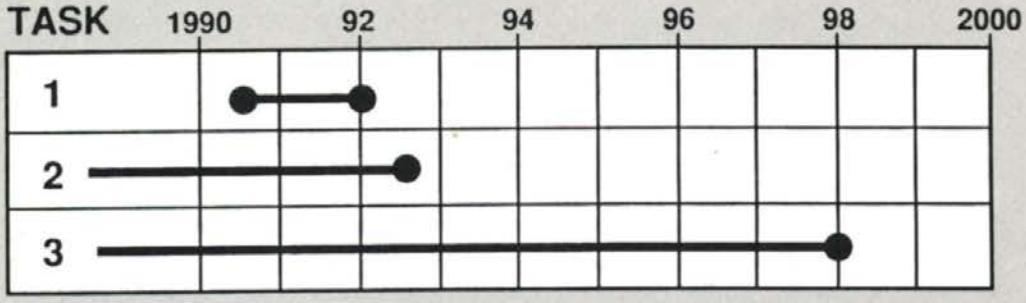

Fig. 3. Timetable for tasks relating to issues of provenience.

SCIENTIFIC ISSUES AND SHROUD RESEARCH IN THE 1990s

L. A. SCHWALBE

In October 1978 an internationally represented group of scientists spent a week-long period subjecting the Shroud of Turin to an unprecedented series of direct observations and testing. The work of reducing, correlating, and interpreting the data they collected continued for about three years. By the end of 1981, the results were made available to the wider scientific community as well as the general public in the form of publications in peer-reviewed scientific literature. With the exception of the carbon-14 experiments conducted in 1988, further direct studies of the Shroud have not been permitted.

Now, after nearly a decade, the situation appears hopeful once again. On August 18 the Vatican announced that it would begin to consider proposals for further testing on the Shroud. By making this decision, the church has taken the first step toward a complete scientific understanding of the cloth and its intriguing image. However, the promise of continued research can only be rewarded if the scientific community does its part by successfully adopting and executing an effective technical agenda. This means that we can and should now begin to conduct a comprehensive reexamination of the scientific issues surrounding the Shroud so that we can define the relevant experiments and establish their priorities and sequences.

This very task was the subject of an oral presentation that I prepared for the *Symposium Scientifique International de Paris sur le Linceul de Turin* held in Paris in September 1989. The full text of the talk will appear in the proceedings of the conference; *Spectrum*'s edited version follows. Although dated in certain aspects (such as the timetables shown in the Figures), the issues, experiments, and priorities that I presented last year are still valid today. I therefore offer my considerations as a potential framework and plan for continuing research on the Shroud of Turin.

INTRODUCTION

Most of the discussion at this symposium has been given to historical matters. The topics have included reviews of accomplished work, critiques of existing data, thoughts on various ideas people have expressed — all of which constitute reflections on the past.

The subject of this presentation is somewhat different. As the first international gathering in well over a decade given primarily for discussions of scientific issues, this symposium offers a unique opportunity for planning the future course of studies on the Shroud of Turin. I have therefore chosen to use this opportunity for a look toward the future.

Where do we hope to be in our scientific understanding of the Shroud by the year 2000? What technical issues will dominate our attention in the next decade? What are the most promising avenues of research that we can begin pursuing right now? My purpose in this presentation is to answer these questions as best I can from my own experience and perspective. I hope to relate my desired goals and to define the technical issues I believe will become most important in the coming decade. Finally, I will describe what we must do together to meet these goals.

SCIENTIFIC OBJECTIVES

Before we begin speculating too freely about the future, it is useful to review where we stand today. We can point to many technical accomplishments as we enter the 1990s, but three of these are particularly noteworthy in my view. First, I believe we understand the basic chemistry of the body image and the physical distribution of the discoloration well enough to claim confidently that the image is not a painting.[1,2] The second objective is equally well established: the chemistry of the blood stains leaves little doubt that they were produced by blood and probably nothing else. Third, the recent radiocarbon tests[3] are consistent with the cloth's production sometime in the XIVth century. Although some may disagree with one or more of these findings, I have not yet seen a rigorous and complete technical challenge to any of these conclusions based on data currently available.

Imagine a scientific symposium, reconvened in the year 2000. What would you want to hear included in the list of technical accomplishments having been met during the 1990s? What would you like to point to as perhaps one of your own unique contributions? At the top of my list, I would place conservation studies. By the end of the next decade (and preferably much sooner), I would like to have all questions relating to the Shroud's preservation thoroughly investigated. As a further, practical matter, I would also, like to see standard procedures established for the safe storage, handling, and display of the cloth.

The second item on my list concerns the complex and longstanding question of the image-formation mechanism. Ten years from now, I wish to have a convincing idea of how the body image was produced on the surface of the cloth. And finally, I would like to know the cultural circumstances of the Shroud's origin and history. I want to know exactly when and where it came from and

how it became the property of the French knight Geoffrey de Charny in the mid-XIVth century.

ISSUES, TASKS, AND TIMETABLES

Although my list of scientific objectives is comparatively short, it includes pretty much everything I ever wanted to know about the Shroud of Turin. My list may seem ambitious, but I believe with sufficient dedication, work, and cooperation, these goals are quite realistic. If enough of us share these aspirations, and if we adopt these goals, we can then start asking what technical issues are likely to emerge in the next decade. Such considerations are more than merely academic; apart from funding constraints, the major technical issues in any branch of science determine the course and progress of that discipline.

What technical issues follow from the list of objectives outlined above? We have defined our goals in terms of three broad categories that we might refer to as conservation, image-formation, and provenience studies.[4] It is therefore fitting that we discuss the technical issues under the same broad headings.

Conservation

In the area of conservation, many specific issues are not yet well-defined. Textile conservation is not my area of expertise, but I understand from specialists in this field that our base of chemical and physical data is not yet broad enough to support recommendations for any long-term conservation measures.

Thus, a primary issue will be deciding what further analytical tests are necessary to characterize the physical, chemical, and biological state of the Shroud. With these data in hand, the next issues will concern specific actions to be taken. Textile conservators must study the problem and agree on a specific set of handling procedures and environmental standards that follow from these data.

I believe we should consider building a new, modern repository where the Shroud can be stored safely and displayed more frequently. Optimally, the Shroud should be stored in a flat, horizontal, and extended configuration, not rolled up as it is currently. Precise and reliable environmental monitoring systems should be installed. We might even consider including a refrigeration unit to establish and maintain low-temperature conditions, which would slow degradation rates.

The storage repository could be designed to facilitate display as well. For example, the "image side" of the enclosure could be made of a protective, bullet-proof glass covered with easily removable, opaque panels. A design of this sort would allow display by simply removing the panels and rotating the entire case to a vertical position. With this capability, the Shroud itself need not be moved or even physically touched.

Meeting these goals will require a lot of hard work and planning. To facilitate the latter, I have drafted an approximate timetable for accomplishing the work (Fig. 1). The first task (Task #1) is to organize a qualified team of professional textile conservators and Shroud scientists to tackle the issues. In the timetable, I have scheduled Task #1 to begin immediately and to extend to the summer of 1990, when I suggest the Shroud next be made available for direct studies. During that examination I have scheduled the beginning of Task #2, which is the program of data collection discussed above. Eventually, I expect the data collection program to become quite extensive, although for 1990 it may involve only visual observations or, at most, experiments conducted with microscopes or other hand-held equipment.

Although the data collection program should extend to the summer of 1994, the task of drafting recommendations for conservation measures, Task #3, can begin well before that time. I have indicated Task #3 starting in 1992 and extending to 1996. By that time, the recommendations for conservation should be complete and formally presented to the official custodians of the Shroud.

Finally, I have defined Task #4, which involves the planning and construction of a new facility for permanently storing the Shroud. Although some members of the Shroud of Turin Research Project (STURP) have already begun working on the problem, I believe the major effort of locating, designing, funding, and constructing the repository will not start much earlier than mid-decade. I have therefore scheduled Task #4 to start formally in 1995 and be finished by the target date, 2000.

Image Formation Studies

The most intriguing aspect of the Shroud of Turin is, of course, the faint image on its surface. We now have enough information about the chemistry and physical distribution of the image to know how it was not made. But at this point, all we can say positively is that it was produced by some mechanism that changed the chemical nature of the cloth. The two most obvious ideas are that the image was produced thermally, that is, by scorching, or by some sort of chemically-induced reaction.

Arguments both for and against these hypotheses have been discussed elsewhere,[1] but this fundamental issue should continue drawing widespread attention in the 1990s whenever plausible image-formation mechanisms are considered. In the technical area, I hope to see more control experiments to help us better understand the reaction sequences that occur in chemically-catalyzed and thermally degrading cellulose. Experimental studies of scorching may employ apparatus of the type described by Jackson and co-workers,[5,6] who studied thermal reactions at relatively high temperatures and reported some preliminary results. However, future measurements must expand this data base to include measurements

from cloth samples that have been subjected to various chemical pretreatments and ambient environmental conditions. Identifications of the chemical species are also vital. Correlations of these chemical data with data from image-area samples may then either support or rule out the scorch hypothesis as a possible image-formation mechanism.

In the last ten years or so, most of what we have learned about the Shroud has had to do with the chemical nature of the body image. However, in the next few years, I believe investigators will become more active in studies of the physical distribution of the image discoloration. Microscopic observations of the image in 1978 revealed its remarkably superficial nature.[1,2] Observers noted that fibers in the image area are colored only on the crowns of the threads and that the image discoloration extends only two or three fiber diameters into the body of the threads.

Subtle variations on this general pattern might supply clues to how the image was made. We should therefore begin probing for more specific details. For example, we should examine how uniform the image depth is in a global sense. We should look for evidence of directionality — that is, we should search for locations (possibly at the side of the nose) where the discoloration does not exist on the very crowns of the threads, but slightly off to one side, indicating a possible oblique direction in the application of the image. We should measure the intensity of the discoloration on individual threads in areas of nominally uniform color density. It may be that statistical variations of color densities about a mean value can be quantified and subsequently related to similar observations from control experiments where "images" are produced by scorching, chemical catalysis, or other methods.

Members of STURP have formally proposed experiments to follow up on these and related ideas.[4,7] The studies described in their 1984 proposal involve special photographic techniques together with standard and novel procedures for analyzing the data. If opportunities for more direct observations on the Shroud materialize in the 1990s, studies like these and particularly ones involving digital signal analysis could prove very important to our ultimate understanding of the image-formation process.

Along with more direct attention to the body image, we should expect continuing investigations of the chemistry and the physical distribution of the blood material. For example, we may identify the blood as human, or we may deduce the physical condition of the donor from certain of the blood constituents. But an identification of the "blood" as heme-derived material, even that of a tortured human, proves nothing about how the image was formed, where the materials originated, or whether the Shroud was even a shroud for that matter.

I do see a few exceptions to this cautious forecast. One is the possibility of determining from the distribution of blood on individual

fibers, whether the blood was applied before or after the body image was made. Evidence on this question is important for arguing whether the Shroud was actually a shroud or whether it is an artist's production. If an artist produced the Shroud, I would expect the image to have been made first and the blood stains applied later, after their intended locations had been defined precisely. On the other hand, if the Shroud enveloped a tortured body, I would expect the blood transfer to have occurred on, or shortly after, contact with the cloth, and the image to have been formed afterwards. STURP scientists have proposed to perform systematic studies of this question, and I am optimistic that a result will help resolve this issue in the next few years.

Figure 2 shows an approximate timetable for work relating to the issues of the image formation mechanism. This work schedule involves a lot of fundamental research, so it is impossible to forecast exactly when or by what routes many of these questions will be answered. Still a timetable of this sort can convey the logical order various efforts should follow. Also, the estimated time durations can express a researcher's personal feeling for how difficult the individual problems may be.

Therefore, Task #1 is defined to be a systematic program to broaden the present chemistry data base with new blood and image-area samples. The goal of Task #1 is to provide new samples for experimental investigations of questions relating to the image-formation issues described above. In its objectives and estimated time duration, this task is similar, if not identical in many respects, to that of the conservation program (see Task #2 of the previous section). The two sample collection efforts should therefore be tightly coordinated.

The second task under image formation studies is to continue control experiments to better understand thermal and chemically-catalyzed degradation of cellulose. I have indicated Task #2 as already in progress and continuing to 1992. Finally, I have identified Task #3, which is to apply new photographic and image analysis techniques to further probe the physical and color distributions of the blood and image. Task #3 is scheduled to begin in 1990 and to continue for four years to 1994.

To conclude this section: Figure 2 shows a conspicuously heavy concentration of scheduled activity for the first half of the decade and no work at all for the latter half. By no means does this imply that we can expect a complete understanding of the image formation process by mid-decade. On the contrary, the results of the work outlined above are still quite preliminary to solving the complete riddle. Our current research program still has the "shot-gun" nature of preliminary scientific work. As clearly defined as the present issues are, they still lack specificity. We are not asking precisely the "right" questions today because we do not yet know enough about the image to be able to do so.

Even though we will eventually move in more specific directions, it is not possible to predict exactly when. Nonetheless, I trust that as we begin resolving the issues defined above, we will see significant and active work on the image-formation problems in the latter half of the 1990s. If we begin an active research program today, we can expect to meet our ultimate goal of understanding the image-formation mechanism by the year 2000.

Provenience Studies

The subject of the Shroud's origin is particularly timely. Indeed, much of the discussion about the Shroud in the last year (1989) centered on the radiocarbon results, officially announced in October 1988. A number of important issues have been raised, and I discuss these in greater detail elsewhere.[8] Although it may be a bit early to state for certain, I feel the dating issues can and should be settled in rather short order. On the timetable for work relating to provenience questions (Fig. 3), I have indicated Task #1, which involves the resolution of all issues pertaining to radiocarbon dating, complete by the year 1992.

Equally important to an accurate date is knowing where the Shroud originated. Dinegar and Schwalbe[9] have discussed the existing data and the possibilities for further research. Particularly interesting in this regard is the proposal STURP issued in 1984[7] to measure the stable isotope ratios of oxygen and hydrogen in the textile cellulose. Stable isotope measurements can provide information about the climate where the flax was grown as the results of DeNiro and co-workers[10] illustrate.

The second task relating to provenience issues is to collect stable isotope data from an actual Shroud sample and to correlate them with results of textile and pollen studies. The data base for most of this work already exists. Therefore, in Figure 3, Task #2 would be due for completion by 1992.

The final work, Task #3, is to integrate the literary, historical, and analytical data into a consistent historical scenario. Historical and literary studies have been especially intensive in the last 10 or 15 years. While it may seem somewhat naive to specify a target date for the completion of these studies, if our research plan is pursued steadfastly, by 1998 or so we should have a reasonably complete understanding of the Shroud's origin and history.

RESPONSIBILITIES AND COMMITMENTS

Earlier in this presentation, I listed three objectives for Shroud research that I would like to see met by 2000. However, to realize those objectives will require more than simply defining technical issues and describing tasks as I have done. A successful program will require a partnership of cooperation and trust between the scientific community and church authorities. It will be necessary for

both parties to recognize and accept certain responsibilities and commitments.

Shroud Scientists

Most of the scientists' responsibilities relate to rebuilding trust with the public, with the church authorities, and with the wider scientific community. Shroud enthusiasts suffer under many divisive influences. We are a multinational assembly; we are drawn from different religious traditions; we are interdisciplinary in our scientific training. But we cannot let these differences divide us on issues, such as conservation, where we clearly have common interests. For this reason, I am asking for patience and cooperation in putting aside petty differences. At the same time, we must rededicate ourselves to the best in our professional tradition. This includes addressing realizable goals and supporting all hypotheses with quantitative arguments and experimental data. It is also vital that we publish our work in the independently reviewed, professional literature before making public announcements. If we can do this, we can avoid further embarrassment before the public and thereby reinstate confidence with the church and possibly even recover some of our lost prestige in the scientific community.

My second request is that we commit ourselves to some long-range objectives and test plans. It is important to a good working relationship with the church that we show steady progress toward well-defined and understandable goals. It is necessary to good science that the Shroud be made available regularly for testing, and I think the church would be far more willing to oblige our needs if we could show obvious direction and progress in our scientific work.

Finally, because of security constraints, the Shroud can only be made available for short periods (7 days or fewer). To maximize the amount of information we can gather in these short intervals will therefore require a high degree of coordination and a minimum amount of redundant effort. Therefore it is necessary that we maintain close communications among ourselves and with church authorities and that we coordinate our work whenever possible.

Church Authorities

On the part of the custodians of the Shroud, the first initiative should be directed toward a conservation effort. Steps were begun in 1969 and 1973, but nothing of any long-range consequence has followed in nearly two decades. A full-scale program of conservation must begin as soon as possible if we hope to preserve the Shroud for coming generations.

I believe the church should encourage and facilitate scientific efforts. Science is grounded in observation, but without more frequent access, we cannot hope to maintain a vital and active area of

scientific inquiry. I therefore suggest that the church adopt an institutional policy for the 1990s and beyond to make the Shroud available for testing every two years. The timetables presented above are based on a test plan whereby the Shroud is brought out for periods of at least 24 hours and at most 7 days in the summers of the even years: 1990, 1992, ... , 2000.

To make the plan workable it is necessary to establish a schedule for reviewing and subsequently accepting or rejecting research proposals. I suggest that proposals be due no later than, let us say, April 1st of the odd years of the next decade: 1991, 1993, ... , 1999. The scientific advisers to the church authorities should then review the proposals and respond to the research candidates by July 1st of the same year. This will allow one full year of preparation and coordination before the next period of testing.

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