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MEASURING: Dating the Shroud of Turin

The Shroud of Turin, which many people believe was used to wrap Christ's body, bears detailed front and back images of a man who appears to have suffered whipping and crucifixion. It was first displayed at Lirey in France in the 1350s and, after many journeys, was finally brought to Turin in 1578 where, in 1694, it was placed in the Royal Chapel of Turin Cathedral in a specially-designed shrine.

There have been several scientific investigations of the Shroud, usually with the purpose of establishing its authenticity. The first modern study was carried out in 1898 using photography, and other investigations were done in 1969, 1973 and 1978. The latest investigation, involving laboratories at Arizona, Oxford and Zurich, used very small samples (*ca* 50 mg) of the Shroud for radiocarbon dating based on accelerator mass spectrometry; these samples were taken from the Shroud on the morning of April 21, 1988, in the presence of appropriate witnesses. Three *control* samples were also supplied to each laboratory; the sampling and distribution to representatives of the laboratories were fully documented by video film and photography.

The laboratories were not told which of their four samples was that of the Shroud but, due to its distinctive weave, a laboratory could identify the Shroud sample. Because the Shroud had been exposed to a wide range of potential sources of contamination and on account of the uniqueness of the samples available, it was decided to abandon blind-test procedures in the interests of effective pretreatment. [If the identity of the samples had been obscured by unravelling or shredding them prior to distribution, pretreatment would have been more difficult and wasteful.] However, the three laboratories undertook not to compare results until after they had been transmitted to the British Museum; also, at the Oxford and Zurich laboratories, after combustion to gas, the samples were recoded so that the staff making the measurements did not know the identity of the samples.

The three control samples, the approximate ages of which were made known to the laboratories, were as follows, where **C1** was in the form of threads and **C2** and **C3** were whole pieces of cloth:

C1: Threads removed from the cope of St. Louis d'Anjou which is held in the chapel of the basilica of Saint-Maximin, Var, France. On the basis of stylistic details and the historical evidence, the cope is dated at about 1290-1310 AD (reign of King Phillipe IV).

C2: Linen from a tomb excavated at Qasr Ibrîm in Nubia by Professor J.M. Plumley for the Egypt Exploration Society in 1964. On the basis of the Islamic embroidered pattern and Christian ink inscription, this linen is dated to the eleventh to twelfth centuries AD.

C3: Linen from the collection of the Department of Egyptian Antiquities at the British Museum, associated with an early second century AD mummy of Cleopatra from Thebes. This linen was dated in the British Museum Research Laboratory, by other radiocarbon methods, at about 110 BC to 75 AD.

As indicated in the following summary, the subsampling and pretreatment of the four samples in each laboratory had significant common elements but some differences; the summary does *not* show all differences in reagent concentrations, temperatures and treatment times, which are detailed in the left-hand column on page 613 of the original article. The pretreatment codes (a, b; u, b; u, w, s), used in the summary and in the schema overleaf on page HL35.2, are those in the article.

- **Arizona** (4 subsamples)
  - a — Acid, water, alkali, water, acid
  - a — Acid, water, alkali, water, acid
  - b — Detergent 1, water, acid, detergent 2, alcohol (Soxhlet extraction), water (ultrasonic)
  - b — Detergent 1, water, acid, detergent 2, alcohol (Soxhlet extraction), water (ultrasonic)
- **Oxford** (3 subsamples)
  - u — Acid, water, alkali, water, acid
  - b — Acid, water, alkali, water, acid, bleach
  - b — Acid, water, alkali, water, acid, bleach
- **Zurich** (5 subsamples) — Water (ultrasonic)
  - u — (no further pretreatment)
  - w — **Weak**: acid, water, alkali, water, acid
  - s — **Strong**: acid, water, alkali, water, acid
  - w — **Weak**: acid, water, alkali, water, acid
  - s — **Strong**: acid, water, alkali, water, acid

Acid = HCl
Water = Distilled water
Alkali = NaOH
Detergent 1 = 1.5% SDS
Detergent 2 = 1.5% Triton X-100
Alcohol = EtOH
Bleach = NaOCl (2.5%, pH 3)

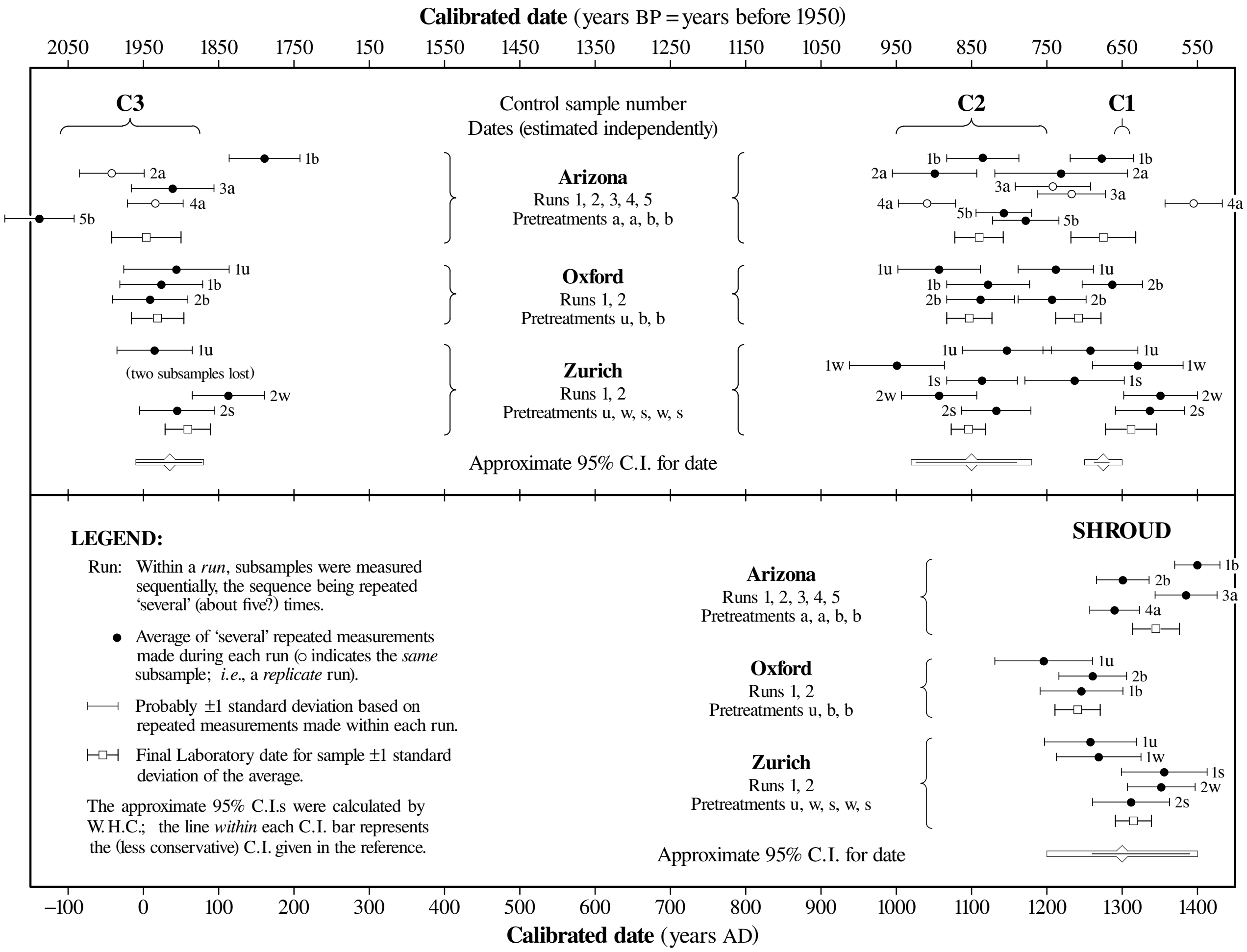
Each laboratory performed independent measurements on their 4, 3 or 5 subsamples of each of the four samples over a time period of about one month; more details are given overleaf on page HL35.2 in the schema Legend. The basic data generated in the investigation (*e.g.*, in Tables 1 and 2 on pages 612 and 613 of the original article) are sample radiocarbon ages given as 'years BP,' meaning 'years before 1950,' but a 'calibration curve' must be used to convert radiocarbon ages to *calendar* dates;

REFERENCE: Damon, P.E. *et al.*: Radiocarbon dating of the Shroud of Turin. *Nature* **337** (16 February): 611-615 (1989).

The *Nature* article summarized above in this Highlight #35 is also used in Figure 2.10 in the STAT 220 Course Materials and in Figure 6.5 in the STAT 231 Course Materials.

(*continued overleaf*)

these corrected (or actual) dates are referred to as 'calibrated dates', either BP or AD. In producing the schema below, which is a graphical portrayal of information in the three Tables and the Figure in the article, the (relatively small) correction factors used are 49 for sample C3, 87 for C2, 47 for C1 and 41 for the Shroud; these values appear to be close to those used in the article (*e.g.*, as the basis of Table 3 on page 614).



1. On the basis of the information presented in the schema above, which Laboratory would you identify as being most realistic in its assessment of the uncertainty in its results? Give your reasons briefly.
   - In general, do your think investigators are more prone to *over-* or *under*estimate the uncertainty in their results? Briefly justify your choice.

2. On the basis of the information presented in the schema above, which Laboratory do you consider to have produced the 'best' result for each sample? Explain briefly in each case.
   - If you had to choose *one* of the three Laboratories to carry out a future investigation of this nature, which would you select? Briefly justify your choice.

3. It is desirable that the Plan for the investigation be such that the data yield information on the variation introduced into the results by the following *six* factors: sample, laboratory, subsample, pretreatment, run, measuring process. Describe briefly how well the Plan achieves this objective.
   - What are the consequence(s) of any deficiencies you identify in this component of the Plan?

4. Describe briefly what the data suggest about the effect(s) of the pretreatments of the subsamples.
   - If a similar investigation were to be carried out in future, which pretreatment(s) would you recommend? Justify your choice briefly.

5. Comment briefly on any *un*desirable feature(s) of the single-letter codes used for the pretreatments.
   - Suggest a brief explanation for how these undesirable feature(s) arose.