would answer the problem. The ideal antibiotic for this should be clinically effective and bactericidal; resistance to it by the staphylococcus should develop slowly or not at all, and it should have no toxic side-effects. In the past the occurrence of strains of staphylococcus resistant to streptomycin, the tetracyclines, chloramphenicol, erythromycin, and novobiocin has prevented any of these antibiotics from solving the problem. Vancomycin and ristocetin are bactericidal, and no staphylococci showing gross resistance to these drugs have so far been reported; their use, however, has been limited by serious toxic effects, notably on the eighth nerve.

So far methicillin seems to be a considerable advance. It is a bactericidal drug of low toxicity, and, whatever may be the result of its extensive use in hospital communities, it is clear that staphylococci do not rapidly acquire resistance to it. In some of the cases reported here, however, the staphylococcus was not eradicated; in a few cases ischaemia or carcinoma militated against this, but in two patients the organisms persisted despite an apparently favourable opportunity for the drug to act.

Three patients were infected with a phage type 75/77+ which showed a minor degree of resistance to methicillin. The resistance preceded methicillin treatment, so that it appears that the strain was "naturally" resistant. Strains showing a similar degree of natural resistance have been isolated from two other hospitals (Jevons, 1961; Barber, 1961) and it is of considerable interest that both these strains have a similar if not identical phage pattern to that of the strain recorded here.

As stated above no side-effects have been encountered. Two rather thin patients had considerable pain at the sites of injection, but in general this does not seem to be more marked than with procaine penicillin.

As a result of this experience methicillin has become the antibiotic of choice in severe antibiotic-resistant staphylococcal infection in this hospital. The only other antibiotic with comparable activity in such infections is vancomycin, which is both toxic and difficult to administer. Methicillin, however, should not be used for the treatment of penicillin-sensitive staphylococcal infections, since in such cases benzylpenicillin is effective in much smaller doses and is also cheaper and easier to administer. In hospitals where penicillin-resistant infection is common it is reasonable to start treatment of the severe staphylococcal infections with methicillin, pending a report on the antibiotic sensitivity, but should the infecting strain be found to be sensitive to benzylpenicillin treatment should be changed to the latter. Methicillin is not suitable for infections with other organisms.

Summary

Clinical experience with methicillin in a large general hospital during a 16-months period is described. It has been used in the treatment of 34 patients and has proved to be a powerful addition to the range of antibiotics. Because of its bactericidal action and the lack of side-effects methicillin has now become the drug of choice for severe multiple-resistant staphylococcal infections.

Methicillin is not always effective in removing a sensitive organism. Several of the patients continued to harbour the infecting staphylococcus after treatment.

Replacement of the original flora by *Ps. pyocyanea* occurred in a number of cases, but this has been a

feature of treatment with other antibiotics in this hospital.

One strain of *Staph. pyogenes* which has been responsible for several infections was partially resistant to methicillin. The resistance was present before treatment.

Our thanks are due to Dr. Mary Barber and the consultants of this hospital for permission, help, and encouragement to write this paper. Also to Beecham Research Laboratories for the supplies of methicillin used in the earlier cases.

REFERENCES

- Barber, M. (1961). *J. clin. Path.*, **14**, 385.
 — Dutton, A. A. C., Beard, M. A., Elmes, P. C., and Williams, R. (1960). *Brit. med. J.*, **1**, 11.
 Douthwaite, A. H., and Trafford, J. A. P. (1960). *Ibid.*, **2**, 687.
 — McGill, D. A. F., and Evans, I. E. (1961). *Ibid.*, **2**, 6.
 Jevons, M. P. (1961). *Ibid.*, **1**, 124.
 Lowbury, E. J. L., Lilly, H. A., Miller, R. W. S., Cason, J. S., and Jackson, D. M. (1961). *Lancet*, **1**, 1318.
 Stewart, G. T., Nixon, H. H., and Coles, H. M. T. (1960). *Brit. med. J.*, **2**, 703.

BODY TEMPERATURE IN PACIFIC ISLANDERS AND ITS RELATIONSHIP TO BLOOD-PRESSURE

BY

I. MADDOCKS, M.D., M.R.A.C.P.

AND

R. R. H. LOVELL, M.D., F.R.C.P., F.R.A.C.P.

*University of Melbourne Department of Medicine,
Royal Melbourne Hospital, Victoria, Australia*

We have recently reported measurements of blood-pressure in population samples in Fiji and in the Gilbert Islands (Lovell *et al.*, 1960; Maddocks, 1961). During these surveys the opportunity was taken to study body temperature. The main reason for this was that Pickering (1955), in commenting on the complexity of environmental factors which might explain the relatively low blood-pressures reported in some tropical peoples, had suggested that repeated fevers might prevent the rise in blood-pressure with age which is a feature of Western peoples. Pickering's suggestion was based on the observation that blood-pressure may fall during febrile illness (Volhard, 1931) and that the same effect can be produced by the injection of pyrogenic material (Chasis *et al.*, 1942; Bradley *et al.*, 1945).

It is extremely difficult to separate, in any population, those who have suffered recurrent fevers and those who have not. However, it was thought that, by taking the temperatures of the entire populations of two tropical Pacific islands, it would at least be possible to discover if fevers really were frequent there. The findings in the Islanders led us to study body temperature in Melbourne during and after a spell of very hot weather. This paper reports these two studies, and also an examination of the relationship between body temperature and blood-pressure recorded together at a single examination.

Material and Methods

Temperatures were measured concurrently with blood-pressure in the entire population of the island of Gau, in Fiji, and in almost the entire adult population

of the main land mass of the atoll of Abaiang, in the Gilbert Islands. Temperature measurements were omitted in about 10 aged people of Abaiang whose blood-pressures were recorded in their houses because they could not attend a central gathering-place. The measurement of blood-pressure in these two populations has been described elsewhere (Maddocks, 1961).

Temperatures were measured in the mouth. Subjects were rested and seated in shade. Six standard clinical thermometers were used which had been checked over a range from 97 to 100° F. (36.1 to 37.8° C.) against a standard laboratory thermometer and found accurate. The thermometers were placed under the tongue, and held in the closed mouth for at least five minutes. Readings were taken to the nearest 0.2° F. Most measurements were made during the forenoon, but occasionally work extended into the afternoon. The temperatures are described as casual to distinguish them from more nearly basal measurements such as those made on subjects resting in bed.

Environmental temperatures were not recorded simultaneously, but they are relatively constant throughout the year in both Fiji and the Gilbert Islands. The mean temperature in Suva, Fiji, is 78° F. (25.6° C.) with a mean 9 a.m. relative humidity of 78%. In the Gilbert Islands, which lie astride the Equator, the temperature in the month in which the survey was conducted varied only a few degrees either side of 80° F. (26.7° C.) even at night. Mean relative humidity was approximately 65%.

In Melbourne we recorded the oral temperatures of consecutive patients waiting between 1.30 and 3 p.m. to attend a medical out-patient clinic in this hospital during and after a spell of hot weather in February, 1961. Attendance of a patient with a febrile illness at this clinic is rare. Environmental temperatures during the hot spell were 76–87° F. (23.3–30.6 C.) and after it 70–74° F. (21.1–23.3° C.).

Results

Body Temperature of the Islanders

Table I shows the size of the population samples and the mean and standard deviation of temperatures for each decade of age. Fig. 1 illustrates the relation of mean oral temperature to age.

Temperatures tended to fall with age. Calculation of the regressions of mean temperatures on age over the

TABLE I

Age	Fijians (741)			Gilbertese (917)		
	No.	Mean Temperature (° F.)	Standard Deviation	No.	Mean Temperature (° F.)	Standard Deviation
<i>Males</i>						
20–29	100	98.95	0.52	120	99.11	0.49
30–39	104	98.78	0.56	116	99.05	0.43
40–49	73	98.81	0.48	68	98.98	0.53
50–59	42	98.73	0.48	88	98.93	0.50
60–69	17	98.55	0.50	39	98.90	0.54
70+	9	98.40	0.70	12	98.60	0.53
	345			443		
<i>Females</i>						
20–29	170	99.40	0.57	171	99.32	0.46
30–39	113	99.34	0.42	123	99.28	0.39
40–49	58	99.25	0.50	83	99.22	0.41
50–59	35	99.22	0.40	67	99.25	0.44
60–69	14	99.03	0.75	25	99.14	0.43
70+	6	99.06	0.20	5	99.28	0.57
	396			474

FIG. 1.—Relationships between mean oral temperatures and age.

third to the seventh decades showed that temperatures fell respectively 0.085 and 0.054° F. per decade for male Fijians and Gilbertese, and 0.086 and 0.039° F. per decade for female Fijians and Gilbertese. Thus the tendency to fall with age was less in Gilbertese than in Fijians, though not significantly so.

There was a constant and significant difference between the sexes in both races, mean temperatures for females being 0.1 to 0.7° F. higher than those for males.

The mean temperatures, as at age 45, for subjects in the third to the seventh decades were almost identical

TABLE II.—Frequency Distributions of Oral Temperature

Temperature (° F.)	Males (Age in Years)						Females (Age in Years)					
	25	35	45	55	65	70+	25	35	45	55	65	70+
<i>Fijians</i>												
96.4–96.6			1									
96.6–97.0						1						
97.0–97.4												
97.4–97.8												
97.8–98.2												
98.2–98.6	9	14	10	6	4	3	4	1	1	1	2	4
98.6–99.0	24	29	20	14	8	2	11	8	4	5	2	1
99.0–99.4	30	32	27	13	2	2	38	23	14	9	2	1
99.4–99.8	18	19	10	6	2	2	48	40	19	10	3	1
99.8–100.2	16	7	3	1	1	1	39	32	14	10	2	
100.2–100.6	3		2				22	8	4	1	2	
100.6–101.0		1					4	1				
101.0–101.4							3					
101.4–101.8							1					
101.8–102.2												
102.2–102.6												
Total	100	104	73	42	17	9	170	113	58	35	14	6
<i>Gilbertese</i>												
97.6–97.8	1		1	1	1				1			
97.8–98.2	5	4	7	7	2	2	1		3			1
98.2–98.6	19	21	10	19	10	3	18	8	3	7	3	1
98.6–99.0	32	42	23	28	13	4	36	33	29	15	9	1
99.0–99.4	39	30	16	27	7	2	51	53	28	25	7	1
99.4–99.8	18	16	8	6	4		48	23	18	16	4	
99.8–100.2	5	3	3	1	2		15	4	3	2	1	2
100.2–100.6	1						2	2		1		
100.6–101.0												
101.0–101.4												
101.4–101.8												
101.8–102.2												
102.2–102.6												
Total	120	116	68	88	39	12	171	123	83	67	25	5

FIG. 2.—Frequency distributions of oral temperatures for both entire populations. —, male; ---, female.

for females of both races, being 99.25° F. and 99.24° F. for Fijians and Gilbertese respectively. The mean for male Fijians, 98.76° F., was significantly less than that of 98.99° F. for male Gilbertese ($P < 0.01$).

The frequency distributions of temperatures in each decade of age are shown in Table II, and illustrated for both entire populations in Fig. 2. The distributions appear normal, modal values for males being 98.8–99.0° F., and for females being 99.2–99.4° F. Only two temperatures are detached from the main distributions—one of 96.6° F. and the other of 103.4° F. There is no suggestion of bimodality in the distributions.

Body Temperature in Melbourne

The casual oral temperatures of the Melbourne out-patients during and after a spell of hot weather are shown in Table III. When environmental temperatures were 76–87° F. the mean oral temperatures of patients of both sexes were significantly higher than the means when environmental temperatures were 70–74° F.

TABLE III.—*Melbourne Out-patients*

Environmental Temperature (°F.)	Males				Females			
	No.	Age $\pm$ S.D.	Oral Temperature (°F.)		No.	Age $\pm$ S.D.	Oral Temperature (°F.)	
			Mean $\pm$ S.D.	Range			Mean $\pm$ S.D.	Range
76–87	25	45 $\pm$ 17.8	99.1 $\pm$ 0.51	98.2–100.6	34	54.1 $\pm$ 16.1	98.9 $\pm$ 0.54	97.6–99.8
70–74	26	47 $\pm$ 17.8	98.5 $\pm$ 0.52	97.6–99.6	25	47.2 $\pm$ 18.0	98.4 $\pm$ 0.78	96.6–100.0
Differences			0.6 ($P < 0.001$)				0.5 ($P < 0.01$)	

Body Temperature and Blood-pressure of the Islanders

The blood-pressures of these two island populations have already been described (Maddocks, 1961). Neither the means nor the variances of the pressures show the substantial rises in later years which are characteristic of Western peoples.

FIG. 3.—Relationships between blood-pressure and age in subjects with different oral temperatures. ●—●, oral temperature 99° F. or less; ○—○, oral temperature more than 99° F.

The relationship of oral temperature to blood-pressure was investigated by comparing the blood-pressures of subjects whose temperatures exceeded 99° F. with the blood-pressures of those whose temperatures were 99° F. or less. This level was chosen because temperatures above 99° F. are often regarded as abnormal in temperate climates, and because it divided the populations into fairly even numbers. The results are shown in Fig. 3. Blood-pressures of subjects with temperatures over 99° F. tended to exceed the blood-pressures of those whose temperatures were lower. A "t" test comparing the pairs of means showed the difference to be significant ($P < 0.05$) for the systolic pressure of Fijian males and Gilbertese females.

For the population of Gau the relationship between body temperature and blood-pressure was further investigated by calculating correlation coefficients (Table IV). The simple correlation coefficients show that temperature had a significant negative correlation with age, and blood-pressure had a significant positive

TABLE IV
Simple Correlation Coefficients. *Fijians of Gau*

	Males		Females	
	Age	Temperature	Age	Temperature
Temperature	-0.1715†	—	-0.2289†	—
Systolic pressure	0.3491†	0.0598	0.2035†	0.0059
Diastolic "	0.1229*	0.0967	0.0616	0.0060

Partial Correlation Coefficients for Blood-pressure and Oral Temperature holding Age Constant

	Males	Females
Systolic pressure	0.0548	0.1299*
Diastolic "	0.0144	0.1297*

* $P = 0.05$. † $P = 0.01$.

Discussion

Casual oral temperatures do not appear to have been measured before in population samples in which the selection of subjects was not determined to some extent by health. In addition to such differences in selection, variations in circumstances of measurement and in the age-and-sex structures of the population samples make statistical comparisons between previous studies and our own unwarrantable. Nevertheless it is apparent from the studies most closely resembling ours—those of Whiting (1915) in England, Ivy (1945) in America, Renbourn and Bonsall (1946) in India, and Cullumbine (1949) in Ceylon (Table V)—that mean casual oral temperatures tend to be higher in environmental temperatures over about 75° F. than in cooler surround-

ings. This conclusion is confirmed by our own observations in Melbourne (Table III), in which it was found that the mean oral temperatures in hot weather were similar to those of the Islanders. The occurrence of higher oral temperatures in tropical than in temperate conditions is evident even in population samples selected, like those of Renbourn and Bonsall (1946) and of Cullumbine (1949), as being free from disease. In the light of these findings it is reasonable to

differences might be contributed to by premenstrual rises in temperature, so that it is the persistence of the differences in older age-groups which is notable. Wunderlich (1871) commented: "It may be that grown-up women are a trifle warmer than men of equal age; but the number of observations is insufficient to enable us to lay down a safe general rule on this point." This comment appears to remain true to-day so far as non-tropical populations are concerned.

TABLE V

Author	Place	Subjects	Age	Time of Day	Environmental Temperature (°F.)	Mean Oral Temperature $\pm$ S.D. (°F.)	Range (°F.)
Whiting (1915)	England	500 male convicts	43.5 $\pm$ 14.51	p.m.	40-78	98.3 $\pm$ 0.5	96.5-99.1
Ivy (1945)	U.S.A.	276 students		a.m.	Warm classroom	98.1 $\pm$ 0.4	96.5-99.3
Renbourn and Bonsall (1946)	India	894 British and Indian soldiers		Various	78-95	98.8 $\pm$ 0.5	96.3-100.6
Cullumbine (1949)	Ceylon	436 male students	18-25	a.m.	83.5	98.9 $\pm$ 0.4	96.3-101.4
		158 female "	18-25	"	83.5	99.4 $\pm$ 0.3	98.4-101.0

regard the mean temperatures of the Fijians and Gilbertese as natural to their climatic environment rather than as reflecting a high incidence of febrile illnesses.

Several other features of the Islanders' temperatures suggest that this is so. The frequency distributions of the temperatures look normal, as do those of the populations studied by Whiting (1915), by Renbourn and Bonsall (1946), and by Ivy (1945). A high incidence of fevers would cause positive skewness or a bimodal distribution. We found only one substantially raised temperature detached from the main distribution. Secondly, the dispersion of the Islanders' temperatures, as reflected by the standard deviation, is similar to that found in the populations quoted who were selected with regard to health. Thirdly, the tendency for temperature to fall with age, which might have been obscured by a high incidence of fevers, was present and of the same order as that of 0.0499° F. per decade found by Whiting (1915) in convicts in England.

Our failure to find a high incidence of fever in these two malaria-free tropical populations leads us to seek other explanations than that of repeated fevers to account for the failure of their blood-pressures to rise as much with age as do those of Western peoples. It remains possible that infections and infestations, differing as many of them do in nature and frequency from those in Western peoples, contribute to the different patterns of blood-pressure, but that their effect is not mediated by fever. There are, however, no *a priori* reasons for believing that this is so.

The correlation between casual oral temperature and casual blood-pressure is so slight as to suggest no relationship of importance between them.

In conclusion we have two comments on the oral temperatures themselves. We are not certain why the temperatures of the male Fijians were lower than those of the male Gilbertese, but differences in clothing might have been relevant. The Gilbertese males were more often without clothing above the waist than were the Fijian males. Secondly, the finding of higher mean temperatures in females than in males at all ages in both races was remarkable. Cullumbine (1949) found a similar difference between the sexes in Sinhalese students aged 18-25, and Horvath *et al.* (1950) also found higher mean temperatures in American females aged 19-35 than in males of similar ages. In these age-groups, such

Summary

Casual oral temperatures were measured in two complete Pacific island populations, and in Melbourne out-patients during and after a spell of hot weather.

The mean temperatures of the Pacific islanders were higher than those reported in reasonably comparable subjects in temperate zones, but resembled those reported in selected healthy populations in the tropics and those found in Melbourne out-patients in hot weather. The islanders' temperatures were similar to those reported in populations elsewhere in the normality of their frequency distributions, in their standard deviations, and in their relationships to age and sex. It is concluded that the temperatures found in the Pacific islanders are natural to their climatic environment and are not due to high incidence of fever. The failure of the blood-pressure of these peoples to rise as much with age as does the blood-pressure of Western peoples seems not to be due to a high incidence of repeated fevers.

We are grateful to Dr. Dill-Russell and Dr. Roy Edmonds, in Suva, and Dr. W. Rees and Assistant Medical Officer Bwebwentekai Tekanene, in Tarawa, for their help; to Miss B. Patterson for technical assistance; and to the Victor Hurley Research Fund of the Royal Melbourne Hospital and to the Nuffield Foundation, whose grants supported this work.

REFERENCES

- Bradley, S. E., Chasis, H., Goldring, W., and Smith, H. W. (1945). *J. clin. Invest.*, **24**, 749.
 Chasis, H., Goldring, W., and Smith, H. W. (1942). *Ibid.*, **21**, 369.
 Cullumbine, H. (1949). *Ceylon J. med. Sci.*, **6**, 88.
 Horvath, S. M., Menduke, H., and Piersol, G. M. (1950). *J. Amer. med. Ass.*, **144**, 1562.
 Ivy, A. C. (1945). *Gastroenterology*, **5**, 326.
 Lovell, R. R. H., Maddocks, I., and Rogerson, G. W. (1960). *Aust. Ann. Med.*, **9**, 4.
 Maddocks, I. (1961). *Lancet*, **2**, 396.
 Pickering, G. W. (1955). *High Blood Pressure*. Churchill, London.
 Renbourn, E. T., and Bonsall, F. F. (1946). *Brit. med. J.*, **1**, 909.
 Volhard, F. (1931). Quoted by Pickering (1955).
 Whiting, M. H. (1915). *Biometrika*, **11**, 1.
 Wunderlich, C. A. (1871). *On the Temperature in Diseases*. New Sydenham Society, London.

The Northern Ireland Hospitals Authority has issued its *Hospital Service Directory*, 1962. It includes details of the Authority itself, the blood-transfusion, mass radiography, and ambulance services, the hospital management committees, hospital telephone numbers, and other details.