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The Natural Incubation Period of Kuru and the Episodes of Transmission in Three Clusters of Patients

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Abstract. Epidemiological data were collected on the slow virus disease, kuru, among the Fore cultural and linguistic group in Papua New Guinea from 65 kuru patients who died or were diagnosed between 1977 and 1981. From these, 3 episodes of cannibalistic feasts were identified, in each of which 2 or more participants were exposed to the infectious agent for the first time and died within weeks or months of each other 25-30 years later. Thus, it is shown that the natural incubation period of kuru could be as long as 25-30 years and is at times identical in 2 or more individuals infected at the same time, even over this span of years; also it is not determined by age at exposure. Further analysis of the episodes supports the concept on which the study was based, namely the transmission of kuru at the time of cannibalistic mourning with primary infection often occurring in infancy or early childhood.

Detailed genealogical data were obtained for all kuru patients who died between 1977 and 1981 in an attempt to identify sets of patients who jointly participated in a restricted number of cannibalistic feasts of kuru victims in the late 1940s and early to mid 1950s and who developed symptoms of the disease almost simultaneously within the past 4 years. A secondary goal of this study was to assess the lingering memory of the nature of these feasts among the Fore linguistic group and to add this documentation of the endocannibalism practiced by them in the past to the recorded observations of early kuru investigators [1-4].

Methodology

The hamlets of almost all kuru patients since 1977 were visited and members of the patients' families were interviewed. Older relatives were questioned whenever they were available since they could remember the period during which cannibalistic feasts were held (up until the early to mid 1950s) in most detail. A genealogy was recorded for each patient; attempts were made to include as many members and generations as informants were able to recall.

These genealogies revealed those members of the patient's family who had also died of kuru. In several instances, 1 or more of these victims also died within the past 4 years. When a cluster of 2 or more patients who developed kuru almost simultaneously in recent years was thus found, additional interviews were held to try to identify an earlier victim or victims of the disease who were consumed by the members of this cluster as part of a ritual feast of mourning. Such clusters are more readily identifiable now than in earlier kuru epidemiological field work, since there are now fewer current cases, and evidence suggests that these are the results of the last feasts held in each village. Additional information was then obtained on who participated in the feast, how many of these later died of kuru, and when they died.

Genealogical information was collected for a total of 65 recent kuru cases, and 3 sets of feasts were identified which were likely to have resulted in the nearly simultaneous appearance of kuru in 2 or more participants. In early kuru work in the late 1950s, no adult denied cannibalism, all readily discussing and describing their participation in this ritual display of love and respect for their dead relatives. Cases of cannibalism have been witnessed by government officials, missionaries, and 1 of us (*D.C.G.*), and many court records and government patrol reports consistently document that the Fore practiced this ritual. Evidence of the feasts, consisting of dismembered bodies and human bones stripped of their meat, have been observed and displayed publicly, both by the villagers themselves and in government courts throughout New Guinea. However, the most telling evidence for the practices carried out during these feasts remains the eyewitness accounts of the many Fore people who were present at them. In the current investigation, most older men and women readily spoke about the custom and reported their own participation in such events as they remembered it, without embarrassment, often with pride and as a matter of course, illuminating their respect for their dead kinsman. However, many middle-aged informants who were still children or adolescents when the custom died out, often admitted that neighboring villages had held such feasts but denied that their own village had. Such disavowal of any involvement has appeared in the area during the 1960s with increasing contact with Westerners who had tried to eliminate cannibalism. This contact and the prosecution of offenders against the government interdiction of cannibalism in the courts have led the Fore to assume that all Westerners view the practice and perhaps the practitioners as ignominious. Informants under 30 years of age are often totally unfamiliar with the practice.

Older informants openly discussed which kuru victims were consumed, who participated in the consumption, and some of the specific circumstances surrounding each of the cannibalistic episodes. When informants were asked what happened to the corpse of a particular individual, 1 of 2 answers were given. The deceased was either 'katim na kukim na kaikai' (Pidgin English for *cut up, cooked and eaten*), or 'putim long matmat' (*buried in a grave*). Informants consistently explained that there existed a 'taim bilong kukim na kai-

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kai', that is, a time when deceased were consumed by kinsmen, a period clearly defined and differentiated from the present and ending in the early to late 1950s, when cannibalism was practiced as a matter of course. Informants also provided a chronological listing of the order in which individuals died; almost all of those dying before a certain point were said to have been consumed while all of those dying afterwards were buried. When asked when and why cannibalism ended, each of the 3 sets of informants who provided the data for the 3 episodes described below offered a consistent story. The first patrol officers who traveled through the area between 1949 and 1955 told them that the practice was abhorrent to Europeans and that it should stop; thus they gradually replaced the eating of dead kinsmen by burial.

A list of participants for each of these sets of feasts was assembled as a means of reconstructing the events, determining the years they occurred and the numbers of participants. The lists were compiled from 2 sources. First, informants were asked whether members of the recorded kinship lines who were eligible for participation - women and children - were present. These names (abbreviated for publication) are listed in tables I, III, and V in order of the years in which they died, starting with the most recent. The closest living female kinsmen and their younger children were the ones most likely to have actively participated in the feast, and specifically to have handled and consumed the brain and other organs containing the highest titer of the infectious agent.

A second source of names of possible participants was the kuru clinical and epidemiological record, a compilation of all data of all studies done on kuru since the first in 1957. This file includes all patients since that year, with data on the names of parents and the years of birth, onset of the disease and death. The epidemiological record is consistent with data recorded in village census books compiled from 1957 to 1975 at intervals of 6-12 months by government patrols with the aim of contributing to the demographic and epidemiological study of kuru. These census books serve as detailed and reliable sources of data for all Fore since 1957. The only unknown pieces of information for the tables are the years of birth and death for those who died before 1955 when initial monitoring and census collecting were begun. These events before 1955, in otherwise undeterminable years, are noted as such in the tables. However, these data do not contribute to estimation of the natural incubation period of kuru since these participants, born or dying before 1955, were undoubtedly exposed at feasts held before the ones currently under investigation.

In cannibalistic episode II discussed in this paper, informants were presented with all of the names of kuru patients who resided in the village where the feast was held and in neighboring, friendly villages where many members of the patients' line resided. In episodes I and III of this study, the complete lists of all kuru victims who possibly participated, as drawn from our files for the respective villages, were excessively lengthy. Presenting these lists in full to informants risked sacrificing their patience and cooperation and would have yielded additional data that was useful only in increasing our estimates of the number of participants and not in establishing the year of the feast with any further precision. Informants were thus presented with most, but not all, of the names of kuru patients who had died in the relevant villages. Included in the abridged lists were groups of kuru patients whose years of birth, onset of the disease and death were distributed over the full range of those included in the epidemiological record as a whole for that village. Also included in these lists were all those born in the 1940s and 1950s, in order to identify those who had not yet been born at the time of the feast. The year in which the feast occurred was established with more certainty by relating it to the years of birth of those said by infor-

ments to have been born before and after the feast took place. The years of birth drawn from the epidemiological record correspond to census records.

These listings of possible participants, complete in episode II and abridged but fully representative in episodes I and III, and ordered by year of death from the most recent to the earliest, for each village, appear in tables II, IV, and VI.

Informants were unable to recall the names of any individuals other than those derived from these 2 sources who were present at a particular feast. This inability is not surprising, however, since most deaths among South Fore women were due to kuru in the 1950s and early 1960s, during the height of the epidemic, and all of those dying after 1956 were included in the clinical and epidemiological record. The record thus includes most of the participants who lived until at least 1957, and the genealogies provide those who were most actively involved as members of the victim's kindred.

The year in which a particular feast occurred was also determined through reference to critical events in the history of the entrance of Westerners into the region. This method proved a convenient chronological measure, estimated to be accurate within 3 years. The first government patrol entered the North Fore area briefly in 1947. A more extended patrol arrived in 1949 and started censuses in each village. A government post was established at Okapa in 1954 and the first road was built in 1955. The road was extended further south to Purosa in 1957 and the first missionaries entered the South Fore region late that year, establishing a mission at Purosa.

Results

3 sets of cannibalistic episodes were investigated. In each, 2 or more patients who died of kuru within the 4 years prior to this study actively participated and were infected. The data on these feasts reported below include the members of the kinship line who were most heavily involved, the approximate number of participants, and those who eventually died of the disease.

Cannibalistic Episode I:

at Awande Village, North Fore in 1949 and 1953-1954

2 brothers from Awande village in the North Fore group developed symptoms of kuru in 1975; the older of the 2, Ob., died in November 1976 and Kasis. died 6 months later in May 1977. As young boys, they were taken by their mother to 2 feasts held for kuru victims: Nonon., their paternal aunt; and Nen., a member of their kinship line.

Nonon. died of kuru in 1948, shortly before a government patrol entered the area and counted the population of their village. She had lived in Nakongagori hamlet of Kume village, which was closely affiliated with Awande. To travel between these 2 villages, however, one had to pass

Table I. Individ

Name Sex

Kasis.	M
Ob.	M
Yap.	F
Aib.	F
Kam.	F
Way.	F
Tar.	F
Yam.	F
Anap.	M
Omb.	F

Kasin. F

Tum.	F
Ap.	F
Lok.	F
Nab.	F
Amap.	F

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Table I. Individuals appearing on episode I genealogy

Name	Sex	Year of birth ^a	Year of death	Participation		Comment
				Nonon.'s feast	Nen.'s feast	
Kasis.	M	1945	1977	yes	yes	kuru
Ob.	M	1940	1976	yes	yes	kuru
Yap.	F	1927	1973	yes	yes	kuru
Aib.	F	1909	1966	yes	yes	kuru
Kam.	F	1926	1965	yes	yes	kuru
Way.	F	1924	1960	yes	yes	kuru
Tar.	F	1917	1957	yes	yes	kuru
Yam.	F	before 1955	before 1955	no	yes	kuru
Anap.	M	before 1955	before 1955	yes	yes	kuru
Omb.	F	1935	-	no	yes	alive (consumed Nen.'s hand)
Kasin.	F	1930	-	no	no	alive (forbidden to participate)
Tum.	F	1940	-	no	no	alive
Ap.	F	before 1955	before 1955	yes	yes	kuru
Lok.	F	before 1955	before 1955	yes	yes	died (not kuru)
Nab.	F	before 1955	before 1955	yes	yes	kuru
Amap.	F	before 1955	before 1955	yes	yes	kuru

^a Obtained from the kuru epidemiological file where possible.

through lands belonging to Miarasa and Yagusa villages, which were Awande's enemies at war during this period. Travelers risked being shot at with arrows and possibly being killed. Only some of the men dared trespass across this dangerous area to attend Nonon.'s funeral, and not all risked taking their wives and children. The men who ventured forth included Asia., the deceased's brother and the father of Ob. and Kasis., who took his wife, Aib., and their children (table I). In endocannibalistic feasts, close relatives were the chief mourners and were most actively engaged in the consumption of the body. Aib. was placed closest to the corpse as it was cut into large pieces and cooked in Nonon.'s garden. Huddled beside her were her children, her daughter Ag., and her sons, Ob., aged 8 at the time, and 3-year-old Kasis. Tradition dictated that as a sister-in-law Aib. be handed

the cooked brain to consume. She would not have washed her hands for several weeks following the funeral, a practice reported by several informants on separate occasions.

Participants in these feasts may not necessarily have infected themselves through the oral route, that is, by eating contaminated human tissue, though this is a likely way. They may have rubbed their hands, contaminated with the infected tissue, into their eyes and onto their skin. Thus, conjunctival inoculation from rubbing eyes and clearing of infants' often pussy eyes, cutaneous inoculation through open wounds, scratched louse or insect bites, and nasal or oral mucosa inoculation from nose picking and sugar cane eating would have occurred in participants of a cannibal feast during the ensuing few days when the virus of kuru in high titer brain tissue would have remained infectious on their hands, and these practices therefore must be considered as providing alternative routes of transmission.

Informants reported that the brothers Ob. and Kasis. were aged 8 and 3, respectively, consistent with a date of 1948 for the feast, since the 2 patients known to us (*D.C.G.* and *M.P.A.*) since their adolescence had had their years of birth estimated in the 1950s as 1940 and 1945.

Of 10 other kuru patients from Awande selected from the kuru clinical and epidemiological record, as described earlier, 2 were present at Nonon.'s feast (table II). Aon. was a 9-year-old boy at the time and living in Kume. On., a male recorded as born in 1946 from his census age estimate made in his childhood, was approximately 3 years of age at the time, placing the date of the funeral sufficiently close to that estimated above. Tumin., a female patient born in 1950, was reported to have been born after Nonon.'s death, fixing the year even more precisely. When asked why those who were claimed to have been absent had not come, precise explanations were offered, as listed in table II.

Sometime in 1953 or 1954, these 2 brothers were taken by their mother to another ritual feast in Tasongagori hamlet of Awande village, for a member of their kinship line named Nen. She had died of kuru after the first patrol station had been established in Okapa, but before initial work was begun on the building of the road in 1955. Nen.'s husband, Kaw., was the village fight leader, one of the most important men in Awande, and the feast was well attended, though as usual close kin were most actively involved. Of the 16 members of Nen.'s kinship line eligible for participation, 15 were in Awande at the time and 14 were involved. 12 of them later died of kuru. The 1 resident who did not participate was Kaw.'s second wife, Kasin., who was forbidden by tradition in her own village from eating the body of

Table II. Parti
village

Name	Sex
Mam.	M
Aon.	M
Sen.	F
Tub.	F
Pag.	M
Tumin.	F
On.	M
And.	M
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Table II. Partial list of kuru patients in epidemiological file who resided in Awande village

Name	Sex	Year of birth ^a	Year of death	Participation		Comment
				Nonon.'s feast	Nen.'s feast	
Mam.	M	1943	1979	no	no	another line
Aon.	M	1939	1978	yes	yes	
Sen.	F	1912	1977	no	yes	not Nonon.'s line
Tub.	F	1917	1976	no	no	from Woioepa
Pag.	M	1923	1974	no	yes	
Tumin.	F	1950	1973	no	no	born later
On.	M	1946	1971	yes	unknown	
And.	M	1944	1970	unknown	unknown	said to have been born later
Aw.	F	1946	1970	no	unknown	said to have been born later
Is.	F	1945	1968	no	no	from Awarosa

^a Obtained from the kuru epidemiological file.

another of her husband's wives. She is still living and has shown no evidence of kuru to date. The 1 participant who survived is Nen.'s daughter-in-law, Omb., who was said by her husband to have consumed Nen.'s hand, which is not likely to have contained the infectious agent.

The data thus provide a clear case of identical incubation periods for the 2 brothers (21 years to onset if the most recent exposure date is used; 27 years if the date of the earlier feast is used). Other evidence suggests that the incubation periods of other participants are spread over a wider range, though the evidence concerning them is not as comprehensive as that for Ob. and Kasis. Aon., born 1 year before Ob. and present at Nonon.'s and Nen.'s feast, died 2 years after Ob. (onset in 1977; incubation period of 29 years). On., born 1 year after Kasis. and present at Nonon.'s and possibly Nen.'s feast, died in 1971 (onset in 1970; incubation period of 16 or 22 years). Nen.'s sister-in-law, Yap., was a chief participant in this second feast, and she developed kuru and died in 1973 (19-year incubation period). Aon. and On. may have been infected at these and only these feasts, since few, if any, others were held in this village during their lifetimes. The other kuru victims listed in table II participated also in feasts held before 1948 and may have been first infected at these earlier events.

Table III. Individuals appearing on episode II genealogy

Name	Sex	Year of birth ^a	Year of death	Participation	Comment
Pig.	F	1937	1979	yes	kuru, Tom.'s daughter
Iy.	F	1949	1978	yes	kuru
Uren.	F	1937	1973	yes	kuru
E.	F	1938	1971	no	kuru, from Takai
Agu.	F	1922	1963	yes	kuru, adopted daughter-in-law
Pigop.	F	1953	1960	no	kuru, born after this feast
Kabuin.	F	1940	1963	no	kuru, from Kasoru
Mog.	F	1929	1960	yes	kuru
Ogai.	F	1930	1959	yes	kuru
Tap.	F	before 1955	1955	yes	kuru
Tig.	F	before 1955	1953	yes	kuru
Sil.	F	before 1955	before 1955	yes	died in childbirth
Il.	M	1949	-	yes	alive, infant at feast

^a Obtained from the epidemiological file where possible.

Cannibalistic Episode II: at Ketabi Village, South Fore, 1950

This was another cannibalistic feast from which 2 participants simultaneously developed symptoms of kuru. The kuru victim consumed was Tom., and she died in 1950 in the South Fore village of Ketabi. She was originally from the village of Ai. At least 60 women and children assembled in her garden to consume the body. Her daughter, Pig., was among the most active participants. Another member of this same line was Iy., 2 years old at the time. At some point, both were infected. Pig. developed the first symptoms of the disease 28 years later, in July 1978, and she died in February of the following year. Iy. had an onset in January 1978 and died that August. Table III lists the women and children in this kinship line who were alive at the time. Of the 13 eligible to participate, 10 did and 8 later died of kuru. Of the 2 who did not develop symptoms, 1 died of another cause, in childbirth, and 1 male, an infant at the time, is still alive. 1 of these participants was Uren., the wife of Tom.'s adopted son. Tom. had helped to pay her bride price and they were very close. Uren. was heavily involved in the cannibalism. If she was first infected at this feast, then she would have had an incubation period of 22 years, until her onset of kuru in 1972.

Of the sample of 66 other kuru patients from the villages of Ketabi and neighboring Ai and Purosa-Takai, 45 gathered in Tom.'s garden on that day

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in 1950 (table IV). Of these, 21 were from her hamlet, knew her well, mourned her passing most, and seated themselves down closest to the cut pieces of the corpse. Almost all of these women and children had attended such feasts before. They died of kuru themselves at various times over the course of the next 28 years. Of the remaining 21 patients who were not present at this feast, explanations in 20 cases were offered to account for their absence, when informants were queried. 7 women were said to be residing elsewhere at the time and only later married men from this area and settled there. 13 were said to have been born after Tom.'s death: according to the records in the epidemiological file, 2 were born in 1950 (one's mother was said to be pregnant with her at the time), 2 in 1951, 5 in 1952, 2 in 1954, 1 in 1955 and 1 in 1948.

As an index of the reliability of the data, of the 13 claimed to have been born after Tom.'s death, all but 1 are recorded in the epidemiological file as having been born during or after 1950, and none born after this date were said to have been present. Only 1 individual listed as having been born before 1950 was said not to have been born yet; the year of birth recorded was 1948, which is reasonably close to the estimated time of death. In all but 1 of these cases, then, the data recorded from informants was consistent with dates derived from estimations of age made when the kuru patients had been examined clinically between 1957 and 1971. Only 1 other participant, not included in the above lists, was identified and she discussed her participation without the least embarrassment. This woman, named Aniy., was born in 1910 and is still alive, though she is not a member of the deceased's genealogy. Of the 56 known participants, 53 later died of kuru, 2 survived and 1 died of other causes. The possible incubation periods among those present allow a wide variation. However, Fig. and Iy., since there were no further feasts among their own kin, had almost certainly identical incubation periods of 28 years.

Cannibalistic Episode III: at Waisa Village, South Fore, 1953 and 1954

2 male cousins, Mab. and Pet., died of kuru, the first in February 1979 and the second 3 months later in May of that year. Both were from Waisa village in the South Fore area. As young boys, they were present at the feasts of Ton. and An., 2 of their paternal aunts, who died of kuru in 1953 and 1954, respectively, also in Waisa. An. participated in Ton.'s feast and very shortly afterwards developed symptoms of the disease herself. She died approximately 1 year later, the average duration of the disease. Between these 2 feasts, informants report that a government policeman was stationed

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Table IV. Kuru patients who resided in Ai, Ketabi or Purosa-Takai villages

Name	Sex	Year of birth ^a	Year of death	Participation	Comment	Village
Kam.	F	1941	1977	yes		Ai
Kokin.	M	1944	1976	no	in Ilesa	Ketabi
Sim.	M	1954	1971	no	born later	Ketabi
Av.	F	1941	1970	no	from Takai	Ketabi
Apu.	F	1938	1969	yes	same hamlet	Ai
Wam.	M	1952	1969	yes	same hamlet, breastfed at time	Ai
Es.	F	1937	1969	yes		Ketabi
Umben.	F	1951	1967	no		Ai
Tow.	F	1926	1967	yes	same hamlet, mother of Aga. and Wam.	Ai
Awa.	M	1942	1967	yes	same hamlet	Ai
Wagam.	M	1948	1967	no	said to have been born later	Ketabi
Tog.	F	1939	1966	yes		Ketabi
Esib.	F	1926	1966	no	from Kamira	Ketabi
Ton.	M	1950	1966	no	born later	Ketabi
Kwas.	M	1943	1966	yes		Ketabi
Again.	F	1950	1965	yes	same hamlet	Ai
Wan.	F	1935	1965	yes	same hamlet	Ai
Pob.	F	1942	1965	yes		Ketabi
Miku.	F	1943	1964	yes	from Ketabi	Ai
Tov.	F	1928	1964	yes	same hamlet	Ai
Ab.	F	1939	1964	yes	same hamlet	Ai
Mor.	M	1948	1964	yes		Ai
Nont.	F	1926	1964	no	from Takai	Ketabi
Abeb.	F	1930	1963	yes		Ketabi
Kariw.	F	1941	1963	no	from Agakamatasa	Purosa-Takai
Atob.	F	1952	1962	no	same hamlet, born later	Ai
Amuk.	F	1932	1962	yes		Ketabi
Abut.	M	1955	1962	no	born later	Ketabi
Kanig.	F	1918	1962	yes		Purosa-Takai
El.	F	1952	1961	no	born later	Ai
As.	M	1943	1961	yes	same hamlet	Ai
Alon.	M	1948	1961	yes	same hamlet	Ai

^a Obtained from the kuru epidemiological file.

Table IV (conti

Name	Sex
Umen.	M
Abor.	F
Kis.	F
Orit.	F
Kab.	M
Tet.	F
Tuk.	F
Ig.	M
Masen.	F
Anit.	F
Marat.	F
Age.	F
Tukir.	M
Mit.	F
Kas.	F
Mak.	F
Ar.	M
Wab.	F
Aor.	F
Tak.	F
Kog.	F
Kagow.	F
Ta.	F
Pcn.	F
Pitot.	F
Karaw.	F
Kogot.	F
Per.	F
Git.	F
Tag.	F
Sir.	F
Korom.	M
Amak.	F
Kagob.	M

^a Obtained from

Table IV (continued)

villages	Name	Sex	Year of birth ^a	Year of death	Participation	Comment	Village
	Umen.	M	1952	1961	no	born later	Ketabi
	Abor.	F	1930	1961	yes		Ketabi
	Kis.	F	1924	1961	yes		Ketabi
	Orit.	F	1934	1961	yes		Purosa-Takai
	Kab.	M	1952	1960	no	born later	Ai
	Tel.	F	1928	1960	yes	same hamlet	Ai
	Tuk.	F	1928	1960	yes	same hamlet	Ai
	Ig.	M	1954	1960	no	born later	Ketabi
	Masen.	F	1930	1960	yes		Purosa-Takai
	Anit.	F	1943	1960	yes		Purosa-Takai
her	Marat.	F	1924	1959	yes	same hamlet	Ai
	Agc.	F	1929	1959	no	from Takai	Ketabi
	Tukir.	M	1952	1959	no	born later	Ketabi
	Mit.	F	1934	1959	yes		Ketabi
	Kas.	F	1948	1959	yes		Ketabi
	Mak.	F	1914	1959	yes		Purosa-Takai
	Ar.	M	1951	1959	no	born later	Purosa-Takai
	Wab.	F	1936	1959	yes		Purosa-Takai
	Aor.	F	1948	1958	yes		Ai
	Tak.	F	1940	1958	yes	same hamlet	
	Kog.	F	1912	1958	yes		Ai
	Kagow.	F	1949	1958	yes		Ai
	Ta.	F	1950	1958	yes	same hamlet	Ai
	Pen.	F	1920	1958	yes	same hamlet	Ai
	Pitot.	F	1927	1958	yes	same hamlet	Ai
	Karaw.	F	1943	1958	yes	same hamlet	Ai
	Kogot.	F	1935	1958	yes	same hamlet	Ai
	Per.	F	1917	1958	yes		Ketabi
	Git.	F	1922	1958	yes		Ketabi
	Tag.	F	1912	1957	yes	same hamlet	Ai
	Sir.	F	1936	1957	yes		Ai
	Korom.	M	1950	1957	no	born later	Ai
	Amak.	F	1951	1957	no	born later	Ketabi
	Kagob.	M	1949	1957	no	from Takai	Purosa-Takai

^a Obtained from the kuru epidemiological file.

and lived in Bamusi hamlet of Waisa. During his stay, he pressured the villagers to abandon the practice of cannibalism. Only 1 other feast of a kuru victim is said to have occurred in this village after An.'s funeral, and that only a very short time later. Several men in the village insisted that a cannibalistic feast not be held for this later kuru victim, Kandab., since a government patrol was again in the area. The corpse was buried with the understanding that it would not be consumed. A group of women disobeyed, however. They exhumed the body surreptitiously and performed the traditional feast. Unfortunately, informants were either ignorant of or unwilling to discuss the details of this later feast, and in particular to state which women were involved. The fact that An.'s feast was held immediately before this controversial one suggests that the practice was by then already on the wane and that An.'s was perhaps the last publicly sanctioned feast in the village, followed only by rare, covert rituals, and attended by fewer people.

3 boys were taken by their respective mothers to Ton.'s funeral: Pet., an infant at the time, Mab., a young boy, and Toman., who was born within a few days of Pet., and was thus Pet.'s *nagaiya*. This term translates literally as 'my umbilical cord' and refers to 'boys and girls born on the same day or secluded at the same time with their mothers in the birth hut until their umbilical cords wither and fall' [5]. Both Toman. and Pet. were infants, still being breast-fed, at this time. Toman.'s mother, Aman., was the only adult who slept in the same house as An. and was her chief attendant during her demise. The mothers of these 3 boys were among the most active mourners and participants in the feasts and the 3 boys could have been infected at 1 or both. Pet. displayed initial symptoms of the disease in May 1978 and died 1 year later in May 1979. Mab. had an onset in August 1978 and died in February 1979. Toman. had a much shorter incubation period and died in late 1960. It is not likely that Pet. and Toman. were first infected at a different feast occurring later. Few other feasts were held among non-kin in the remainder of their lifetimes and none among their kin, which is where they would have been active participants, consuming the tissues with the highest titers of the infectious agent. Thus, these 2 half-brothers, born within a few days of each other and infected at the same feast, had widely differing incubation periods, while Pet. and Mab. had identical incubation periods. The 2 episodes of cannibalism, held within 1 year of each other, led to onsets of kuru in 24, 24 and 6 years, respectively, for these 3 boys.

Table V lists others in their kinship line present at An.'s feast. Among those eligible, 14 participated, of whom 10 died of kuru, 2 are alive (both

Table V. Individu

Name	Sex
Kok.	M
Pet.	M
Mab.	M
Aur.	F
Kig.	F
Wanes.	F
Nar.	F
Anoin.	F
Kes.	F
Toman.	M
Aman.	F
Kay.	F
Pem.	F
Am.	F
Kase.	F
Imen.	F
Tag.	F

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Toman., who was born aiya. This term translates ys and girls born on the r mothers in the birth hut th Toman. and Pet. were n.'s mother, Aman., was . and was her chief atten- o were among the most id 3 boys could have mptoms of the disease in b. had an onset in August much shorter incubation et. and Toman. were first v other feasts were held es and none among their participants, consuming ous agent. Thus, these 2 ther and infected at the ds, while Pet. and Mab. es of cannibalism, held u in 24, 24 and 6 years,

nt at An.'s feast. Among of kuru, 2 are alive (both

Table V. Individuals appearing on episode III genealogy

Name	Sex	Year of birth ^a	Year of death	Participation	Comment
Kok.	M	1941	1980	no	kuru, from Yagareba
Pet.	M	1952	1979	yes	kuru
Mab.	M	1938	1979	yes	kuru
Aur.	F	1940	1974	yes	kuru
Kig.	F	1952	1963	no	kuru, born later
Wanes.	F	1915	1963	no	kuru, from Ilesa
Nar.	F	1947	1962	yes	kuru
Anoin.	F	1920	1962	yes	kuru
Kes.	F	1920	1961	yes	kuru
Toman.	M	1954	1960	yes	kuru
Aman.	F	1927	1958	yes	kuru, shared house with An.
Kay.	F	before 1955	late 1950s	yes	kuru
Pem.	F	before 1955	1955	yes	kuru
Am.	F	before 1955	before 1955	yes	died, 'fever'
Kase.	F	early 1950s	-	yes	alive
Imen.	F	early 1950s	-	yes	alive, infant at the time
Tag.	F	before 1955	before 1955	yes	died, facial infection

^a Obtained from the kuru epidemiological file where possible.

having been young children at the time) and 2 died of other causes. 1 of the 2 survivors is Toman.'s older sister, who was one of the more active participants in the feast. The other survivor, Imen., was an infant at the time.

Of 21 patients from Waisa village, selected from the 51 listed in the epidemiological record, 13 were present at An.'s feast, 7 were not and information about 1 was unknown (table VI). Of those absent, 5 were from other villages and 2 were said to have been born afterwards (their years of birth were recorded in the epidemiological file as 1951 and 1955). For the first of these, Pas., the sources of data are contradictory. The epidemiological file records that he was born in 1951, though informants claim he was born after the 1953 and 1954 feasts. This disagreement represents an error of 2-3 years either on the part of our present informants or in the previous estimation of age.

This case provides another example of identical incubation periods, and an instance in which the periods vary markedly.

Table VI. Partial list of kuru patients in epidemiological file who resided in Waisa village, by year of death

Name	Sex	Year of birth*	Year of death	Participation	Comment
Mar.	F	1937	1978	yes	
Ye.	F	1928	1977	no	from Paiti
Anas.	M	1950	1976	unknown	unknown by informants
Tumis.	F	1938	1975	no	from Ilesa
Kwag.	F	1941	1974	yes	
Avar.	F	1931	1974	yes	
Abis.	M	1955	1973	no	born later
Mug.	F	1949	1972	no	from Takai
Eim.	F	1943	1972	yes	
Ageg.	F	1935	1968	yes	
War.	F	1935	1966	no	from Ilesa
Kaiy.	F	1932	1965	yes	
Pab.	F	1920	1965	yes	
Iyet.	F	1936	1964	no	from Ilesa
Asi.	F	1931	1964	yes	
Kes.	F	1920	1961	yes	
Tes.	F	1933	1960	yes	
Kag.	F	1937	1960	yes	
Ilum.	M	1946	1960	yes	
Pas.	M	1951	1960	no	said to have been born later
Mamb.	F	1930	1959	yes	

* Obtained from the kuru epidemiological file.

Discussion

The results of this study are supported by the data from experimental transmission of kuru, Creutzfeldt-Jakob disease and scrapie to animals [6, 7]. Thus, the finding that some patients have incubation periods that are extreme, either much shorter or much longer than the mean, provides an exact parallel to the behavior of these slow virus diseases produced in experimentally inoculated animals. The incubation periods of laboratory animals simultaneously infected with the same inoculum through identical routes of infection vary along a steep distribution curve. Most of the animals have an onset of the disease together suddenly at one time, over a period of only a few months, whereas the full range of incubation periods

may be 1-4 year occasionally deviate whose incubation

This study aims to determine when exposure to prion occurs in individual cases and the incubation period in man? Can 2 or more individuals contract kuru virtually simultaneously from a cannibalistic feast? Can incubation periods follow a uniform distribution? Years and vary between members of the pair. These individuals, even when confirmed by our nonhuman primate

The results concerning incubation periods indicate that they vary over a wide range. Patients who were infected and 24 years later were infected at the end of their incubation periods often occur in 2 children of identical means that age at the length of the incubation period whether a host gene of episodes here may explain variability in the entry of the virus into a wide and hard to predict range. It is likely that oral transmission with a wide range of incubation periods; though the number of individuals who come down with kuru is

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may be 1-4 years or more. Only a few of the inoculated animals would occasionally develop the disease much earlier or later than the majority, whose incubation periods cluster tightly together.

This study answers the initial questions raised: is it possible to determine when exposure to the virus occurred with any degree of rigor in individual cases and thus obtain a direct estimate of the natural incubation period in man? Can the incubation period of kuru be found to be identical in 2 or more individuals? The existence of 3 pairs of patients developing kuru virtually simultaneously after having been infected at the same 1 or 2 cannibalistic feasts, occurring close together in time, implies that the virus can follow a uniform course of replication in 2 or more individuals. The incubation periods of the 3 pairs of patients in this study are 21, 28 and 24 years and vary remarkably little, no more than 1 year, between each member of the pair. The disease can thus develop at the same rate in different individuals, even when the incubation period is over 2 decades. This is confirmed by our own experience with experimental kuru in inoculated nonhuman primates.

The results offer other insights into the disease as well. Not all the incubation periods of those infected at a particular feast are identical and in fact they vary over a wide range. In cannibalistic episode III, Toman. and Pet. were infected simultaneously at the same age, but their kuru began 6 and 24 years later. In cannibalistic episode I, Ob., Kasis., Aon. and On. were infected at 1 of 2 feasts. The first 3 of these had almost identical incubation periods while On.'s onset was 5 years earlier. Thus identical periods often occur but are by no means universal. Further, the finding that 2 children of identical age have significantly different incubation periods means that age at the time of infection is not a determining factor for the length of the incubation period. The current data are insufficient to indicate whether a host genetic factor may influence the incubation period. All 3 sets of episodes here rule out the possibility that different strains of the virus may explain variation in incubation periods. Varying modes and doses of entry of the virus may account for the range of incubations, but the range is wide and hard to reconcile with the usual replication rate of viruses. It is likely that oral ingestion of the infectious agents in particular is associated with a wide range in incubation period and possibly also with a variable take; though the number of participants at the feasts who escaped coming down with kuru is remarkably low.

The data show that large numbers of people attended the feasts and that women consequently had many different possibilities of infection at

successive mourning feasts for kuru victims. It is surprising that a high proportion of all the subsequent kuru patients at Ketabi and Waisa villages, respectively, over the next 20 years were found to have been present at the 1950 feast at Ketabi village and the 1954 feast at Waisa village, both identified as being among the last held in each of these villages. In the 3 sets of cannibalistic episodes examined above, at least 14 women and children were present at Nonon.'s death, 17 at Nen.'s, 56 at Tom.'s and 27 at An.'s (these numbers are minimum figures and the last 2 are higher since for them the lists of possibly participating kuru patients presented to informants were much longer).

It follows that women, accompanied by their children, attended numerous feasts of both kin and non-kin until the early 1950s, when feasts became rarer and then non-existent. This finding increases the probability of most participating individuals becoming infected on more than one occasion over a period of a number of years. This likelihood is enhanced by informants' reports that participants did not wash their hands for 3 weeks following the funeral, and thus exposed themselves to the agent over this protracted period of time.

The fact that women attended numerous feasts over a long period of many years makes it surprising that any South Fore woman born before 1957 has been able to survive thus far without yet displaying symptoms. Their survival is exceptional, especially in view of the fact that kuru accounted for most of the deaths among South Fore women born before the 1950s. In cannibalistic episode II, Aniy. attended numerous feasts, yet is still alive. Several other elderly women are also alive in North and South Fore villages. The genealogy of 1 such woman, Ain., from Tagoti hamlet in Takai village, is of interest. Of her 6 children, 4 have died of kuru. Thus, she is likely to have been intensively exposed to the virus, since children handled portions of the corpses given them by their mothers. Several other such women have been identified. Two hypotheses may explain their survival. First, they may not have been infected, which is possible but not probable in view of the low proportion of survivors at any one feast and their attendance at many different cannibalistic feasts of kuru victims. It is known, however, that some women, as with the male warriors, avoided eating more than token amounts of meat at these feasts. Besides elderly women, the other group of survivors are those who were infants at the time of 1 of the feasts discussed above. II. in episode II and Kas. and Imen. in episode III were present at these respective feasts but attended few, if any, additional ones since the practice was abandoned soon afterwards in their kinship

lines. Their subsequent particular feasts probably uncommonly elderly women represent the far unknown to have infected over estimate of the Incubation period cases. Much before the first years were 4-5 year incubation period cases, small, comprising a record from the end of the war.

The data from the interviews and reports indicate that the infected cannibal feast participants were able to survive. The explanation for the individual's survival at a feast in question involves both sexes, sisters, aunts and uncles, and children, who freely reported, an element of accurate sets of informants. The practice of holding feasts involving the holding of tissue debris. In episode I, individuals infected by whom, and participating in the feast.

Establishing that villagers were infected at that time. How long it has been seen in all 3 cases.

is. It is surprising that a high percentage of individuals at Ketabi and Waisa villages, and to have been present at the feast at Waisa village, both identified these villages. In the 3 sets of 10, at least 14 women and children were present, 56 at Tom's and 27 at An's. The last 2 are higher since for them the feasts presented to informants were

by their children, attended usually in the early 1950s, when feasts were being held. Feasting increases the probability of being infected on more than one occasion. The likelihood is enhanced by the fact that they wash their hands for 3 weeks before they themselves to the agent over this

is feasts over a long period of time. A Fore woman born before the war but not yet displaying symptoms.

In view of the fact that kuru has been reported among women born before the war at numerous feasts, yet is still present in North and South Fore, Ain., from Tagoti hamlet in 1964, 4 have died of kuru. Thus, she must have contracted the virus, since children handle their mothers. Several other such cases may explain their survival. It is possible but not probable that any one feast and their attendance could account for the survival of kuru victims. It is known that warriors, avoided eating more

Besides elderly women, the children of infants at the time of I of the cases. Kas. and Imen. in episode III ended few, if any, additional feasts afterwards in their kinship

lines. Their survival demonstrates that not all of those who participated at a particular feast were infected, though these exceptions appear to be remarkably uncommon. A second hypothesis to explain the survival of these elderly women is that they may subsequently die of the disease and represent the far upper limits of incubation periods. At least 1 kuru victim is known to have been over 70 years of age. She may have been repeatedly infected over 5 decades, since the disease began in the region, though no estimate of the actual incubation period in her case is of course possible. Incubation periods do vary and may extend to protracted periods in rare cases. Much briefer incubation periods have also been documented. During the first years of systematically monitoring the disease, several children who were 4-5 years of age at onset were kuru victims, proving that the incubation period can be as short as 5 years or less. The number of such cases is small, comprising 15 of a total of 2,564 cases recorded in the epidemiological record from 1957 to 1981. The number of elderly women at the other end of the range of variation is similarly small.

The data collected for this study serve to reconfirm the earlier observations and reports of Fore cannibalism and that it was through these rituals that the infectious agent was transmitted. The accounts of participation in cannibal feasts do not incriminate enemies but are sincere statements by the participants of their love and respect for the consumed deceased. Informants were able to say who was present and participated in a feast and who did not. The explanations for non-participation were systematic, based primarily on the individual's living elsewhere or not yet having been born at the time of the feast in question. Informants reported the participation of their children of both sexes, sisters and wives in the consumption of their mothers, fathers, aunts and uncles in a matter-of-fact manner, chronicling events in which they freely reported, sometimes proudly, their own participation, and without any element of accusation or excuse. Moreover, on separate occasions, different sets of informants reported consistent details of these rituals such as the practice of holding feasts in the deceased's garden and desisting from removing tissue debris from their hands and bodies as a further mourning practice. In episode I, informants reported details of which parts of the body were eaten by whom, and of the custom in 1 village of prohibiting a wife from participating in the feast of another of her husband's wives.

Establishing the year when a feast occurred often proved difficult, since villagers were completely unaware of a calendar of the passage of years at that time. However, the method employed provided consistent results, as seen in all 3 cases, in comparison with the dates of birth of patients whose

ages had been independently estimated at different times over the period of kuru investigation by 2 of us (*D.C.G.* and *M.P.A.*).

The question of whether the incidents of cannibalism described here were the last to be held in each of the villages was more difficult to answer. The existence of kuru patients who were born a few years later, after the dates of the feasts discussed here in each of these villages, implies that other feasts occurred somewhat later although the cases presented here were reported to have been the last. No kuru patient has been recorded as born after 1959. The controversial cannibalistic consumption of Kandab. shortly after An.'s publicly accepted and widely attended funeral suggests that government patrols were already influencing attitudes towards cannibalism. The evidence suggests that later feasts were performed rarely, secretly, and on a much smaller scale. No subsequent feasts were held in the kinship lines of these patients. It appears unlikely, therefore, that these victims were infected at another, later feast. Nor is it likely that they were infected at earlier feasts, since they were mostly young children at the time of the feasts described here. Consequently, we believe that we have obtained good evidence that the pairs of patients presented here who developed kuru simultaneously in recent years were infected at the same cannibalistic feasts.

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