THE CAUSE OF TRUE OR TROPICAL BERI-BERI.¹

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BERI-BERI, properly so-called, is a disease of the Far East, of Japan and of the ports of China, and is especially prevalent in the British and Dutch Settlements and possessions throughout Malaya. Other morbid conditions which correspond clinically with beri-beri should not be regarded as identical with it, nor should any assemblage of symptoms be accepted as beri-beri unless it can be shown that the same pathogenic agent is involved.

Epidemiology.—Throughout the Dutch East Indies for 150 years, in Singapore and Penang for ninety years, and in the Federated Malay States for the last thirty years, beri-beri has been perennial, endemic, occasionally epidemic. In the British area, which has a population of some 600,000, the recorded deaths in hospitals from beri-beri amount to 2,000 annually, the cases admitted to hospital for treatment being four times that number. The records are therefore rich in facts available for evidence as to the etiology of the disease.

In this large area, and throughout this long period, in all the epidemics described, as well as in sporadic cases, there has been only one factor recognizable as common to all; among communities in places where that factor has been absent there has been no beri-beri.

All races are susceptible to beri-beri, and there is no difference in the degree of susceptibility.

In Acheen—a district of Sumatra practically identical

¹ The paper forwarded by Dr. Braddon has of necessity been considerably abbreviated.

with the Malay peninsula as regards climate and conditions of life—during the twenty-two years 1873-1895, out of an average strength of 15,200 Europeans (Dutch) in military employ no less than 17,520 were invalided for beri-beri, the mean attack-rate being 52 per 1,000. During 1883-1888 the case incidence was as high as 25 per cent. of strength, although beri-beri was unknown locally. In British Malaya, during the same period, the European troops (most of them in Singapore, a notorious hotbed of beri-beri) were entirely free from it.

To explain the prevalence of beri-beri among the Dutch troops and its absence from the British, there must have been some unvarying difference of conditions. Race was not the factor as it affords no immunity; nor was place, as the British lived in a haunt of beri-beri. But there was one constant difference, viz., food. Rice formed the chief component—55 per cent.—of the diet of the Dutch soldiers in Acheen attacked by beri-beri; it is seldom eaten by the British troops in Malaya.

Had in any year one Dutch regiment serving in Sumatra been affected by the disease while a corresponding unit quartered in Singapore remained free, the solitary event might well have called for explanation. But no such experience is narrated. Military service in these places was attended with unfailing regularity by the following results:—

In Sumatra, in the Dutch regiments, year after year for twenty-two years, beri-beri.

In Singapore, in regiment after regiment, throughout the same consecutive twenty-two years, no beri-beri.

This contrast between the Dutch and British troops is of great epidemiological significance, because (1) it relates to Europeans, the conditions of whose lives are well known; (2) the numbers for comparison are large and

the time and area over which the observations have been spread is very extended.

Again, the American Army of occupation in the Philippine Islands, from 1901 onwards, was composed as follows: Americans 30,000 men (1902-3), 19,000 (1903-4); coloured troops (2,640 in 1902-3 only), Malays or Filipinos (4,800 each year). All were allowed a flour ration, Filipinos the option of rice or flour. Among the whites, there were some cases of beri-beri, 7 to 11 per 10,000 of strength, which may be readily explained by the preference of certain men for rice, or by the acceptance as beri-beri of one of the conditions which resemble it clinically. That is to say, the Americans so long as they ate no rice were exempt from beri-beri. Amongst the Filipinos (rice-eaters) the disease attacked 124 per 1,000 of strength in 1902-3-4, and in 1904-5 even more.

To the above experiences may be added those of the French in Cochin China and Madagascar; and of the combined European and native forces in the expedition to Peking. Each of those armies comprised rice-eaters and non-rice-eaters, and in each there was beri-beri, but it was confined entirely to the native troops (rice-eaters). Europeans and others who ate no rice were never attacked.

Racial Preference explained by difference of Diet.—Compare now with these experiences of one race in different places the incidence of beri-beri in different races in the same locality. In British Malaya the European civil population shares with the native races all the possible factors of causation of disease; there is between them the difference only of food. The natives are rice-eaters, the Europeans are not; the Europeans with rare exceptions never get beri-beri, the natives suffer severely. The Sikhs, Pathans and Punjabis, of whom there are

some 10,000 in the Straits Settlements and Malay States, whose customary diet is wheat flour, exhibit as a community an immunity from beri-beri as complete as that of Europeans. Of 4,237 hospital patients of this class less than $\frac{1}{2}$ per cent. were cases of beri-beri, and of that small number those affected fed on rice.

The exemption which Europeans and natives of Northern India enjoy, when free, prevails also when they are incarcerated in gaols or asylums, if they are allowed their own food. In Singapore Gaol and Singapore Asylum, the latter severely infected by beri-beri, the disease attacked only rice-eaters; Europeans and Indians who were dieted on flour and bread escaped.

TABLE I.

RACE INCIDENCE AND MORTALITY FROM BERI-BERI IN
BRITISH MALAYA.

Of 16,716 CASES of BERI-BERI ADMITTED TO GOVERNMENT HOSPITALS, 16,325, or 97 per cent., were CHINESE; CASES among TAMILS amounted to $\frac{1}{4}$ per cent. In 1891 there were 2,757 admissions for BERI-BERI; all but 2 per cent. were CHINESE, TAMILS NONE. In 1901 there were 8,159 admissions for BERI-BERI, TAMILS ONLY 54.

Twenty-five per cent. of all registered DEATHS among CHINESE are DUE TO BERI-BERI. In 2,423 consecutive registered DEATHS among TAMILS (IMMIGRANTS) FROM 1891 to 1900, ONE ONLY WAS ASCRIBED TO BERI-BERI.

TABLE II

RACE INCIDENCE (*Continued*).

Of 328,936 admissions to THIRTY-ONE DISTRICT HOSPITALS in SEVEN YEARS, CHINESE CONTRIBUTED 73 per cent. OF ALL CASES, AND ALL BUT 1 per cent. of admissions for BERI-BERI. Of 79,871 TAMILS ADMITTED, BERI-BERI IS GIVEN AS A DIAGNOSIS IN ONLY TWO CASES.

Elsewhere also facts conform with those statistics. In Japan, where the disease is endemic among the natives (rice-eaters), the numerous colony of Europeans and Americans and the indigenous Ainhos (non-rice-eaters) escape. It is evident that where beri-beri is endemic those who do not eat rice always escape (see Tables I. and II.).

The converse condition where rice-eaters become attacked by beri-beri in the midst of non-rice-eating communities is illustrated by abundant examples, *e.g.*, the notorious epidemics in New Caledonia which carried off 700 Annamite immigrants in 1891, 600 Japanese in 1892, and 1,000 in 1901. All over the world, in Calcutta, in Australia, in Vancouver, and on the Congo, beri-beri has attacked Japanese and Chinese wherever they have settled, when no factor was peculiar to them save only that their food was rice.

Special Qualities of Rice essential to the Production of Beri-beri.—The propositions that beri-beri depends on rice, that it effects rice-eaters only, and that those who eat no rice escape, the writer submits are proved by the general epidemiological evidence. It is, however, sometimes urged that if beri-beri is due to rice its incidence on rice-eaters ought to be everywhere the same, instead of showing violent contrasts as at present, one rice-eating community being unaffected while another is almost exterminated. That argument assumes rice to be always in the same condition, which it certainly is not, and the following facts prove my second contention, *viz.*, that beri-beri attacks only eaters of *certain sorts of rice*.

Immunity of Tamils to Beri-beri.—Tamils, natives of Southern India, migrate in thousands yearly to Malaya, and many of them settle there on the expiration of their indentured terms. During the last two decades at least half a million Tamil coolies have lived in British Malaya for periods of over a year, and their numbers to-day may be estimated at 150,000. Within that period still greater numbers of Chinese have been pouring into the same districts, and they now number nearly 600,000. In conditions of toil, fatigue, exposure, influence of climate and place, in deficient sanitation, and depraved habits,

there is no single condition affecting the Chinese to which the Tamil is not equally exposed. The food of the two races, however, differs. For each the staple is rice, but for the Tamil the rice is prepared from grain which is boiled before the husk is removed (cured rice). The Chinese, on the other hand, never use cured rice. Both races, as has been seen, are susceptible to beri-beri. All Tamils as well as Chinese are certified free from beri-beri before landing, and there are thus introduced into a beri-beric area two communities of susceptible individuals, both equally exposed to disease influences, save in so far that there is a distinction in the preparation of their rice.

Although, in ordinary circumstances both communities should equally incur or equally resist beri-beri, the result is far otherwise. Always and everywhere the uncured rice-eating community (the Chinese) suffers from beri-beri; the cured rice-eaters (the Tamils) invariably escape. Thus, of 16,716 cases of beri-beri admitted to Government hospitals, 16,325 ($97\frac{1}{2}$ per cent.) were Chinese. The cases among Tamils, including the occasional uncured rice-eaters, amounted to only $\frac{1}{2}$ per cent. In 1891 there were 2,757 admissions for beri-beri, all but 2 per cent. Chinese: the records show no Tamils. In 1901 there were 8,159 admissions for beri-beri. The Tamil proportion should have been 1,119 cases, but the records show only 54, including cases in uncured rice-eaters.

Beri-beri accounts annually on an average for one-fourth of all registered deaths among Chinese, but in 2,423 consecutive registered deaths among Tamils in 1891-1900, one only, and this probably erroneously, was ascribed to beri-beri. In 1907, in 6,239 deaths among Tamils, ninety-seven only were ascribed to beri-beri.

From 1891-1900 the writer had under his care 7,884

Chinese, 43 per cent. of whom had beri-beri, and 3,368 Tamils, of whom only sixteen, or 4 per 1,000, suffered from the disease. Of these latter six were uncured rice-eaters. Apart from beri-beri, Tamils are far more sickly than Chinese.

The exceptions, 5 per 1,000 of all Tamils treated, is less than the proportion which in the British Isles would be admitted to hospitals from various causes simulating beri-beri. To this class belong the cases reported as beri-beri in Tamils, subsisting on cured rice. The statistics, moreover, deal with all cases of beri-beri seen in Tamils, some of whom were known to eat uncured rice, and these figures also include Singalese who do not use cured rice.

Again, during the last three decades there has been in British Malaya a population averaging some 600,000 (Chinese and Tamils). Of these 500,000 were eaters of uncured rice, and 100,000 of cured rice. Among the uncured rice-eaters 80 per 1,000 were attacked annually by beri-beri. Among the eaters of cured rice none were affected.

Exemption of Tamils is due to their Diet of Cured Rice.—The figures show that the cured rice-eater is exempt while the uncured rice-eater is attacked, but they do not show that the consumption of cured rice is the only factor peculiar to the Tamil.

Some other condition such as race might, it is suggested, operate to protect the Tamil from beri-beri. Further, the circumstance that, when fed on uncured rice, he gets beri-beri in the same way as the Chinaman, may be met with the supposition that deprivation of cured rice involves loss of other protective factors.

The following two experiments meet these objections:—

(a) *Fletcher's Asylum Experiment.* — From the Selangor Lunatic Asylum in which beri-beri was constantly prevalent, all the inmates who had signs of beri-beri were removed, and the remainder in December, 1905, were divided into two parties, one of which was fed on *cured rice*, the other on uncured rice; all subsequent admissions were allotted to one or other of these two parties alternately. Save in their rice, the rations of all were the same; all associated freely, and to test the possibility of place infection (bed bugs, &c.), the parties occupied each others' quarters for alternate terms.

Results.—Up to the end of 1906 among 120 patients on uncured rice there were forty-three cases of beri-beri, two of whom were admitted with the disease, with eighteen deaths. Among 123 patients on cured rice there were only two cases of beri-beri both of whom were admitted with the disease. Ten lunatics actually suffering from beri-beri were put on cured rice, and all recovered without relapse; of twenty-six beri-beri patients who were not put on cured rice eighteen died.

On January 1, 1908, after two years on uncured rice, during which beri-beri attacked so many of its members, the first party was put on cured rice, and, since that date (ten months), no cases have occurred. The cured-rice party which for twenty-five months had had no case of beri-beri was on the same date put on uncured rice and, in six months, eight cases of beri-beri developed. Since June, 1908, both parties have been on cured rice and both have remained free from beri-beri.

It should be noted that 85 per cent. of the inmates of the Asylum were Chinese, and 10 per cent. Tamils. The immunity of the Tamil cured rice-eater is therefore not racial.

(b) *The Durian Tikus Investigation.*—In 1907 the

writer was granted an opportunity by the Government to test by means of this experiment his views as to the cause of beri-beri and the means of preventing it, and the Director of the Institute of Medical Research, Kuala Lumpor, Dr. H. Fraser, assisted by Dr. A. S. Stanton, undertook control of the proceedings.

The experiment consisted in placing on cured rice for a year one half of a force of 300 Javanese who were working at road making, and dieting the other half with uncured rice for the same time. If beri-beri were observed in either party before the expiry of the period, it was arranged that the dietaries would be reversed for the remainder of the time. Other conditions were exactly the same for both parties. During the six months preceding the experiment, which began on May 12, 1907, all the men had been on cured rice, and in April all were examined and found free from beri-beri.

Briefly stated, the results were that the cured-rice eaters remained free from beri-beri, whilst among the uncured-rice eaters beri-beri was prevalent.

FRESH RICE IS INNOCUOUS.

There is also abundant evidence to show that rice eaters who consume fresh village rice, *e.g.*, agricultural Malays and Dyaks, are exempt from beri-beri, so that, among rice eaters, beri-beri attacks only those who eat certain sorts; cured and fresh rice are innocuous. Now as cured rice consists of the whole grain from which, after boiling, only the husk has been removed, rice itself, *quid* rice, is not poisonous; and the factor in uncured rice which entails beri-beri must be some quality added to or lacking in the original grain. In uncured rice the fat and proteid content is reduced; moreover, the seed,

divested of its protective envelope, readily decays, and is more easily attacked by decomposition. It is always more or less stale.

Numerous observations prove that lack of fat is certainly not a cause of beri-beri; and although there seemed to be more evidence in favour of the proteid starvation view propounded by Takaki, a survey of the published dietaries of the communities among which beri-beri was severe furnishes evidence that proteid, if deficient, was not so much so that its want could have been productive of disease. No one who has seen vigorous young labourers, massive with muscle and otherwise in perfect nutrition, suddenly stricken down and in a few days killed by beri-beri can readily believe that the condition is produced by any form of starvation.

Considerable Quantities of Toxin Necessary to Produce Beri-beri.—The presence of a poison in uncured rice explains all the phenomena of beri-beri. Further, the disease is due to a poison which is present in variable proportion, and its effects are proportionate to the quantity of noxious rice eaten, the length of time during which it forms the food, and the degree to which the consumer becomes accustomed to its effects. In epidemics in which the diet was improved, and the disease thereby apparently checked, there was always, simultaneously with the addition of other foodstuffs, a reduction in the amount of rice.

During the Japanese sanitary naval reform the rice of the crews was reduced by 24 per cent., while in New Caledonia it was decreased by 30 per cent. In the Singapore Gaol during 1885 to 1896, *i.e.*, so long as the rice in the dietary was low (35 per cent.), there was little or no beri-beri, but when the proportion was raised in 1897 to 46 per cent. and in 1900 to 57 per cent., each

increase was followed by outbreaks of beri-beri. The incidence of the disease varies, therefore, not only with the sort but with the quantity of rice eaten.

The Toxin a Result of Change in the Grain.—It is plain, therefore, that the toxic quality is an added effect; either the grain itself becomes altered (as by the formation of poisonous proteins, &c.), or it becomes the seat of growth of agents (*e.g.*, ferments, bacteria, fungi) which produce poisons of their own. Both cured and fresh rice are boiled almost at the same time they are husked—the one for preservation, the other for consumption; uncured rice is boiled and eaten only long after it is husked.

The difference between rice which is toxic and rice which is non-toxic is therefore a question of boiling early or boiling late. A time element is here imported, and it implies a change in uncured rice which would not have occurred had the grain been boiled before it was stripped of its envelopes. There can be little doubt that this change is caused by a living force, but whether it is an enzyme or an epiphyte, who can say?

From an observation that horses fed on unhusked rice became affected with a disease resembling beri-beri one conjectures that the active agent lives in or upon the envelopes of the rice, and is able to invade the grain saprophytically when it is husked. Probably also it is peculiar to rice, as the use of no other cereal has been shown to entail beri-beri.

Practical Results.—The evidence now laid before you, it is claimed, has proved the theory of rice infection—a theory which from want of facts Van Dieren was unable to do more than indicate as probable; and it has also demonstrated that the change which renders rice poisonous may be avoided by boiling before husking. In the Straits Settlements several of the medical institu-

tions have substituted cured for uncured rice in their dietaries, with the following results :—

At the Singapore Lunatic Asylum, where formerly beri-beri attacked nearly every inmate, Dr. Ellis reports : “From October 13, 1903, to October 13, 1904, all patients were fed on cured rice, and but one case of beri-beri occurred, and that early in November, 1903. In October, 1904, we returned to the uncured rice, and in December fifteen cases of beri-beri arose, although none occurred amongst the controls on cured rice. Cured rice was again resorted to, and in 1906 the official report states :—

“No cases of beri-beri occurred in the Asylum and two patients admitted with it made rapid recoveries.”

In the Singapore Prison cured rice was issued to 70 per cent. of the prisoners from November 1, 1904. The months of November and December had usually furnished most cases of beri-beri ; and in these two months in the previous year there had been 118 cases. On the new diet there were only twelve (*see* Table III.).

TABLE III.

NUMBER OF CASES OF BERI-BERI OBSERVED IN THE PRISON, SINGAPORE,
DURING THE MONTHS OF NOVEMBER AND DECEMBER.

1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
100	24	61	67	87	118	14	<i>Nil</i>	1	<i>Nil</i>

During the ensuing seven months three-tenths of the total rice issued continued to be uncured, and fifteen cases occurred as compared with 147 for the same time in the previous year. From August 1, 1905, onwards only cured rice was used and beri-beri disappeared from the prison. Further, the substitution of cured rice not only prevents the development of the disease, but arrests its progress and promotes cure. In Tan Tock Seng's

Hospital, Singapore, to which about 900 cases of beri-beri are admittedly annually, the mortality fell from 35 per cent. to 17.5 per cent. on the adoption of cured rice (*see* Table IV.).

TABLE IV.
ADMISSIONS FOR BERI-BERI AND MORTALITY FOR SEVEN YEARS AT
TAN TOCK SENG'S HOSPITAL, SINGAPORE.

	1901	1902	1903	1904	1905 (Jan. to May)	1905 (June to Dec.)	1906	1907
Admissions ..	737	715	963	1,125	402	464	812	821
Deaths ..	399	305	395	521	193	86	139	102
Case mortality %	54%	43%	41%	46%	48%	18%	17%	12%

After the adoption of cured rice in Province Wellesley there was a reduction in the death-rate from 44 per cent. to 15 per cent., and at Malacca it fell from 28 per cent. to 7.35 per cent. In the hospitals under the writer's own charge in Negri Sembilan, cured rice has been in use since 1907, and in the dietary of beri-berics during 1907 bread was substituted for rice (uncured rice was used by all the other hospitals) with the result that in the former hospitals a far lower mortality has been attained (*see* Table V.).

TABLE V.
CASE MORTALITY OF BERI-BERI IN BRITISH MALAYA DURING SEVEN YEARS,
PER 1,000 CASES TREATED.

	1901	1902	1903	1904	1905	1906	1907
Perak	155	150	165	258	212	318	384
Selangor	150	121	183	156	148	192	198
Straits Settlements ..	383	300	330	338	$\frac{320}{240}$	142	101
Negri Sembilan ..	40	91	71	54	43	74	64

This table furnishes sufficient evidence of the remedial value of cured rice, even if no other facts were available.

Conclusion.—As some 2,000 cases annually are admitted

to the hospitals of the Straits Settlements the reduced mortality (25 per cent.) from the adoption of cured rice has been the means of saving many lives. The application of similar measures for the protection of the general public is a more difficult but not an insuperable task; and were it demonstrated—say, in England, as it has been in regard to beri-beri in Malaya—that there was a simple and practicable means of prevention, the public would rightly expect the remedy to be enforced.