The Mystery of the Shroud of Turin Challenges 20th-Century Science

On the face of it, the very idea that the linen cloth in which Jesus Christ was wrapped in the tomb should have survived to this day would seem incredible. It demands even more of human credulity that the cloth bears a photographic likeness which would seem to be that of Jesus as he lay in the tomb. [From *The Shroud of Turin* by IAN WILSON]

The Shroud of Turin is a linen cloth of herringbone weave. It is approximately 14 feet long and 3 feet wide; it bears the anatomically correct image of a crucified man. The Man of the Shroud was about 5 feet 7 inches tall; he had a beard and wore long hair gathered in a pigtail at the neck. He must have been laid on one end of the cloth with the remainder drawn up over his head and across his body to his feet because the Shroud bears his image as seen from the front and from the back (see the painting by Clovio). A pattern of dumbbell-shaped marks on his back suggest he was scourged with an instrument that could have been a Roman *flagra*. What appear to be blood spots ring his forehead; a wound on his right side is a sign he was pierced by a lance.

The Man of the Shroud lies posed in an attitude of death, his hands crossed on his pelvis. Nail holes penetrate the wrists; the mark of a single nail penetrates his feet which lie left on top of right in what has come to be the familiar artistic representation of Christ on the Cross.

The Shroud, nominally owned by Umberto II, the deposed king of Italy who now resides in the resort town of Cascais, Portugal, is kept securely locked in a silver casket in the Royal Chapel of the Cathedral of St. John the Baptist in Turin, where it has been for 400 years.

An enigma embodied in a piece of good linen, the Shroud of Turin has for centuries both been venerated as the manifestation of the resurrection of Jesus Christ and denounced as a cruel fraud. It is known to be at least 600 years old, as there are good records of its first appearance in France in the 1350's, but even then the family that owned it refused to say much about its origins and Church bishops decried it as a forgery. Nevertheless, the Shroud is a remarkable relic of historic, archeologic, and scientific interest.

Two central mysteries surround the Shroud. The lesser is the question of its true age; the greater is the mystery of the image—no one can explain how it was formed. The Shroud, only rarely on public view, has been made available for scientific study even less frequently, and what studies have been conducted have produced only limited data. Nevertheless, on the basis of circumstantial evidence, it is possible to all but rule out some of the more obvious mechanisms of image formation (painting, for example) and to at least speculate that the Shroud was once in Palestine.

A Belgian scientist has reported that bits of cotton that are woven in with the linen fibers are characteristic of cotton used in the Middle East two millennia ago. And the former head of the Zurich Police Scientific Laboratory has found that various particles of pollen on the Shroud are characteristic of pollen from plants that grow only around Palestine.

Armed with 20th-century technology for nondestructive testing of materials and computer enhancement of photographic images, it is also possible to draw up a list of experiments that collectively might reveal the Shroud's true nature. This is precisely what a team of American scientists—including two with a proven track record for exposing artistic forgeries—has done, hopeful that Italian authorities will allow them to travel to Turin to apply the technical prowess of the space age to a relic of the past. Although the Italians have not as yet announced their approval of the scientists' request, there is reason to believe that it is forthcoming. In celebration of its 400th anniversary in Turin, the Shroud will be on public view from 27 August through 8 October. The American team, coordinated by physicist John J. Jackson of the U.S. Air Force Academy in Colorado, may have access to the Shroud after that.

Jackson's first encounter with the Shroud came when he was a teenager. "My mother showed me a picture of it and it made quite an impression on me," he recalls. But his interest lay dormant until years later when, while he was a graduate student at Colorado State University, he read a book about the history of the Shroud by British writer John Walsh. It was 1968; the Mars flyby mission was being planned at the time and computer enhancement of images was coming into its own. Jackson wondered whether computer enhancement would reveal hitherto unknown features of the Shroud. Within 6 years, he would learn

Christ being wrapped in a shroud by Clovio, 16th century. From Wilson's Shroud of Turin, *Doubleday & Company, Inc., 1978.* [*Courtesy of Dom Boscoe Filmstrips*]

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that the answer appeared to be "Yes."

Many of the American scientists who for the past few years have made a professional hobby out of unraveling the mystery of the Shroud say they were "hooked" once it became apparent that the process of image formation defied the ready presumption that modern science could come up with an explanation in no time at all. They range in age and religious affiliation but have in common complementary scientific disciplines—physics, aerodynamics, chemistry, computer enhanced image analysis—and come from like institutions—the Air Force Weapons Laboratory, Sandia Laboratory, and the Los Alamos Scientific Laboratory, all in New Mexico, and the Jet Propulsion Laboratory (JPL) in California. While waiting hopefully for word from Italy, they have been busy conducting preliminary analyses of the image—largely working from existing photographs—and thinking about what they would do if they ever got to see the Shroud in the original, which none of them ever has. They have been working on their own time, with their own money—there are no NASA or NSF grants for Shroud studies—though in some cases they have been granted permission to use their institutions' equipment on a time-available basis. Altogether they number two dozen or so and hope that their collective scientific talents, when put to the test, will reveal (i) the ingenuity of an extraordinarily clever 14th-century forger, (ii) a rare but explicable natural phenomenon, or (iii) the physics of miracles.

The Image as Photographic Negative

Those who have seen the Shroud in the original report that the image, which is a sepia tone with a slightly darker color forming the "blood" spots, is extremely subtle—almost indistinguishable to the unaided eye. British Shroud historian and journalist Ian Wilson writes, ". . . the closer one tries to examine it, the more it melts away like mist."*

But in photographic negative, the image is unmistakable; subtlety sharpens into clarity and the face of the Man of the Shroud is revealed, his features strikingly like those that artists since at least the 6th century have given Christ.

The first photographs of the Shroud were taken in 1898 by a man named Secondo Pia. What astonished Pia, and continues to astonish Shroud scholars, is that the image that appeared on his photographic plate was not a characteristic negative in which light areas are dark, dark light, and left and right reversed. Instead, Pia's negative showed all the qualities of a positive print. The image of the Man of the Shroud showed gradations of tone that gave the body depth and contour. The face had the qualities of a photographic likeness, not the flatness of a negative. Thus, it seems that the Shroud itself must be, or possess some of the properties of, a photographic negative. It is as if the cloth were a piece of film.

Pia's photographs made possible a number of studies of the Shroud and were particularly useful in showing that the image correctly reflects the anatomy of crucifixion (see box on page 238), but they lack the quality of contemporary photography. In 1931, when the Shroud was exhibited in celebration of the marriage of Prince Umberto (now Umberto II), a second set of photographs was taken that includes close-ups of the face and other special features. (Pia's photographs, by contrast, were only of the full image, front and back.) The photographer was a man named Giuseppe Ernie, and his black and white shots are said to be as high quality as any that could be taken today, although he, of course, did not have the range of filters, films, and so forth that will be employed in taking new pictures intended for computer analysis. Nevertheless, it is on the basis of Ernie's fine pictures that existing scientific opinion rests.

The Shroud and Space Age Technology

The American scientists have been actively engaged in sindonology (Shroud study) since 1974, when Jackson first put his idea about computer studies to the test, using negatives of Ernie's photographs supplied to him by the Holy Shroud Guild of the United States† (of which he has since become a member of the board). Those early studies, conducted with Don Devan,‡ an image analysis expert, gave him enough mathematical data to proceed, and in the course of events he recruited many of the others who are now hooked on the mystery of the Shroud. By 1977 there was enough information about the Shroud to justify the first U.S. Conference on Research on the Shroud of Turin, which was held in Albuquerque in March of last year. Among those present was Ray N. Rogers, a thermal chemist and spare-time archeologist from the Los Alamos Scientific Laboratory who is intent on discovering the chemical properties of the image.

1532: The Perfect Thermal Experiment

In 1532 the Shroud was in a fire. It lay folded in a silver casket when the church of Sainte Chapelle in the French town of Chambéry burned. The Shroud was saved, but not before it was scorched by drops of molten silver that left triangular shaped marks along the edges of the cloth. On the basis of the known melting point of silver mixed, as it would have been at the time, with some base metal, Rogers estimates that the temperature within the casket reached 200° to 300°C before the Shroud was doused with water. Thus, a calculable thermal gradient existed and serves as the foundation for certain judgments about the nature of the image.

If the image were composed of an organic pigment or an inorganic pigment in an organic vehicle (Rogers has considered more than two dozen pigments and stains known to have been used by 14th-century artists), it would have been affected by the intense heat. But there is no indication that any of the color has "run" or that its intensity has changed in proportion to the severity of the heating it received. Similarly, if the image were the result of some natural biologic process related to the decomposition of a human body or to the aloes (oils) and spices with which it was anointed, those products too can be expected to be affected by the heat. Says Rogers, "If large, complicated, natural-product, organic molecules were responsible for the image, they should have decomposed, changed color, or volatilized at different rates depending on their distance from the high-temperature zone during the fire. There is no evidence for any variation at all."

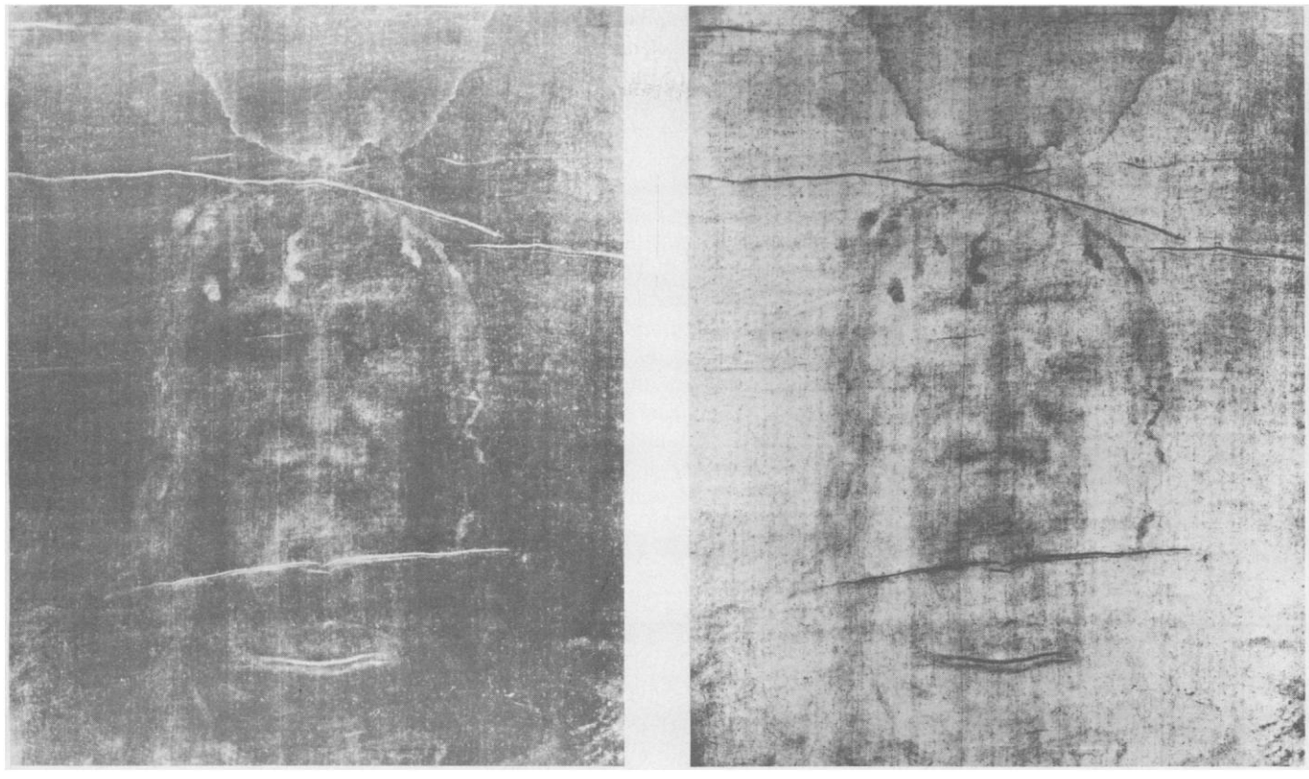
An additional strike against the hypothesis that the image is a painting or a stain is the observation that the color appears only on the surface of the linen without any penetration of the cellulose fibers. But this observation, first reported by individuals who examined the Shroud in 1973, needs to be confirmed.

Rogers says that if the image was painted, "a stable, particulate, inorganic pigment in a water base had to have been used." Detection of appropriate pigment metals would not prove that the image was painted; however, the painting hy-

*For more detail about the Shroud, especially with respect to historical evidence that it may have come from Palestine, see *The Shroud of Turin* by Ian Wilson; Doubleday, 1978.

†The U.S. Holy Shroud Guild can be contacted through Dr. Jackson, 2858 Keystone Circle, Colorado Springs, Colo. 80918.

‡Don Devan, in a paper presented at the first U.S. conference on Shroud research (1977), describes image enhancement as a computer process that sharpens blurred images or exaggerates subtle differences in gray shade or color value or removes background "noise"—for instance, the herringbone weave of the cloth—to enhance visualization by eye. Image analysis, on the other hand, involves the measurement of some property of the image that can be converted into a number. It can, for example, tell in numerical terms how sharp an edge is in terms of how quickly color value changes over a given spatial distance.



The Man of the Shroud in photographic negative (left) and positive. [Photos from the U.S. Holy Shroud Guild]

pothesis could be conclusively disproved by demonstration of the absence of any inorganic pigment. Rogers says that the best nondestructive test for its presence or absence is x-ray fluorescence.

Joseph S. Acetta of the Air Force Weapons Laboratory is the team's fluorescence expert. Because all elements have characteristic emission spectra when excited by x-rays, fluorescence data should yield information about the chemical composition of the image and of the so-called blood spots. Preliminary fluorescence work shows that the image itself, the burn marks, and the blood spots all fluoresce—a finding that has led to some skepticism about the blood because blood does not fluoresce. If the scientists are allowed to conduct x-ray fluorescence studies of the Shroud, one thing they will look for in particular is any evidence of trace elements of blood in the appropriate regions of the cloth.

Donald J. Lynn and Jean J. Lorre at JPL were introduced to the problem of the Shroud in the spring of 1976, when they were deeply involved in computer enhancement of photographs being sent back to earth from the Viking Mission to Mars. Nevertheless they agreed to do some enhancement studies of the Shroud during what they euphemistically called their "spare time." "We didn't exactly have a lot of it," Lynn recalls.

Working with negatives and slides provided by Jackson, Lynn and Lorre proceeded with two objectives: (i) "to enhance various characteristics of the image in order to present to the eye as much detailed structure . . . as possible," and (ii) "to reveal any information about the intrinsic structure of the image which might indicate the way in which it was formed." Using a microdensitometer that registers variations in density, the film was scanned and converted into an array of numbers (image density could be measured at 256 discrete levels) that could be read and manipulated by a digital computer. Next, they processed the digital image, which was recorded on magnetic tape, on the IBM 360/65 computer that was developed by JPL's Image Processing Laboratory to support NASA's planetary exploration program. Finally, the digital image was recorded on film. From there, the two image enhancement specialists manipulated their computer images to see what the computer could see that they could not. They got some interesting though tentative results. (Image enhancement, it should be noted, is not an infallible technique.)

For instance, they found that "The water marks and the numerous small intense features on the body have abrupt edges, whereas the large burn marks have smoothly decaying edges. This suggests a different mechanism of formation for the two types of features." In addition, analysis of the facial region revealed that the image is "composed of a wide range of spatial frequencies which are oriented in a random fashion. This indicates that the feature-generating mechanism was probably directionless (a characteristic which would not be consistent with hand application)."

While Lynn and Lorre were conducting image analysis experiments, Jackson, his Air Force Academy colleague Eric J. Jumper, and Sandia image analyst William Mottern were exploring the Shroud in 3-D. Early on, a French biologist named Paul Vignon had noted that the intensity of the image appeared to vary inversely with what one would assume to be the distance between the body and the cloth, the nose, for example, being more intense than the hair. Jackson decided to test that hypothesis mathematically with the aid of highly sensitive image recording equipment. To begin with, they created a full-scale model of the Shroud by tracing the image from a photographic projection onto a piece of cloth. Then, using an Air Force volunteer who matched the height and general build of the Man of the Shroud as a model, they draped their shroud over him and, from a set of photographs, measured the cloth-body distance from the ridge line of the cloth model. (The ridge line indicates the body's highest points of contact with the Shroud.) Scanning the image with a microdensitometer to record variations in intensity, they pro-

ceeded to measure image intensity along the ridge line and correlate that with cloth-body distance. "It is apparent that a definite correlation exists," Jackson says, explaining that this means that the image on the Shroud contains three-dimensional information about the body it covered.

Evidence to support the 3-D hypothesis came when Mottern, using Interpretation System's VP-8 Image Analyzer, which converts shades of light and dark to vertical relief, produced a three-dimensional recreation of the Shroud image. The researchers pointed out the significance of this finding in their 1977 paper for the Albuquerque conference. ". . . [O]rdinary photographic images cannot usually be converted to true three-dimensional reliefs," they said. "The photographic process does not cause the objects filmed to become exposed in inverse relationship to distance from the camera; hence, three-dimensional information is not usually recorded onto film. Only when the degree of illumination received from an object depends, in some way, upon its distance (for example, in a stellar photograph), would three-dimensional analysis and reconstruction be possible (by the VP-8 Image Analyzer)." To illustrate their point, they produced a three-dimensional relief of a photograph of Pope Pius XI; the nose appears distorted and looks pushed into the face, the arms seem to be pushed into the chest, and the "entire relief appeared flat and unnatural." By contrast, in a three-dimensional relief of the face of the Shroud, features appear correctly defined.

Jackson and his colleagues believe that the three-dimensional quality of the image on the Shroud suggests strongly that the image-forming process did not depend on direct contact with the body and that, whatever it was, it acted uniformly on both sides of the body. This, too, mitigates against any hypothesis that the image was painted, as, Jackson believes, does another feature of the image that was first revealed by his experiments. There appear to be button-like objects placed over the eyes of the Man of the Shroud which, on preliminary analysis, seem to be coins. (Ancient burial customs include the placing of coins or potsherds over the eyes of the deceased.) To Jackson's mind, the coins over the eyes, if that's what they turn out to be, could contribute to evidence of the authenticity of the Shroud, especially if it is possible, with new photographs of the eye region, to identify markings on the objects.

Jackson and his colleagues conclude:

> If the identification of these images as solid objects over the eyes is correct, then another significant aspect of the image forming process comes to light: whatever process formed the image had to have acted the same way not only over the body and hair, but also over presumably organically inert fragments situated atop the eyes. This conclusion, we believe, is of significance, for it places great restrictions on the possible image formation process. In short, three-dimensionality implies that the image forming process acted uniformly through space over the body, front and back, and even seemed to act independently of the type of surface, organic and inorganic, from which the image was generated.

Speculation

How, then, might the image have been formed? There is no uniform view among the scientific team; indeed, many are unwilling to even speculate. But Jackson, Jumper, and Rogers say the best guess is that the image was caused by a scorch, which would account for several properties of the Shroud. For example, scorch marks fluoresce; so does the shroud. They would not be affected by heating, as in the fire of 1532. They make sense with respect to the sepia color of the image. However, as Jackson notes, one problem with the scorch hypothesis is the clarity of the image of the Man of the Shroud—the incredible detail. Various attempts have been made to produce an image by scorching cloth with a variety of instruments from a mercury lamp to a laser beam (Rogers recently spent days searching the Los Alamos–Albuquerque area for yards of pure linen for some experiments) but so far no one has managed to create a clear image, though they can reproduce the general color of the image on the Shroud.

In any event, the real drawback to the

The Anatomy of Crucifixion

Since the early 1900's, the Shroud has attracted the attention of biologists interested in the anatomy of crucifixion. Among the first to approach the problem were Paul Vignon, a French biologist, and Yves Delage, an anatomy professor at the Sorbonne. In 1902, Delage gave a lecture to the Paris Academy of Sciences in which he reported that the image appeared to be in every respect anatomically correct. Although *The Lancet* critiqued his paper as being sound, Delage's peers at the Academy did not think much of it and refused publication. Subsequently, Delage wrote: "If, instead of Christ, there were a question of some person like a Sargon, an Achilles or one of the Pharaohs, no one would have thought of making any objection. . . . I recognize Christ as a historical personage and I see no reason why anyone should be scandalized that there still exist material traces of his earthly life."*

Physicians and anatomists in England, Italy, Germany, and the United States who have examined the image all come to the same conclusion—anatomically, it fits. Of particular interest is the observation that the nail marks penetrate the wrists rather than the palms, as is characteristic of most artistic portrayals of the crucifixion. The weight of a human body could not be supported by nails through the palms, whereas it could be held by nails through the muscles of the wrists. Those gathering evidence in support of the authenticity of the Shroud claim that a forger would have to know a lot about crucifixion to be clever enough to produce such an anatomically accurate representation.

On the other hand, art historians have used the placement of nails to argue the opposite—that the Shroud is a fraud. Generally speaking, artistic representations of the crucifixion showing Christ with one nail penetrating both feet date to the 13th and 14th centuries, after which they became common. But in earlier art, crucifixion portraits show four nails, one in each foot. Erwin Panofsky, the renowned art historian, makes reference to the Shroud in a note in *Early Netherlandish Painting* (vol. 1, p. 364), challenging its authenticity. Rejecting the proposition that the Shroud was the model of "the three-nail type" of representation, Panofsky writes, ". . . there is, so far as I know, no evidence that *any* Shroud reached France before the middle of the fourteenth century when the specimen now venerated at Turin made its appearance in the Collegiate Church at Lirey. . . ." He adds that, to his knowledge, the "only Shroud to show Him with His feet crossed is the late specimen at Enxobregas near Lisbon, manifestly influenced by the then generally accepted type of Crucifix."

*Quoted in *The Shroud* by John Walsh (W. H. Allen, London, 1963).

scorch hypothesis lies in postulating the source of the heat which would have had to have acted uniformly on both sides of the body to account for the fact that the front and back images seem to be equally intense. Jumper wrote that radiation occurring in a "very short molecular 'burst' " of "around 3 sec" could be the mechanism of image formation. Rogers talks of "flash photolysis," a short, intense burst of light. But neither has any plausible notion of what the source of the radiant energy might have been.

Plans for Turin Experiments

Given the hubris of contemporary science, it is not surprising that the Shroud researchers are confident that, given time enough, they can explain how the image of the Man of the Shroud came to be. In anticipation of permission to conduct some experiments, they are already preparing for Turin. A giant frame with soft magnets is being built at an estimated cost of $20,000 to hold the Shroud. Equipment is being assembled, much of it on loan. Thought is being given to every detail, right down to the problem of electrical outlets and current. Because a number of scientists would be conducting experiments either simultaneously or in close succession, the "choreography" of the tests must be worked out.

In addition to x-ray examination, they would like to study the Shroud with infrared radiation and expose it to extensive high-resolution photographic coverage, using a variety of films and filters and techniques to get pictures ideally suited to computer analysis. Rogers would like to be able to take what he calls "surface transfer samples" of some areas of the image, using pure hydrocarbon tape that contains no reactive moieties, for subsequent chemical identification of the image composition.

And a man named Walter McCrone of McCrone Associates, Inc., in Chicago, hopes to approach the Shroud as an expert in small particle identification. McCrone is one of the few scientists to become involved in the Shroud study independently of the John Jackson connection. It was McCrone who, a few years ago, proved that Yale University's "Vinland Map"—supposedly a map of the new world that predated Columbus—was a fraud by showing that one of its pigments contained a synthetic chemical first made in the 1920's. After that, British sindonologists asked him if he'd be interested in the Shroud.

McCrone wants to "vacuum" the Shroud with a "microvacuum cleaner" that would pass air through the cloth to a filter that would collect particles whose chemical composition he could then determine back in Chicago with a new machine for micro-Raman analysis. The instrument, which focuses a laser through a microscope at particles as small as 10^{-12} gram, reveals molecular composition through characteristic Raman spectra, which McCrone says are related to the infrared spectra. He can use it to identify organic and inorganic substances and told *Science*, "If it has atoms, we ought to be able to tell what it is."

Eventually, McCrone hopes to receive permission to apply carbon-14 dating to the Shroud, from which a few threads, now in the custody of Italian authorities, have already been removed. Current carbon-14 techniques require a larger sample of material than is possible to take from the Shroud, but McCrone anticipates the availability of new methodology that makes use of a linear accelerator and can accurately date a sample as small as a 1-centimeter length of a single thread.

And so it seems likely that modern science and religion may soon meet in a cathedral in Turin, with no outcome guaranteed. The circumstantial case for the Shroud's authenticity, while intriguing, is hardly compelling. In light of the fact that it has been largely inaccessible to scientific researchers, it must be noted that some of the existing "data" about its features could prove to be incorrect; in any event, no final judgment will be possible until the cloth is accurately dated and carbon-14 dating is at least a couple of years away. Furthermore, it could turn out that sophisticated scientific examination will reveal new information that explains how the image was made.

Still, Rogers, in a philosophical frame of mind muses, "What better way, if you were a deity, of regenerating faith in a skeptical age, than to leave evidence 2000 years ago that could be defined only by the technology available in that technical age?"—BARBARA J. CULLITON

Britain's National Health Service: It Works and They Like It, But—

The British are marking the 30th anniversary of the National Health Service (NHS) this summer, and the occasion has been marred somewhat by recognition that the NHS is in trouble. Earlier this year, for example, spokesmen for the British Medical Association warned that a dispute over pay could lead to mass resignations by NHS physicians. The threat now seems to have been less of a forecast of action than an expression of discontent, but the NHS faces financial, administrative, and ideological issues serious enough to have prompted creation of a Royal Commission on the National Health Service, which is expected to report in the spring of 1979.

During its three decades, the NHS has been a topic of keen interest and controversy in the United States. Opinion here has ranged between the views of those who see the NHS as proof of the perniciousness of "socialized medicine" and those who regard it as a desirable alternative to the American health care system. Recently, with the discussion of national health insurance plans for the United States on the upswing, the NHS has been getting more attention here.

Perhaps the first thing an American interested in the NHS must do is come to grips with the paradox of British attitudes toward their own health system. While even the most ardent supporters of the NHS concede that it has major shortcomings, opinion polls consistently show public approval of the NHS to be overwhelming. And although physicians as a group have been the strongest and most persistent critics of the NHS, only a very small minority practice outside the health service or, indeed, oppose it in principle.

Advocates for the NHS tend to stress that, in marked contrast to the United States, no one in Britain is afraid of being sick because of the cost of care. The quality of acute care in Britain is generally acknowledged to be high and the British seem to have done a relatively good job of ensuring patients' access to the health care system via a large corps of

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