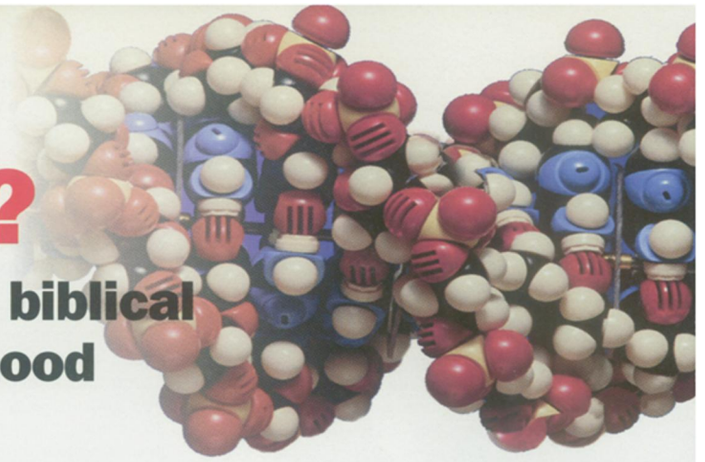
The Priests' Chromosome?



DNA analysis supports the biblical story of the Jewish priesthood

By JOHN TRAVIS

A bit more than 3 years ago, while sitting in a synagogue in Toronto, Karl Skorecki looked at some of his fellow worshippers with curiosity.

Like several others in attendance that day, Skorecki, then a kidney disease researcher at the University of Toronto, considered himself a cohen, which is Hebrew for priest. According to biblical accounts, after the Jewish exodus from Egypt, Moses' brother Aaron was selected as the first cohen. The designation was also given to his sons, providing the basis for a firmly entrenched Jewish tradition in which a male cohen bestows the status upon his children. A daughter of a cohen can become a priest, but she cannot pass on the honor.

Like all cohanim (plural of cohen), Skorecki has no proof that he belongs to the priesthood other than the word of his father and his father before him. As he sat in the synagogue years ago, Skorecki wondered whether he had anything besides this oral legacy in common with the other cohanim he knew.

The answer, he realized, could reside in his DNA. The Y chromosome passes solely from father to son, exactly like the cohen status. If all modern cohanim were indeed descendants of Aaron, or a relative of him, their Y chromosomes should have an ancient common origin, explains Skorecki, who is now at the Technion-Israel Institute of Technology in Haifa.

Two recent studies by Skorecki and several of his colleagues find that the cohanim indeed have some Y chromosome features distinct from other Jews. This shared genetic material, moreover, may stem from an ancestor who lived several thousand years ago, roughly the time estimated for the beginning of the Jewish priesthood.

Calling the results "powerful," Laurie Zoloth-Dorfman, director of the Jewish studies program at San Francisco State University, compares their impact to her experience when she visited Jerusalem for the first time and laid her hands on the Western Wall of the Second Temple that she had read about in the Old Testament.

"It's to me an extraordinarily moving and intense experience of history and sacred history coming together," she says. "I think the [Y chromosome research] does the same thing genetically. It's a tangible, embodied moment of connection to our past."

For several centuries, starting about 3,000 years ago when the First Temple of Jerusalem was built, the cohanim played a leading role in the Jewish community. Today, rabbis have taken over as the teachers and authorities of Jewish religion and law. They acquire their place through religious training rather than through heredity.

The cohanim still often play a special role in worship services, such as being the first to read from the Torah. They also may recite blessings at Jewish festivals.

While anyone can claim to be a cohen and would likely draw no challenge, the priesthood's few remaining privileges are countered by obligations. Cohanim cannot get married to widows, divorcees, or anyone from outside the Jewish faith, even converts. Moreover, they can't attend most funerals, because contact with the dead would contaminate their religious purity.

"There are real restrictions to those cohanim who follow the traditions. Surprisingly, many do, even individuals who might not be observant in other respects," says Skorecki.

To explore the origins of the cohanim, Skorecki turned to an area of research called genetic archaeology, or genetic anthropology. Until recently, this discipline has focused on mothers, not fathers. That's because when sperm fertilize eggs, snippets of genetic material known as mitochondrial DNA are passed on only from the mother to the embryo. For reasons still unexplained, a sperm's mitochondrial DNA is lost (SN: 1/25/97, p. 58).

Making use of this oddity, scientists have studied variations in mitochondrial DNA to reconstruct the evolution and movement of people. In the 1980s, for example, such an analysis reinvigorated the controversial African Eve hypothesis, which traces human origins to a small group of people living some 200,000 years ago in Africa.

More recently, researchers have turned to the Y chromosome to conduct similar investigations (SN: 5/27/95, p. 326). Although the other 22 human chromosome pairs swap DNA in the creation of sperm and eggs, the Y almost completely refrains from exchanging genetic material with its counterpart, the X chromosome. Consequently, a man's Y chromosome retains a largely unsullied DNA history of his male ancestors.

Hoping to tap this genetic gold mine, in 1996 Skorecki contacted Michael F. Hammer of the University of Arizona in Tucson, who has used the Y chromosome to investigate the origins of people in Japan (SN: 2/15/97, p. 106) and elsewhere. Working with colleagues at University College London, Skorecki and Hammer obtained DNA samples of 188 Jewish men from Israel, Canada, and the United Kingdom, 68 of whom called themselves cohanim.

The scientists focused on two genetic markers on the Y chromosome. The most striking data came from an Alu element, a short DNA sequence that has the ability to copy itself and insert the copy elsewhere in the same or a different chromosome.

About 1 million Alu elements litter the human genome. In his past work, Hammer has studied an Alu sequence that in some men sits at a particular site on the Y chromosome. The sequence, designated YAP, jumped to this chromosomal home so recently in human evolution that only a portion of the population has it. So, by examining whether individuals and populations are either YAP-positive or -negative, researchers can model historical relationships and migrations.

The investigators found that fewer than 2 percent of the cohanim studied were YAP-positive, while more than 18 percent of the other Jews possessed this Alu element. The scientists also asked those providing the DNA samples whether they were Ashkenazim or Sephardim. These two Jewish communities split nearly 2,000 years ago, some time before the fall of the Second Temple of Jerusalem. Modern Ashkenazim descend from a population that settled in eastern Europe and Germany hundreds of years ago, while today's Sephardim trace their origins to Jews residing in North Africa, Spain, and Portugal around

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the same time.

Despite the geographical isolation of these two populations, the researchers found that 15 to 20 percent of lay Jews in each group have a YAP element, while cohanim of both groups rarely do. In fact, none of the 24 Sephardic cohanim had the Alu sequence.

From their analysis of YAP and another genetic marker, Skorecki, Hammer, and their colleagues concluded that the Y chromosomes of cohanim are indeed distinct from those of others Jews, which supports the oral tradition of father-to-son transmission of priestly status. Since the YAP disparity also held for both the Ashkenazim and Sephardim, "this result is consistent with an origin for the Jewish priesthood antedating the division of the world Jewry into Ashkenazic and Sephardic communities," the researchers said in the Jan. 2, 1997 NATURE.

While Skorecki and his colleagues created a brief media sensation with their initial announcement, they wanted to obtain more definitive data from the Y chromosomes of cohanim. "We realized that more markers would not only strengthen the conclusion . . . but allow us to do a better dating" of the priesthood's origin, says Skorecki.

After the first study, Skorecki and his collaborator Neil Bradman enlisted the help of David B. Goldstein at the University of Oxford, into whose laboratory Bradman had moved. "I have a real interest in applying genetics to historical problems, and this is a classic example, perhaps one of the most successful applications so far," Goldstein says.

For their second study, the researchers gathered even more DNA samples, increasing the number of Jewish men studied to 306, including 106 cohanim. They also expanded their selection of markers on the Y chromosome from 2 to 12. Six of these markers, including YAP, are considered unique-event polymorphisms, genomic alterations thought to arise on a single occasion in human evolution. For four of the markers, the people studied had one of two subtly different DNA sequences at a specific location on the Y chromosome. YAP and one other marker, however, were either present or absent.

Solidifying the hypothesis that the Y chromosomes of Jewish priests have a common origin, Skorecki and his colleagues found that 97 out of the 106 cohanim possessed the same array of the six chromosome markers. In contrast, only 109 of the 200 other Jews had this same array of markers, the scientists report in the July 9 NATURE.

Believing that they might have identified a prototypical Y cohanim chromosome, as defined by the six markers, the researchers next asked when this chromosome established itself. Although it might indeed date back to the time of Aaron, as the oral tradition of the priesthood holds, there were other possibilities.

For example, several hundred years ago, a group of closely related Jewish men could have suddenly labeled themselves priests. If their descendants were today's cohanim, they would also likely share the same unique-event polymorphisms on their Y chromosomes. "It's important to rule out a recent origin of these priestly chromosomes," says Goldstein.

To do so, the investigators examined differences, rather than similarities, among the Y chromosomes of cohanim. In particular, they studied six markers consisting of microsatellite DNA. "Microsatellites are stretches of DNA in which a particular short motif is repeated a number of times," explains Goldstein.

> *God spoke to Moses, saying . . . . Bring Aaron and his sons to the Communion Tent's entrance, and have them immerse in a mikvah [ritual pool of water].*
>
> *Then have Aaron put on the sacred vestments, and anoint him, thus sanctifying him as a priest to Me.*
>
> *Bring forth Aaron's sons and place the tunics on them.*
>
> *Then anoint them, just as you anointed their father, so that they will be priests to Me. It will be done so that their anointing will make an eternal (hereditary) priesthood for all generations.*
>
> *Moses proceeded to do exactly as God had commanded him.*
>
> Exodus 40:1,12-16 (Rabbi Aryeh Kaplan, *The Living Torah*, 1981, Maznaim Corp.)

Scientists describe a genetic sequence with the letters A, C, G, and T, which represent the four subunits, or nucleotides, that make up DNA. A microsatellite consists of a brief nucleotide sequence, such as CA, found over and over again at a particular place on a chromosome.

"Individuals tend to have a different number of repeats, and so you can distinguish them," notes Goldstein. This variation in number of repeats results from the difficulty that the DNA copying machinery of cells has in processing repetitive DNA sequences. Consequently, from generation to generation, the number of repeats in a microsatellite sometimes fluctuates up or down by one or more.

If the prototypical cohanim Y chromosome arose fairly recently, then the number of microsatellite repeats should be relatively similar among all the cohanim. The older the cohanim chromosome is, says Goldstein, the more time there would be for its microsatellites to suffer mutations that change the number of repeats.

With the help of mathematical models that incorporate an estimate of how often mutations occur in a microsatellite, Skorecki and his colleagues analyzed the six Y chromosome microsatellite markers and concluded that the last common ancestor of the cohanim studied lived at some time between 84 and 130 generations ago. Allowing 25 years per generation, a further calculation indicates a range of 2,100 to 3,250 years ago—a time coinciding with the oral history describing Aaron and his descendant cohanim.

For more than 90 percent of cohanim today to share the same unique-event polymorphisms after such a period of time is a testament to the devotion of the cohanim wives over the years, Goldstein adds. Even a low of rate of infidelity would have dramatically lowered the percentage, he says.

While this time frame is consistent with the traditional view of when the Jewish priesthood was founded, the researchers caution against statements that they have proved the events described in Exodus. "The nature of the calculation is such that it can give only a very rough range," says Skorecki.

"There's a couple of major areas of uncertainty associated with that date calculation," agrees Goldstein. For example, the researchers' conclusions depend on the assumption that a mutation in a microsatellite changes the number of repeats by only one. Moreover, says Goldstein, "the mutation rate is not known with certainty for any microsatellite." Indeed, a calculation factoring in the uncertainty in the mutation rate expands the time frame when the cohanim could have originated to between 34 and 455 generations ago (850 to 11,375 years before the present).

Since Skorecki and his colleague have described their results, a number of people have asked to see if they have the "cohanim chromosome." The scientists have declined to perform such tests, saying that the research was not intended to prove or disprove anyone's priestly status.

Other people have asked whether the genetic markers evident in the Y chromosomes of the cohanim confer any special attributes upon the priests. The markers are DNA sequences that don't encode any proteins used by the human body, explains Skorecki. "There's nothing unique or special about these markers," he says, pointing out that many noncohanim, and even non-Jews, possess the same markers.

In fact, the researchers hope to document the dispersal of the original Hebrew people from which Jews originated by studying the frequency with which the cohanim chromosome appears in various Jewish and non-Jewish populations worldwide.

"This particular chromosome might actually be what we call a signature of that ancestral population," says Goldstein. "We'd like to know where else it shows up in the world. Essentially, we're on a hunt to see where we can find this chromosome." □