gun. These followed the psychophysical method of limits. The threshold was the mean of ten ascending and ten descending series for each subject. These were obtained in two sessions, one in the morning and the other in the afternoon.

Two criteria of "threshold" were used. In one, the subjects were required to report when they could perceive a change in the thermal sensation produced by a change in the stimulator temperature. These thresholds appear in Fig. 1 as open squares and are henceforth referred to as the "just noticeable difference" (jnd) thresholds. The other criterion required the subjects to identify the sensation as being either warm or cool. These thresholds are shown by filled squares in Fig. 1 and are referred to as absolute thresholds.

Two males, ages 21 and 38, and two females, ages 20 and 26, were the subjects in these measurements. None of the subjects had any known physical defects which might impair their sensitivity to temperature changes. Each subject had received more than 30 hr of practice in making the discriminations prior to threshold measurements. The thresholds of the subjects were averaged, except the thresholds to temperature reductions at adapting temperatures above 33°C. Here the males (curve 1) and females (curve 2) differed so markedly that they were plotted separately.

Figure 1 shows that the just noticeable difference curves follow those of the absolute thresholds throughout most of the range of adapting temperatures. However, the thresholds to temperature increments diverge at low adapting temperatures, while those obtained from temperature decrements diverge at high adapting temperatures. This suggests a change in the conditions of measurement, which appears to be related to the degree of sensory adaptation experienced by the subjects at the various adapting temperatures. All the subjects failed to adapt completely (complete loss of thermal sensation) to temperatures below 33°C. Additional time did not change the level of adaptation. The subjects invariably reported a persisting cool sensation. Increments in the stimulator temperature of 0.4°C could be detected as a change (just noticeable difference threshold). Considerably greater changes had to be produced for the subjects to identify the change as "warm." Increments in the stimulator temperature of greater than 0.4°C, but less than that required to produce a sensation of warm, were identified as "less cool."

When the subjects were adapted to temperatures greater than 33°C, increments in the stimulator temperature were readily detected and no differences were observed between the just noticeable difference and the absolute thresholds.

The female subjects reported complete sensory adaptation to higher temperatures (41°C) than males did (36°C). The thresholds obtained by decrements in the stimulator temperature started to diverge at these points. At higher adapting temperatures a persisting warm sensation was experienced throughout the threshold measurements. While decrements in temperature of as little as 0.6°C could be detected, they did not result in a cool sensation; much greater changes were required. Changes of more than 0.6°C, but less than that required to produce a cool sensation, resulted in reports of "less warm."

In general, these data show that small rapid changes in skin temperature produce sensations appropriate to the direction of the temperature change. However, when the skin temperature is low, small increments can be detected, but result in sensations of less cool. Larger elevations are required to produce a sensation of warm. When skin temperature is high, sudden small reductions can also be perceived but are sensed as less warm. Larger changes are required before cool is experienced.

The elevations of the absolute warm threshold at low adapting temperatures and the absolute cool threshold at high adapting temperatures are indicative of the manner of operation of the thermal receptors. Two explanations appear possible at this time. First, the variations in thermal thresholds observed here may have resulted from changes in the thermodynamics of the tissue due, perhaps, to the greatly altered cutaneous blood flow in response to the temperature to which the skin is adapted. If tissue thermodynamics were the only consideration, one would expect that the just noticeable difference threshold, as well as the absolute threshold, would be altered equally. It is obvious that this is not the case. It might also be expected that both the warm and cool absolute thresholds would be affected at both extremes of the adapting temperature. A second explanation must be entertained—that of altered receptor sensitivity resulting from the temperature at which they are required to operate. Kenshalo and Nafe (*3*) have reviewed a theory of thermal reception, presented earlier by Nafe (*4*), which is based on the direct action of thermal energy upon the smooth muscle of the cutaneous vascular system. It predicts changes in thermal sensitivity associated with changes in the skin temperature.

D. R. KENSHALO
JOHN P. NAFE
BARBARA BROOKS

Department of Psychology, Florida State University, Tallahassee

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Dating Desert Ground Water

Abstract. Tritium in Arabian rainfall has followed the trend observed in North America with peaks in 1958 and the spring of 1959. These measurements will be useful for future hydrologic studies. Water from wadi gravels averages 10 yr old. Carbon-14 measurements of deep waters indicate ages of several thousand years.

Samples of water collected by the Arabian American Oil Company in the course of field operations in Saudi Arabia during the past 2 yr were made available for analysis in the tritium and carbon-14 laboratories of the U.S. Geological Survey to help evaluate the use of the radioactive isotopes in studies of desert ground water.

Some of the samples of deeper ground water tested for tritium indicated an age (time since exposure to atmospheric supply) older than the limiting time span of about 50 yr measurable by this technique. However, values of 3.7, 3.8, and 5.2 tritium units (T atoms per 10^{18} H atoms) with a possible error of $\pm$ 0.5 came from three samples from "wadi" gravels in the central region of the Arabian peninsula, from which the age of waters in the lower part of a great incised dendritic drainage system seems to be on the order of 10 yr (as of 1958), unless fallout from 1952–54 hydrogen bomb explosions had spread into the system. The location of the wells, the

Table 1. Precipitation data.

Sample No.	Date	Tritium units* (av. error, ± 8 percent)
	Dhahran	
352	5–6 March 1959	112
	Near Dhahran	
353	7–8 March 1959	96
354	7–8 March 1959	124
	Rub' al Khali area, showers	
420	25 May 1959	63
423	25 May 1959	69
421	26 May 1959	59
422	26 May 1959	54
	Rub' al Khali area	
604	1 January 1960	20
606	3 November 1960	18

* Tritium atoms per 10^{18} hydrogen atoms.

presence of calcium carbonate cement in the upper part of the gravel fill in downstream gorges, and the distances up-wadi to where slopes of stream beds are above grade lead us to believe that there was no man-made tritium in these waters. On the other hand, water from a large open dug well in Wadi Aleysan at Riyadh tested 8.9 tritium units, evidently indicating a mixture of more recent tritium-enriched water with older water seeping out of the gravels in the walls of the well. A year later, rain samples from the Persian Gulf and Rub' al Khali regions gave values up to 124 tritium units, which correspond to the Northern Hemisphere spring tritium peak observed elsewhere. Later rains show the tritium-level decay characteristic of later 1959 and 1960. Tritium values for precipitation are given in Table 1. The value of the large increase in tritium from bomb fallout in infrequent desert rainstorms remains to be evaluated, but certainly age determinations of water in the shallow gravels of the desert will have to be checked by other methods during the next several years.

The C^{14} determinations give hope of widespread use for dating older and deeper desert waters. Six samples consisting of the bicarbonate and CO_2 extracted from deep water samples (Table 2) were analyzed for C^{14} content to determine the time since their precipitation as rainfall. The waters came from aquifers more than 1200 ft below the land surface at the wells. The distances from the outcrop of the aquifers to the wells range from 24 to 250 km.

The method of dating ground waters by their C^{14} content has been applied in the German till plains by Brinkman *et al.* (*1*). The age computations made by Brinkman and his co-workers of the water in this humid carbonate-rich area are based on an initial C^{14} content of 85 percent of modern wood. This subtracts approximately 2000 yr from their dates. In the low-latitude deserts, it is believed that the rainfall, episodic and often violent in nature, adds water directly to the nubian-type sandstones and dunes above the sandstones without uptake of "dead" carbonate. For this reason, the ages of these samples were computed on the basis that the initial C^{14} was the same as that of contemporary wood, or more exactly, 95 percent of the National Bureau of Standards oxalic acid C^{14} standard. The uptake of "dead" carbon by the solution of limestone during transport of the water through the aquifer would tend to be inhibited by the increased temperature (decreased CO_2 solubility) as measured by the geothermal gradient. The ages for the deep artesian waters at Buraida, Riyadh, Khurais, and Abqaiq range from 20,400 to 24,760 yr. This time span is of the same order of magnitude as an estimate of 18,500 yr for the water to move from the outcrop to Abqaiq, as calculated by Whitman Dimock of the Arabian American Oil Company from pumping test data and broad assumptions of aquifer coefficients (*2*). The climax of the Wisconsin glacial stage occurred at about this time, and the high rainfall during this pluvial period must have charged the aquifers. The ages greater than 33,000 yr for the water samples from the western Rub' al Khali may be due to old carbonate taken up from the carbonate rocks in the Yemen highlands and the calcareous loess east of the highlands, or they may be the true age of the water there, which would have fallen as rain during the early Wisconsin glacial stage (*3*).

Table 2. Carbon-14 ages in deep waters of Saudi Arabia. WW, water well.

Sample No.	Water well	Depth of sample (ft)	Age of aquifer	Min. distance to outcrop (km)	Water Temp. (°F)	Water Age (yr)
W-904	Town well, Buraida	1250	Cambrian and Ordovician	24	100	20,400 ± 500
W-889	Riyadh, WW 180	3647 to 3974	Triassic or Jurassic	60	126	24,630 ± 500
W-897	Khurais, WW 8	1490 to 1693	Cretaceous	70	80	20,760 ± 500
W-894	Abqaiq, WW 32	3003 to 3402	Cretaceous	250	134	22,500 ± 500
W-888	St. WW 7	1617 to 3035	Jurassic and Cretaceous	75	100	> 33,000
W-887	St. WW 13	3435 to 3506	Permian	200	98	> 33,000

LELAND THATCHER
MEYER RUBIN
GLEN F. BROWN

U.S. Geological Survey, Washington, D.C.

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Haptoglobin and Transferrin Gene Frequencies in a Navajo Population: A New Transferrin Variant

Abstract. The distribution of serum haptoglobin, transferrin, and ceruloplasmin has been studied by starch gel electrophoresis for a Navajo Indian population in Arizona. Only the three common haptoglobin phenotypes were observed, but a high percentage of a new faster-moving transferrin variant B_{0-1} was discovered. No unusual ceruloplasmins were found.

The development of starch gel electrophoresis and the subsequent discovery of the genetic basis of human serum haptoglobin types (*1*) have led to an unprecedented proliferation of gene frequency estimates for the two common haptoglobin alleles in numerous population groups. In the comparatively short period of 5 yr, the world haptoglobin map has been rapidly filled. As tabulated by Sutton *et al.* (*2*), the Hp^1 frequency ranges from a low of .09 for Malaya Indians to a high of .87 for Nigerian Negroes and of .93 for Lacandon Indians in Central America. An interesting feature of the haptoglobin map is the progressive increase in Hp^1 frequency from Southeast Asia via Alaska and North America to Central and South America.

A genetic basis has also been established for the inheritance of human