Hopi Indians, Inbreeding, and Albinism

The high frequency of albinism among Hopi Indians is an intriguing problem in population genetics.

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Albinism results from an inborn error of metabolism that involves the conversion of tyrosine to a brown or black insoluble polymer. Melanogenesis takes place in melanocytes, a group of specialized cells. The first step, the hydroxylation of tyrosine to dihydroxyphenylalanine ((DOPA), is catalyzed by tyrosinase. The second step, the oxidation of DOPA to the quinone, is also catalyzed by tyrosinase. The rest of the pathway leading to the production of the polymer (melanin) may be nonenzymatic (*1*).

Although albinism in man is most often caused by a recessive autosomal gene, genetic heterogeneity may be present. The Trevor-Roper pedigree (*2*) of two albino parents producing normally pigmented offspring is suggestive evidence for at least two different types of recessive albinism in man. Supportive evidence comes from the experiments of Witkop, Van Scott, and Jacoby (*3*) who placed unfixed albino hair bulbs into a solution of L-tyrosine (50 milligrams per 100 milliliters, *p*H 6.8). They observed that the hair from some albinos formed pigment, but the hair from others did not. Genetic heterogeneity is not unexpected since a mutation in the structural gene, a controlling gene involved in the production of tyrosinase, or at some other locus resulting in the presence in the melanocyte of some enzyme-binding substance, would all disrupt melanogenesis.

Albinism occurs at different frequencies in various human populations. In Europe the overall frequency is about 1 in 20,000, with estimates ranging from 1 in 10,000 in Norway to about 1 in 30,000, or less, in southern Europe (*4*). In marked contrast are Indian populations in Central and North America. The Cuna Indians of San Blas Province, Lower Panama, show a frequency of about 1 in 200 (*5*). Frequency values of a similar magnitude characterize the Hopi Indians of Arizona and the Jemez and Zuni Indians of New Mexico (*6*). These North American Indians are not well known as having a high frequency of albinism, mainly because of the reduced population. A frequency of about 1 in 200 results in a conspicuous number of albinos in a total population of about 20,000 Cuna Indians; the impact of this frequency is not as great in populations of less than 6000 individuals.

The detrimental nature of albinism has been well established. Albinos are prone to skin cancer. Myopia and lateral nystagmus are usually part of the genetic syndrome, and albinos are extremely sensitive to sunlight. Neel *et al.* (*7*) conclude that, in present-day European and Japanese populations, the relative reproductive (Darwinian) fitness (f) of albinos is about 0.7 to 0.8, but in past generations it was more like 0.4 to 0.5. A relative fitness of 0.4 implies that albinos leave 40 functional offspring for every 100 left by nonalbinos.

When a deleterious trait is due to an autosomal recessive gene (c), and when carriers (Cc) and noncarriers (CC) have the same relative fitness value ($f = 1$), the frequency of affected individuals (cc) in a large population is a function of both the mutation rate (μ) and the selection coefficient ($s = 1 - f$) against affected individuals. The frequency at equilibrium is $R = \mu/s$. The mutation rate at the albino locus is unknown, but if a value of 1/40,000 is assumed (that is, there is one gamete containing the mutant gene among 40,000 produced), and the relative fitness of albinos is given the value $f = 0.4$, the frequency of albinos at equilibrium in the population would be $R = \mu/s = (1/40{,}000)/(0.6) = 1/24{,}000$. For this mutation rate, which is an acceptable value for man, the frequency of albinos at equilibrium would be relatively low, even if selection against them were less severe. For example, if the fitness of albinos were 0.9, then the frequency of albinos at equilibrium would be $R = (1/40{,}000)/(0.1) = 1/4{,}000$. The occurrence of Indian populations with an albino frequency of 1 in 200 indicates that some force other than mutation and selection against albinos has been operating in past generations.

Hopi Indians and Albinism

During the spring of 1961, one of us (C.M.W.) became interested in albinism among the Hopi Indians because an acquaintance remarked that she had observed an albino child in one of the Hopi villages. A trader then told her that albinos are common on the reservation, and the Hopis consider it a "good luck charm" to have one or more residing in their village. Hrdlička recounted a visit to the Hopis in 1900 and described 11 albinos from ten sibships (*8*). Based on this number of albinos and an estimated population size of 2000, the frequency in 1900 was 1 in 182.

The Hopi reservation is located in northeastern Arizona, where it is completely surrounded by the Navajo reservation (Fig. 1). The Hopi villages with one exception are located on the top or at the base of three mesas, known as First Mesa, Second Mesa, and Third Mesa, which are fingers off Black Mesa (Fig. 2). The villages on the mesas are adjacent or separated by only a few kilometers. The villages of Hano, Sichomovi, and Walpi are on First Mesa (Fig. 3). Polacca, which is part of the First Mesa population, is located at the base of the mesa. About 19 kilometers westward is Second Mesa with the villages of Mishongnovi, Shipaulovi, and Shongopovi (Fig. 4). Another 16 kilometers westward is Third Mesa with Bacavi, Hotevilla, and Oraibi on the top, and New Oraibi at the base. Oraibi (Fig. 5), occupied since about A.D. 1150, is the oldest continuously inhabited community in the continental United States (*9*). Moencopi, founded originally by members of Oraibi, is located 64 kilometers farther west on the western range of the Navajo reservation. The Hopi inhabitants of Moencopi

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are included in the Third Mesa population.

The village of Hano on First Mesa was established by Tewa emigrants from the Rio Grande area in New Mexico. Seeking refuge after the Spanish revolt, they arrived in about 1700. They were allowed to remain on First Mesa on the condition that they help protect the Hopis from hostile nomads (*10*). The Hopis and Tewas on First Mesa have intermarried extensively in recent generations. In this paper, unless specified otherwise, the Tewas are considered as part of the Hopi population. Accurate census data are not available for the Hopi population. The Hopi Indian agency, Bureau of Indian Affairs, Keams Canyon, Arizona, estimates (1968) that there are about 6000 Hopi Indians living on or off the reservation. The Hopi-Tewa population on First Mesa numbers about 1000.

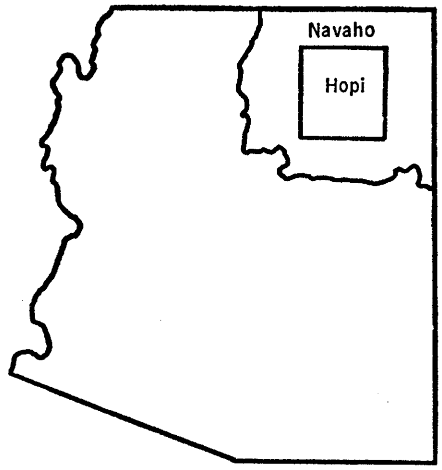


Fig. 1. Locations of Hopi and Navajo reservations in Arizona.

Objectives of Study

A study was initiated with the following objectives: (i) to determine the frequency of albinos in the Hopi population; (ii) to construct pedigrees using living albinos and those described by Hrdlička as reference points; (iii) to estimate the mean population coefficient of inbreeding for the various village and mesa populations in order to determine the influence of inbreeding on the frequency of albinos; and (iv) to determine, if possible, what forces account for the high frequency of the detrimental gene in this population.

A pilot study (*11*) verified Hrdlička's conclusion that albinos are common in the Hopi population. The observed frequency in 1962 was 1 in 227. It was soon noted that generalized albinism occurs only in the Second Mesa and Third Mesa populations (*6*). Two male siblings with piebaldness (partial albinism) and subtotal nerve deafness are from First Mesa. These males are striking because of their uniformity in depigmented pattern even though they differ in age by 4 years (*12*). The gene responsible for this syndrome is different from the one causing albinism in the Second and Third Mesa populations.

It was a formidable and sometimes impossible task to construct Hopi pedigrees. Hopis tend to be suspicious of anyone, especially a white person, who attempts to obtain information about their families or culture. They fear he is going to "write a book" and expose Hopi secrets. The inhabitants of Hotevilla and Bacavi are especially suspicious. There are no written records, and traditional Hopis wish not to mention the name of deceased relatives. "Don't speak his name, let him rest in peace." It is not uncommon to find a person who has never heard the given name of a deceased grandparent. Among traditional Hopis, pre- and extramarital relations are accepted as part of the Hopi way of life. Divorce is easy to obtain, and new arrangements are accepted by the villagers. These activities introduce errors into pedigree studies; however, Hopis talk about these activities and are often aware of true paternities. The matrilineal clan system and occurrence of ceremonial and adopted relationships present a problem of communication in a genetics study. Hopis inherit membership in the clan of their mother. Men and women of the same clan and same generation are considered as brothers and sisters. When a young Hopi is initiated into a society he acquires a ceremonial father. Furthermore, an older man who befriends a Hopi in a special way may become an adopted father. In a conversation with a white person, a Hopi may not make a distinction between a biological, clan, ceremonial, or adopted relationship. He may refer to several different women as his mother, name distant relatives as brothers and sisters, or state that a given man is his father, then later refer to the same man as his older brother or son (*13*). Relationships are bewildering to white persons and even to young Hopis, as evidenced by an account in the autobiography of Sun Chief (*14*).

> So this old man came in the morning for peaches and collected peach stones to plant. He would walk past me with his stick and say, "Good morning and good luck to you, my father." I did not like to be called father (ina'a) and showed that I was offended. One day my mother said to me, "Don't treat your son that way, Chuka. He used to have a father who belonged to our Sun Clan. His father was your great-great uncle; that makes me his aunt and you his father. Try to treat your son better." After a while I grew used to having him call me father.

Definitive progress was made in the collection of pedigrees when one of us (F.C.D., a Hopi Indian from First Mesa) became associated with the study. He obtained pedigree data (*15*) which would have otherwise been most inaccessible.

In this matrilineal society, all property is owned by females, and even though exceptions do occur, it is customary for an individual to identify

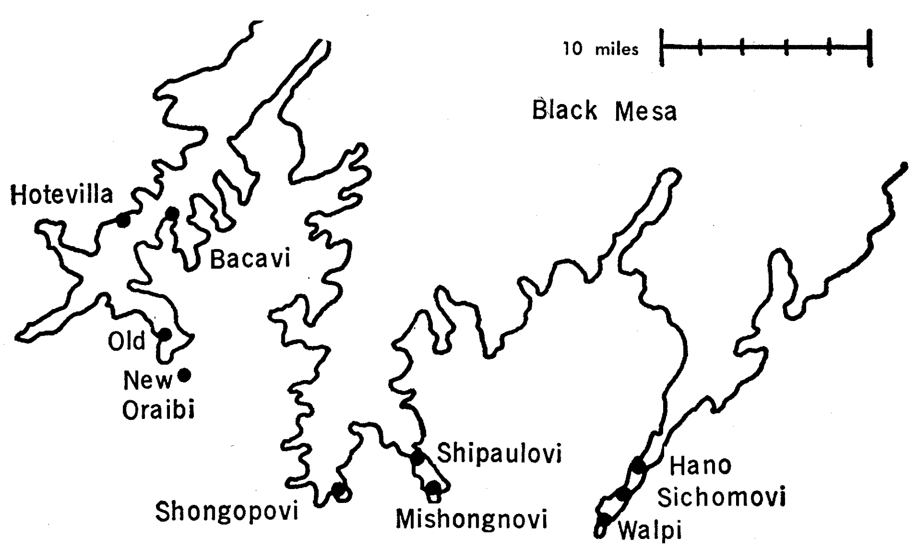


Fig. 2. Location of the Hopi villages on or at the base of First Mesa, Second Mesa, and Third Mesa.

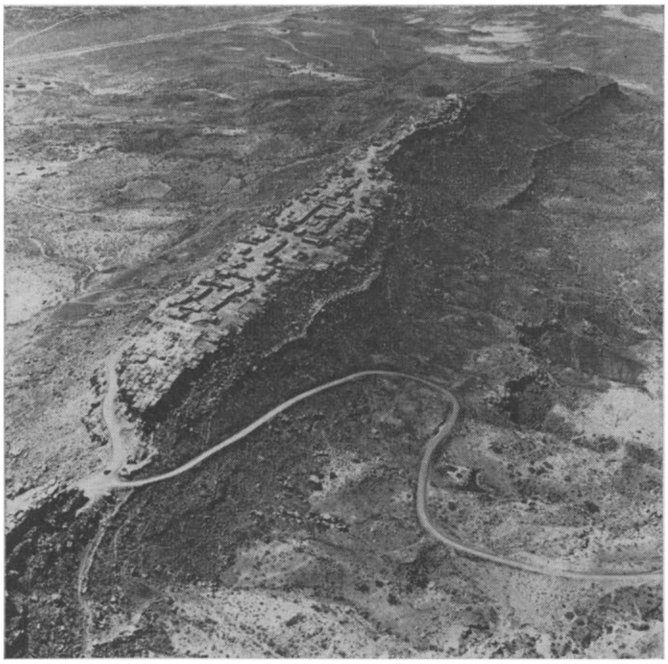


Fig. 3 (left). Air view of the three villages on First Mesa. Walpi is at the tip of the mesa (upper part of photograph). Sichomovi (middle village) is adjacent to Hano. [Reproduced through the courtesy of Johannessen & Girand, Consulting Engineers, Inc., Phoenix, Arizona, and Aerial Mapping Company, Phoenix, Arizona] Fig. 4 (right). Air view of the Second Mesa villages of Shipaulovi (lower part of photograph) and Mishonogovi. Each village is located on a different peak of this finger of Second Mesa. These villages presently have the largest number of albinos. [Reproduced through the courtesy of Johannessen & Girard and Aerial Mapping Company]

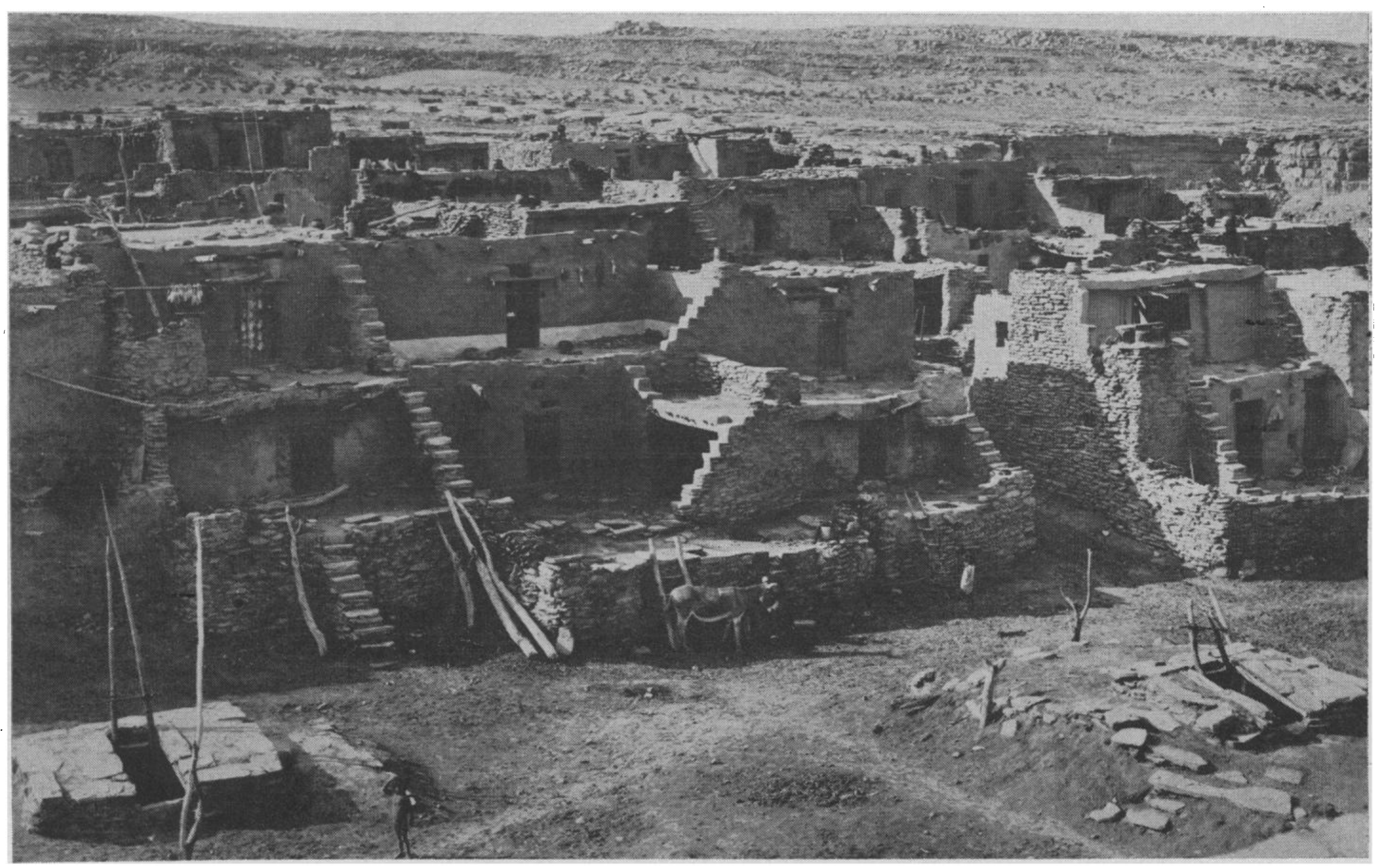


Fig. 5. The Hopi village of Oraibi on Third Mesa is the oldest continuously inhabited community in the continental United States. It has been occupied since about A.D. 1150 (9). This photograph was taken sometime during the period 1897–1900. Only a few families presently live in Oraibi. The village is now in almost total ruin. [Reproduced through the courtesy of the Field Museum of Natural History, Chicago, Illinois]

with the place of residence of his mother, which is usually his place of birth and rearing. Even if a Hopi is born and reared off the reservation, he will identify with his mother's mesa. If his mother is not a Hopi, an individual may be adopted into a clan of his choosing and may identify with the place of residence of his father. With these few exceptions, the matrilineal system was used in our study to denote village and mesa membership.

In the total population of 6000, there are 26 albinos, or 1 in 231. As in 1962, all cases of albinism observed occur at Second Mesa and Third Mesa. Apart from First Mesa, the frequency is 26 in 5000, or 1 in 192. The albinos are affiliated with the following villages: Mishongnovi, nine; Shipaulovi, four; Shongopovi, one; Bacavi, one; Hotevilla, five; New Oraibi, one; and Moencopi, five. Three albinos living in 1900 were not described by Hrdlička—two from Oraibi and one from Shipaulovi.

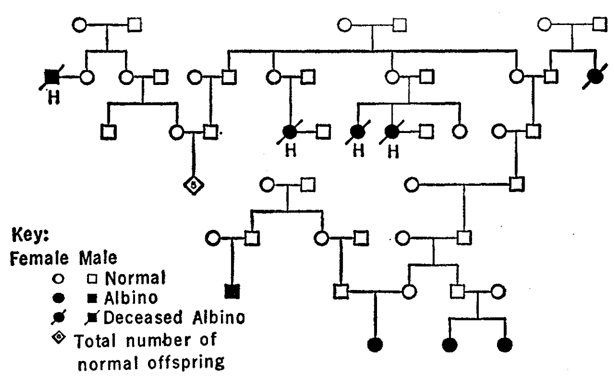
Abbreviated pedigrees showing living and related albinos are given in Figs. 6–10. Also shown in these pedigrees are the 11 albinos observed by Hrdlička in 1900. These latter albinos are designated by the letter *H*. A photograph of a young Hopi albino girl is shown in Fig. 11.

Inbreeding in the Hopi Population

The frequency of a recessive trait in a large population is a function of the frequency (q) of the recessive gene and the degree of inbreeding among the members of that population. This is expressed by Wright's equilibrium law (*16*) where the frequencies of *CC*, *Cc*, and *cc* individuals in a population at equilibrium are given by $D = p^2 + \alpha pq$, $H = 2pq(1 - \alpha)$, and $R = q^2 + \alpha pq$, respectively. The mean population coefficient of inbreeding symbolized by α, can range, theoretically, from 0 (random mating) to 1 (complete inbreeding). The Hardy-Weinberg law is a special case of Wright's equilibrium law, where $\alpha = 0$. When, for example, the frequency of a recessive gene is $q = 0.001$, the frequency of those homozygous for the gene ($R = q^2 + \alpha pq$) would be 20.98 times more frequent in a population where $\alpha = 0.02$ than in a random mating population. Inbreeding has relatively little effect on the frequency of individuals homozygous for a common recessive gene. If $q = 0.1$, the frequency of individuals homozygous for the gene would only be 1.18 times more frequent when $\alpha = 0.02$ than when $\alpha = 0$.

The history of the three mesa populations suggests that First Mesa should be the least inbred and should have the lowest frequency of the recessive gene for albinism. An obvious reason is the mixing of the Hopi and Tewa gene pools. Furthermore, First Mesa is the closest to Keams Canyon, which during recent times has been a center (boarding school, trading posts, Bureau of Indian Affairs government offices) where Hopis have encountered white Americans and members of other Indian tribes, mainly Navajo and New Mexico Pueblo Indians. On the basis of blood group studies, Brown *et al.* (*17*) concluded that the population of First Mesa shows considerable mixture of Hopi, Tewa, and Navajo genes.

Inbreeding in the village and mesa populations was measured by estimating mean population coefficients of inbreeding. Married couples were selected randomly in the various villages. For each couple, an inbreeding coefficient was calculated from the formula $F = (\frac{1}{2})^N [1 + F_A]$, where N is the number of individuals along the chain from one individual to another and F_A is the inbreeding coefficient of a common ancestor (*18*). The F represents the inbreeding coefficient of a child born to each couple; therefore, this method assumes that each married couple has the same



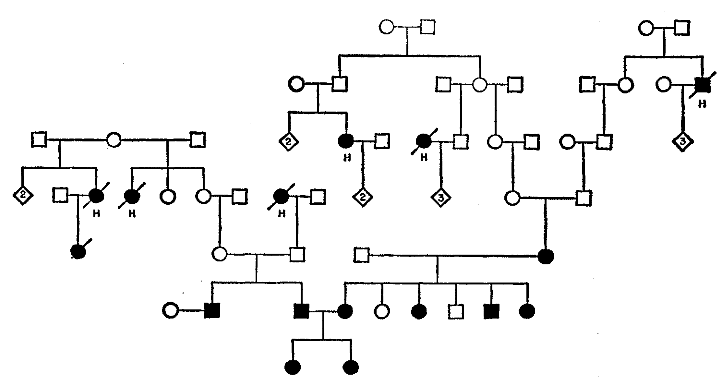
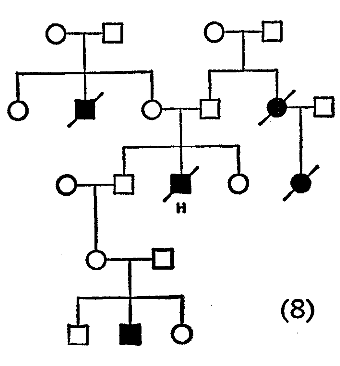
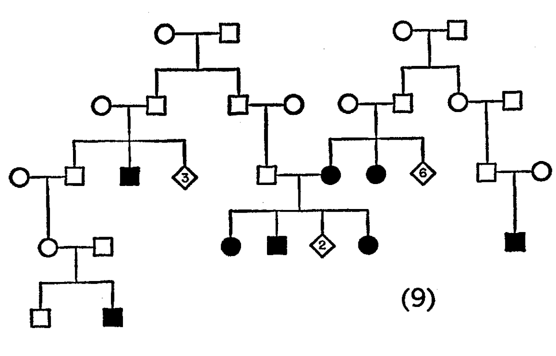
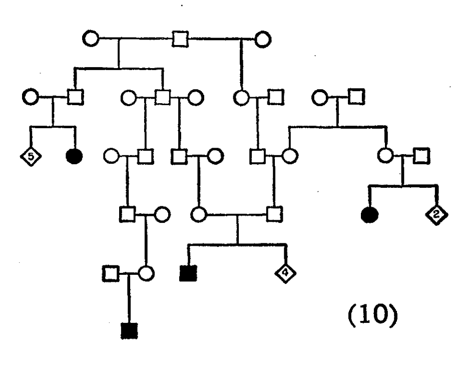


Fig. 6 (left). Pedigree No. 1 of albinism. The albinos symbolized by *H* in this pedigree and other pedigrees were observed by Hrdlička in 1900 (*8*). Fig. 7 (right). Pedigree No. 2 of albinism.







Figs. 8–10. Pedigree Nos. 3, 4, and 5, respectively, of albinism.

Fig. 11. Hopi albino girl. Photograph was taken during the period 1897–1900. [Field Museum of Natural History, Chicago, Illinois]

reproductive potential. The number of married couples sampled was 388 (First Mesa, 131; Second Mesa, 133; and Third Mesa, 124). The F values were averaged to obtain an estimate of the mean population coefficient of inbreeding. Moencopi was not studied because it is not on the Hopi reservation, and it was considered more informative, for the time available, to concentrate on the villages geographically associated with the three mesas.

The data show that Second Mesa is the most inbred ($\alpha = 0.01365$), Third Mesa is intermediate ($\alpha = 0.00702$), and First Mesa, as expected, is the least inbred ($\alpha = 0.00250$). The mean population coefficient of inbreeding based on all 388 F values is 0.00797. These estimates are lower than the true values since it was difficult to trace pedigrees back for more than about six generations. Furthermore, even a Hopi Indian from another mesa is unable to obtain cooperation from all inhabitants of Hotevilla and Bacavi. Consultants from these villages helped collect data, and even they had difficulty in obtaining cooperation from their fellow villagers. Refusal to cooperate introduces additional bias in the estimates of α for these villages.

The Hopis are relatively inbred when compared with various European, white American, and Japanese populations (*19*). However, the Hopis are perhaps no more inbred than other southwestern Indians. Spuhler and Kluckhohn (*20*) obtained an α value of 0.0080 for the Ramah Navajos in New Mexico, a value almost identical to the overall value (0.00797) obtained for the Hopis.

Before the coming of roads and modern means of transportation, the mesa populations were semi-isolates. The distances involved, the rigors of a trip during the wintertime, and the threat of attack by Navajos and Utes during certain periods of time discouraged the casual exchange of visitors among mesas. These factors promoted mesa endogamy in the biological sense. Even today cultural activities are strongly mesa-oriented, resulting in a certain degree of rivalry among the mesas. Although the physical location of the villages has strongly favored biological endogamy, cultural regulations forbidding certain types of consanguineous matings have reduced the inbreeding potential. Closely related clans are grouped into a single phratry, a brotherhood or fraternity of clans. An individual is discouraged from marrying or having a sexual relationship with a member of his own clan or phratry, or with a member of his father's clan or phratry. Such restrictions eliminate certain relatives as spouses. However, it is of interest that this cultural regulation allows for marriage between half-sibs when they have the same father and their mothers belong to unrelated clans. Such marriages occur.

The frequency of the albino gene may be used as an indicator of the "purity" of the Hopi gene pool. Second Mesans tend to boast that they marry non-Hopis less frequently, and that they are the "most Hopi" of all. They also boast the largest number of albinos. No Hopi now living recalls the birth of an albino at First Mesa; however, the albino gene is present in this population. Two males from First Mesa married to females from Mishongnovi and Moencopi are the fathers of albino children. Each male had grandparents from Second Mesa. The mixing of the First Mesa gene pool has greatly reduced the frequency of the albino gene. Mixing is also found in a section of the Third Mesa population.

At the turn of the century, a serious dispute arose among the inhabitants of Oraibi, then the only village on Third Mesa. Some (the "friendlies") wished to support the government by enrolling their children in schools. Others (the "hostiles") wished to maintain the traditional Hopi way of life. As a result, the hostiles moved from Oraibi in 1906 and established the village of Hotevilla, and later the village of Bacavi. New Oraibi was established at the foot of the mesa by friendlies so that they could live in close proximity to the government school. Some of the friendlies from New Oraibi selected spouses who were not Hopi. The split has led almost to the total decline of Oraibi. Only a few families live there. The residents of Hotevilla and Bacavi soon found themselves in the dilemma of having too few clans. They sought marriage partners from Moencopi rather than from Oraibi or Second Mesa. Moencopi, located 64 kilometers away on the Navajo reservation, consists of Hopi and Navajo inhabitants. It is divided into an upper and lower village. The lower village consists mostly of traditional Hopis; the upper village is composed of Hopis and Navajos. Mixing of Hopi and Navajo genes has occurred at Moencopi, especially in recent years. These marriage patterns are reflected in the data on inbreeding (Table 1) and the distribution of albinos. The 26 albinos tend to be of pure Hopi lineage. The five albinos from Moencopi are from the lower village. A major exception occurs in the village of Shipaulovi on Second Mesa. The mother of two albinos is a Navajo. The albino children have been adopted into a Hopi clan, identify with the village of their father, and are considered Hopis by the Hopis. Albinism is not

Table 1. Inbreeding coefficients in different segments of the Hopi population.

Village	Number of marriages	1/8	1/16	1/32	1/64	1/128	Other	α	
				First Mesa					
Hano	50	0	0	1	1	1	0	0.00109	
Sichomovi	51	0	1	0	0	1	0	0.00137	
Walpi	30	1	0	1	0	0	1	0.00677	0.00250
				Second Mesa					
Mishongnovi	43	1	2	2	2	2	3	0.01226	
Shipaulovi	28	0	5	3	3	1	3	0.02176	
Shongopovi	62	0	6	5	5	4	5	0.01222	0.01365
				Third Mesa					
New (Old) Oraibi	59	0	2	1	2	1	1	0.00463	
Hotevilla	37	0	4	2	1	3	1	0.00950	
Bacavi	28	0	3	1	1	1	0	0.00864	0.00702
Total	388	2	23	16	15	14	14	0.00797	
		(0.5%)	(5.9%)	(4.1%)	(3.9%)	(3.6%)	(3.6%)		

uncommon to the Navajo, especially in the vicinity of the Hopi reservation (*6*). This is best explained by the Moencopi influence and the fact that for centuries the Navajos have been raiding the Hopi villages for the purpose of obtaining food, women, livestock, and other booty.

Estimate of Gene Frequency

The frequency of albinos and the inbreeding coefficient can be used to estimate the gene frequency in the Second and Third Mesa population. Based on an estimated population size of 5000, the frequency of albinos becomes $R = 26/5000 = 0.0052$. If $\alpha = 0.01088$ for Second and Third Mesa, and if we assume equilibrium, and solve for q in the equation $R = q^2 + \alpha pq$, we obtain a gene frequency of $q = 0.067$. The frequency of heterozygotes in this population becomes

$$H = 2pq(1 - \alpha) = 0.124$$

The high frequency (12.4 percent) of carriers of the gene for albinism is reflected in the pedigrees shown in Figs. 6 to 10. The frequency of the gene for albinism is so high that even if the population resorted to random mating, the frequency of albinos would be reduced only slightly ($R = 1/223$ as compared with the present value of $R = 1/192$). The intriguing problem is to account for the high gene frequency in this population, as well as the Cuna, Jemez, and Zuni Indians.

Selection for the Heterozygote

A deleterious recessive gene is maintained at a relatively high frequency in a population when the heterozygote has a reproductive advantage. For example, if the relative reproductive fitness values for heterozygotes and albinos are set at 1.00 and 0.5, respectively, it can be shown that the relative fitness of homozygous persons would have to be only 0.962 in order to maintain an albino frequency of $R = 1/200$ in a large population. This slight advantage of the heterozygote, which would be difficult to measure in a practical situation, might manifest itself by increased fertility, vigor, maturation rate, or resistance to a disease. The implication is that, in the presence of a specific homozygous background produced by genetic drift and many generations of inbreeding, heterozygosity for certain mutant genes increases reproductive fitness. The corollary is that the advantage ceases with the advent of genetic variability. The presence of albinism at a high frequency in some populations and not others would imply that the latter lacked the proper genetic background or the allele had not been introduced by migration or mutation. This form of selection cannot be ruled out as the explanation for the high frequency of albinism in various Indian populations.

Genetic Drift

Genetic drift implies that a gene could be common in a population if one or more of the few early settlers carried the gene (founder principle), or because of chance segregation and recombination during a time when the population was small. Indian populations in the southwest have been plagued by epidemics, periodic starvation conditions, and raids by hostile groups. These populations have often consisted of a small number of individuals. If the albino gene were present in one of these small populations, the frequency would fluctuate and might rise by chance to a relatively high value. Furthermore, it is likely that many, if not all, of the present southwest Indian populations were founded by a small group of migrants. The frequency of the albino gene could be high in a present population if one or more of the founders were heterozygous for the gene.

If the high frequency of the albino gene in the Hopi population is accounted for by a chance process occurring in past generations, what is the origin of the mutant gene? The albino gene in the Hopi, Jemez, and Zuni Indians is likely "identical by descent" since gene flow occurred among the Pueblo Indians of Arizona and New Mexico in historic and prehistoric times. The presence of albinism in the remote Cuna Indians suggests further that the mutant gene is not of recent origin, and draws attention to Central America as the possible site of origin. There were many albinos in Montezuma's royal household at the time of the conquest of Mexico. Albinos along with malformed individuals were considered by the Aztecs as suitable wards of the state (*6*). The extent of this practice in Central America before the coming of Cortez is unknown. The protection of albinos in early American cultures would have favored the propagation of the albino gene in certain segments of the population. Groups migrating northward could then have carried the albino gene to the southwestern part of the United States. Climate would influence greatly the destiny of the albino gene acquired at a high frequency by migration. Natural selection against the gene would be more effective in the hot desert populations of southern Arizona than in the more temperate climates of northern Arizona and New Mexico. Pueblo dwellings which afford protection from the sun would lessen the effectiveness of natural selection.

The hypothesis of genetic drift may be questioned because of the existence of albinism at a high frequency in three different southwest Indian populations. It is not likely that a deleterious gene would reach a high frequency in all three populations by only a chance process. Some selective mechanism has likely been operating in one or more of these populations.

Role of Cultural Selection

A high frequency of a gene in a population is determined by processes operating in previous generations. We believe that the most acceptable hypothesis to explain albinism in the Hopis is the acquisition of the gene by migration (or mutation) and maintenance at a high frequency by cultural selection. Albinos have been protected in the Hopi society.

Traditional Hopis believe that albinism, along with other congenital defects, is the result of some specific action in the life of a parent or close relative. Typical retrospective explanations are as follows.

> When —— was a young man, he owned a white donkey. Everywhere he went he rode this donkey. He liked it so much two of his granddaughters were born white.
>
> —— liked to portray Eototo (white kachina). Therefore [his daughter] was born white.
>
> —— worked with white sand while his son was being formed.
>
> His mother [father] slept with a white man [woman].

There is no recognition of the heredity phenomenon. An albino child born to an albino parent is explained merely by the existence of "whiteness" in the parent. Because of this logic it is assumed that albino parents may produce albino children.

Younger Hopis who have learned that albinism is a genetic defect may show a certain degree of discrimination against albinos; however, comments made by traditional Hopis reflect only a positive attitude toward them. Albinos are accepted completely in the Hopi society. They perform in ceremonies along with other Hopis. Several have been influential chiefs and priests. One, who was chief at Oraibi about 100 years ago, is legendary as a rainmaker. "During a plague of prairie dogs one fall he is said to have called for a Masau Katcina dance, which caused a veritable cloudburst that drowned all the prairie dogs" (*13*). Comments by traditional Hopis illustrate the acceptance of albinos in the Hopi society.

> Albinos are smart, clean, nice and pretty. There is nothing wrong with them.
>
> Albino girls are very pretty. I like their nice color. I would like to marry one, but they probably wouldn't have me.
>
> I would like to have an albino baby. There were albinos when I was a child, so they are not new to me. In fact, I am related to one. He's my brother [clan affiliate].
>
> I know lots of them, and they are good Hopis.
>
> Here [on Second Mesa] we have lots of them and we are very proud of them. There are more here than at the other mesas. We take good care of them.
>
> It is lucky to have albinos [in the village]. They are very special.

Albinos are considered as part of the Hopi heritage on Second and Third Mesa. This was evident in the revealing answer to the question asked of a member of Third Mesa as to why there are no albinos on First Mesa. "Oh, they are Tewas."

Marriage is important in the life of a Hopi. It is extremely rare to find an adult, especially a woman, who has never been married. For this reason, the fact that many albinos have remained unmarried contradicts the attitude of complete acceptance in the traditional Hopi society. One albino male stated he was unable to work in the fields and therefore could not grow corn for a wife and family. Although the inability to provide adequately for a family is the excuse usually given for males, the reason is not obvious for females. Answers to questions as to why specific albino females did not marry usually implied withdrawal of the female. The difficulty of being an albino in a dark-skinned population seems to have such a repressive action that suitors are rejected. This point needs further investigation. The acceptance by Hopis of this Hopi heritage apparently stops short of marriage. Females should reject males who cannot work in the fields. Titiev (*13*) quotes a discriminating comment regarding the albino chief from Oraibi who had the reputation of being a good rainmaker: "Nakwaiyamptiwa never married, 'because in those days ladies did not like albinos.' "

However, any real or subconscious bias towards marrying an albino apparently does not manifest itself in the selection of a sex partner. For this reason albino males in past years had an advantage in regard to sexual activity. Hopis for centuries have made their living by farming. Men and boys would leave the mesa tops and go to the fields, often many kilometers from the mesas. It is commonly known, among the inhabitants of Second and Third Mesa, that albino males were not expected to labor in the fields. They remained in the villages and performed tasks such as weaving. In the villages they were protected from the sun and hostile nomads, and most importantly, they had ample time and opportunity to engage in sexual activity. One albino is especially legendary for this activity.

> I knew that old man. Some say he had about twelve kids; others say about fifteen.
>
> He never married.
>
> They say he was always around trading with the ladies. He would make babies with them.
>
> He was real funny, and knew a lot of good stories. Everyone liked him.

In a small population, a sexually active male will have an imposing effect on gene frequencies of the next generation.

The acquisition of the albino gene by migration (or mutation) and a form of cultural selection whereby albino males are given a slight sexual advantage would explain the frequency of the albino gene in the Hopi populations. Whether a similar hypothesis is acceptable for the high gene frequency among the Cuna, Jemez, and Zuni Indians remains to be determined. Indeed there is no reason to conclude that the high frequency in all four of these Indian populations is due to the same force or forces. There appears to be cultural selection against albinos in the Cuna population (*5*).

Albinos are not considered as "good luck charms" for a village. The word lucky is used frequently in the English vocabulary of a Hopi. The meanings of the expressions "He is lucky with corn" or "He is lucky with girls," are apparent. However, the statement "It is lucky to have albinos," can be given the wrong interpretation by an outsider. The statement implies that it is difficult to produce albinos because they do not appear in all families or in all villages. There is no evidence that any special religious significance was ever attached to albinism that would predispose to the present positive attitude toward them. This point was investigated thoroughly because Hopi tradition would allow for a religious symbol being attached to albinism.

Hopis share the legend permeating Central American Indian cultures that someday a white leader will return and lead them to a better life. Just as Cortez was welcomed by the Aztecs as their white leader, Pedro de Tovar, the first white man to visit the Hopis, was welcomed by the Hopis as their "lost white brother" (*21*). Tovar and his men quickly subdued the Hopis. The lost white brother has yet to arrive. If the birth of an albino was ever considered as a symbol or reminder of their lost white brother, it is unknown to any living Hopi. The intriguing problem remains, however, as to why albinos, especially albino children, are considered so affectionately in all villages. The admiration of their whiteness is clearly not an identification with white Americans; it represents instead an association of whiteness with cleanliness, goodness, and purity; attributes honored by traditional Hopis. Rain is essential for existence in the barren mesa country. White clouds symbolize rain and are a constant reminder of the necessity of living a pure life. "If Hopis live a clean, good and harmonious life, there will be plenty of rain and an abundance of food for the children to eat."

Conclusion

Although selection for the heterozygote or genetic drift may account for the high frequency of the albino gene in the Hopi population, the most apparent explanation is acquisition of the gene by migration and cultural selection of the type described here. A study of the Hopi people also indicates that time will soon erase albinism as a Hopi heritage on Second and Third Mesas. Paved roads now link the Hopi mesas so that only minutes are required to travel from one mesa to another by truck or automobile. These modern transportation facilities, schools on and off the reservation where members of different ethnic groups associate, and a growing population forcing young people to seek employment off the reservation all promote outbreeding, reduce the frequency of the albino gene, and decrease the probability of homozygosity for this gene. The eclipse of agriculture as a way of life negates any reproductive advantage held by albino males in past generations. The frequency of albinism among the Hopis will decrease rapidly with the decline of their culture.

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A Carbon-Phosphorus Bond in Nature

A spot on a chromatogram leads to a new field of phosphorus biochemistry.

James S. Kittredge and Eugene Roberts

Several years ago we made a study of the easily extractable ninhydrin-reactive constituents of the tissues of a number of marine invertebrates (*1*). Two-dimensional paper chromatograms of extracts of the sea anemone *Anthopleura elegantissima* revealed an acidic ninhydrin-reactive material migrating like ethanolamine phosphate. In contrast to the latter substance, the material in anemone extracts was resistant to prolonged acid hydrolysis. Another ninhydrin-reactive substance in the extract was observed to release additional amounts of the acidic compound during hydrolysis. The acid-stable substance was isolated by ion-exchange chromatography and crystallized. The serendipitous observation that there was considerable ash left on combustion of a sample during elemental analysis led to the determination that 25 percent of the weight of the material could be accounted for as stably bonded phosphorus, and to the identification of the substance as 2-aminoethylphosphonic acid (AEP). The substance in the extract yielding AEP on hydrolysis was identified as a glyceryl ester of AEP, and the liberation of AEP on hydrolysis of the lipid extracts of the anemone suggested AEP as a possible constituent of phospholipids (*2*).

We were preparing a report on the above finding when it was brought to our attention that Horiguchi and Kan-

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