Discussion

The Oxford City evidence has the advantages and disadvantages of a city field trial. These have already been discussed. The results show that the pertussis vaccine in a total (English) dosage of at least 40,000 million organisms did not significantly affect the incidence of whooping-cough. In the residential nursery trials the groups were almost identical in constitution and risk of exposure to infection, and the clinical data were more reliable, but the number of children under observation was necessarily much smaller. The results, however, bear out the findings in Oxford City that the vaccine was of no value in preventing whooping-cough.

Doull and his colleagues (1939) have already recorded results almost as disappointing as our own; but the majority of the reports from the United States and Canada suggest that vaccination against pertussis is effective. Although it is possible to find faults with points in the planning or statistical analysis of some of the trials it is difficult to avoid the conclusion that vaccination conferred some protection. It is noteworthy that most of these trials were carried out in clinic populations in which it is extremely difficult to obtain perfect equalization of the inoculated and control groups, particularly in regard to exposure to infection. In one of the few trials conducted in residential institutions, where a far greater degree of similarity can be attained between the two groups, little or no success was claimed (Siegel and Goldberger, 1937).

Our own results may be criticized on the ground that the vaccine was of insufficient antigenic potency or that the dosage employed was too low. Examination of the data recorded by different observers who have apparently been successful in whooping-cough prophylaxis shows that a wide variety of vaccines has been used, and there is little to suggest that any one method of vaccine preparation is greatly superior to any other. In respect of dosage, we have already pointed out that there is a gross discrepancy between the results yielded by the methods of vaccine standardization in this country and the United States, and that if our vaccine had been prepared in an American laboratory its strength would have been estimated at about 60,000 millions instead of 20,000 millions per ml. It is probable, therefore, that our total dosage was higher than that used in any of the investigations recorded in Canada or the United States. This is borne out by the severity of the reactions that we obtained after inoculation of the larger doses of vaccine.

Since the possibility could not be excluded that the Wellcome vaccine used in our investigations differed in some material way from vaccines prepared in the United States and Canada, it was decided by the Whooping-cough Subcommittee of the Preventive Medicine Committee of the Medical Research Council to carry out a fresh investigation in which a vaccine of American origin was used. Such a trial is now being undertaken in Oxford, under carefully controlled conditions, using a vaccine manufactured by Messrs. Parke Davis of Detroit to the formula of Dr. Sauer, of Evanston, Ill. The results of this inquiry will, it is hoped, be published in due course.

Summary and Conclusions

Over 600 susceptible children of 6 months to 3 years of age attending welfare clinics and wartime day nurseries in Oxford City, and 110 evacuee children of 6 months to 3 or 4 years of age distributed in eight residential nurseries in Oxfordshire, Berkshire, and Buckinghamshire, were divided into "inoculated" and "control" groups by methods designed to render the two groups similar in every respect other than inoculation.

The inoculated children were given either two doses of pertussis vaccine at a 4-weeks interval, or four doses at intervals of 1, 1, and 4 weeks. The total dosage ranged from 40,000 to 100,000 million organisms, corresponding to an American dosage of about 120,000 to 300,000 millions.

Whooping-cough occurred sporadically in Oxford City during the succeeding 18 months, and broke out in four of the residential nurseries 2 weeks to 9 months after the last inoculation.

No significant difference was observed in the incidence or severity of whooping-cough between the inoculated and the control children. In Oxford City 12.5% of 327 inoculated and 14.1% of 305 control children developed definite whooping-cough. In the residential nurseries the corresponding figures were 55% of 33 inoculated and 63% of 30 control children.

The evidence obtained from this investigation lends no support to the view that pertussis vaccine is of value in the prophylaxis of whooping-cough; and it is suggested that the use of this vaccine should be discontinued till some positive evidence of its value is obtained in further carefully controlled trials.

We are indebted to Dr. R. B. Fisher for statistical advice; to Dr. G. C. Williams, Medical Officer of Health, Oxford C.B., for permission to carry out the investigation among the children under his care; to the medical officers and health visitors on his staff for their co-operation and active help; to Dr. E. Donaldson, Principal Regional Medical Officer, for his assistance in the choice of suitable residential nurseries; to the Waifs and Strays Society, the Margaret Club Day Nursery, the Whitefield Day Nursery, and the county councils of Buckinghamshire, Berkshire, London, and Oxfordshire, for permitting us to visit these nurseries; to the medical and nursery staff of each nursery we selected, particularly to Dr. J. A. Hill, Dr. G. N. Stathers, Dr. G. R. N. Henry, and Dr. N. Black; and to the Matrons of Cottesford House, Culham Court, Waddesdon Manor, and the Margaret Club Day Nursery for the collection of much of the data we needed. We particularly wish to thank Messrs Burroughs Wellcome and Co. for the free supply of vaccine.

REFERENCES

- Doull, J. A., Shibley, G. S., Haskin, G. E., Bancroft, H., McClelland, J. E. and Hoeschler, H. (1939). *Amer. J. Dis. Child.*, **58**, 691.
Fisher, R. A., and Yates, F. (1943). *Statistical Tables for Research Workers*, 2nd ed., Oliver and Boyd, London.
McFarlan, A. M., and Topley, E. (1943). *Mon. Bull. Min. Hlth. Lond.*, **2**, 122.
Siegel, M., and Goldberger, E. W. (1937). *J. Amer. med. Ass.*, **109**, 1088

PROBLEMS OF NAVAL WARFARE UNDER CLIMATIC EXTREMES*

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PART III.—LECTURE II (continued)

Psychological Effects of Long Service in the Tropics

A common opinion in the Tropics is that after about a year there is a noticeable deterioration in drive, alertness, keenness, memory, the capacity and speed of thought, and power of making decisions. These symptoms may be accompanied by an obvious lassitude, procrastination, irritability, sometimes bibulousness, and slovenliness in personal appearance. The better-educated are conscious of their own declining efficiency, and they note the same change in others; that is to say, the phenomena are both subjective and objective. The symptoms are popularly ascribed to the climate, whether hot and humid or hot and dry, and the point of view is freely ventilated that one to two years should be the maximum tenure in uncongenial tropical regions.

Since we are waging a naval campaign in equatorial waters, the problem has many important bearings. Medical advice is needed on several points. Do, in fact, changes in intellect or personality follow long tropical residence? If so, what is their nature?; how can they be prevented or alleviated?; what is the optimum duration of tour in the Tropics?

A new-comer may be struck by certain personality traits in some who have served for a time on a tropical station—traits made up of undue irritability, alcoholic indulgence, mild hypochondriacal preoccupation, and a tendency towards paranoid feelings of resentment. Castellani applied the term "cacophoria tropicalis" to a state of lassitude and mild general malaise. Whether actual falling off in performance and intellectual capacity exists we do not know for certain, but we suspect it. To determine the nature of this clinical picture is important. Superficially, the syndrome might strike one as representing a mild dementia with some personality deterioration were it not for the victim's clear insight and the fact that the condition is apparently "cured" after leave at home. More probably it belongs to the realm of the neuroses, with hysterical features motivated by a strong if thinly veiled desire to return home: in other words, a nostalgic reaction.

* Being the Croonian Lectures delivered to the Royal College of Physicians, July 10 and 12, 1945.

One must not assume that hot climate is the sole cause of this picture. The total situation must be visualized. Service factors such as boredom, isolation, lack of amenities including beer and familiar diet, home worries—financial or marital—all these occur and may outweigh the hazards of enemy action. Add the stresses and strains of disordered sleep, fatigue, bodily discomfort (perpetual sweating, skin irritations, diarrhoea, flies); and also the constant association with coloured folk and a growing intolerance of their inexplicable habits.

From a Service standpoint it is important to decide how much of this "tropical neurosis" is due to these auxiliary factors, some of which could perhaps be alleviated, and how much is due directly to climate. Though the literature upon this subject is growing, it is inadequate. Many tropical practitioners who have written upon the matter have not been psychiatrists, while the psychiatrists have not always had tropical experience. Of late there has been a tendency to decry the tropical neuroses and to minimize the part played by climate, as opposed to the many auxiliary factors.

The climatic factor would be supported if one could demonstrate: (1) that the same psychiatric features occur in tropical civilians whose homes and families are on the spot, having elected freely to take up a career in hot climates; (2) that nervous and mental symptoms do not occur when individuals live in artificially cooled quarters in the Tropics or when they have frequent spells up-country; (3) that the characteristics of the clinical picture are unlike those in neurotics at home; (4) that meteorological and clinical fluctuations run parallel; and (5) that the efficiency and the personality of tropical indigenes alter when they emigrate to a cool country. How far are these things possible?

1. It is difficult to escape the conclusion that neurotic symptoms are commoner in the Tropics than at home, though the incidence may be less in civilian than in Service personnel. There is agreement that loss of efficiency does gradually develop in the Tropics with time, that it is improved by leave in hill stations or in the United Kingdom, and that the civilian psychiatric picture resembles that seen in the Forces. That efficiency deteriorates is shown by the practice of the Colonial Office, and various banks and trading concerns, who have found that it pays to make compulsory long and frequent spells of leave at home.

Statistics reveal a high incidence of nervous or mental breakdown among civil servants in East and West Africa. Thus, psychiatric disorder was responsible for one out of every three invalidings from East Africa, and one out of every 2.7 from West Africa. Alcoholism was responsible for one out of every 24 and 30 respectively. (Tropical disease proper accounted for 1 out of 9 and 1 out of 10 respectively.) Of the deaths, 1 in 6 and 1 in 3.8 were directly due to tropical affections in East and West Africa, while 1 in 11 and 1 in 13 were suicides (see Table). These high figures, be it noted, apply to carefully selected Europeans who had chosen a career within the Tropics.

	East Africa				West Africa			
	Invalidings			Deaths	Invalidings			Deaths
	Total	Trop. Dis.	N.P. Dis.	Alcohol	Total	Trop. Dis.	N.P. Dis.	Alcohol
1930	25	6	6	1	23	6	2	1
1931	29	3	15	1	24	6	2	1
1932	22	2	7	—	16	5	2	3
1933	23	2	4	—	18	1	3	4
1934	27	2	8	1	16	3	—	4
1935	16	2	3	1	19	6	2	3
1936	24	4	11	2	24	1	1	3
1937	26	2	8	1	22	3	4	4
1938	20	1	7	1	21	1	2	2
1939	18	2	5	1	16	2	—	2
1940	11	—	6	1	25	4	—	3
Total	241	26	80	10	224	38	20	390
								37
								143
								13
								197
								52
								15

N.B.—The cases of alcoholism are included within the totals for neuro-psychiatric (N.P.) disorders.

Of 166 psychotic American soldiers in 1901, 120 were stationed in the Philippines and the rest in the United States; the following year the number was 114 out of 186. In 1903 the suicide rate for the U.S. Army at home was 7 per 100,000 and in the Philippines 16 per 100,000 (C. E. Woodruff).

2. No figures are yet available as to the incidence of neurosis before and after the air conditioning of homes and offices in the

Tropics, though it has been shown that the output of work is considerably speeded up after the installation of cooling plants.

3. In some respects the tropical syndrome differs from the usual neurotic pattern. The earliest and prominent features of the tropical neuroses are intense irritability, poor memory, and mental and physical lassitude, while the characteristic anxiety and depression so common in our experience at home are much rarer and appear later. Then again, the frank psychoses of the Tropics show a certain bizarre in their picture. Nothing like the Malayan *latah* and *amok* can be found in our mental hospitals, though the cause may be racial rather than environmental. The same applies to the *koro* of the Celebes islanders and the *uas-uas* of the Tripolitanian Arabs. But among white troops in the East special clinical entities are sometimes described—the amoebiasis psychoneurosis, the depression of the rubber plantations, the mepacrine psychoses—though in all cases the suggested aetiology is dubious and the status of the syndrome insecure. Queer explosive and violent outbursts with confusion and subsequent amnesia occur on occasion among European troops in the Tropics, but they are not so much attributable to the climate as to the taking of native spirits—*arak*, *zebib*, *lagbi*, or *buha*.

4. In tropical and subtropical areas spells of inclement weather may cause great discomfort and exaggerate whatever psychiatric features already exist. This is illustrated by the hot dry winds of high velocity. Dexter noted that Denver school-children were more unruly when strong southerly winds were blowing. The *mistral* of the South of France is said to produce a curious irritable state—*le cafard*. In Libya and the Levant there is the *khamisin*, in West Africa the *harmattan*, and in Malta the *xirocco*—all of which are climatic phenomena directly associated with psychiatric anomalies.

5. When Indians, Chinese, and negroes take up residence in a cooler part of the world their capacity for efficient mental work probably improves. This idea is supported by M. MacKinnon, who has studied the intellectual growth of European children born or reared in Kenya. At first they developed a mental alertness far superior to that of children at home, but after the age of 10 or so a gradual mental exhaustion and deterioration was the rule. These phenomena were in his opinion due to climate—to the stimulating effect of sunshine followed by the ill effects of undue heat. The circumstances were complicated, however, by the high altitude at which the children were living.

Psychological Effect of Long Service in Polar Regions

Naval ratings usually fare better in the extreme north than in the Tropics. Likewise, Scott's Antarctic team found the passage out through hot humid weather more trying than the cold climate which came later. We can, however, describe psychiatric features in the Arctic as in the Tropics, though possibly to a lesser extent. There are affective disorders which one associates with the solitude, darkness, and icy cold of the long polar winters. According to Burton, melancholy might result from lying "in stoves and caves half a year together in Iceland, Muscovy, or under the Pole itself." Explorers have noted these manifestations. We recall the "barrack-fever" of the German Forces occupying the most northerly part of Norway. The Finns speak of a *Värtrotthet*, or "spring-tiredness," which comes on towards the end of the winter season. Then there is the "light hunger" described in Russia by Katz and the "sun-thirst" of Goethe. It is interesting that depression is the dominant symptom in these Arctic disorders rather than irritability or forgetfulness as in the tropical neuroses. Similarly the incidence of manic-depressive psychosis among the insane population of Iceland far outnumbers that of schizophrenia; the reverse is true of Norway, where the racial stock is similar but the climate different. Mental disorders of the Tropics are reflected in the extreme north by a number of strange psychotic states. Thus we have the *piblokto* of the Greenlanders, with its impulsive features; the Siberian *mirvachet*, with its coprolalia and mimetic symptoms, so similar to the Malayan *latah*; and the Labrador *wihtiko*, with its cannibalistic urges.

Again, we find in the Arctic the same explosive alcoholic episodes which are encountered in the Tropics. Bouts of berserker violence may follow sudden intemperance among the inhabitants of such "dry" countries as Iceland. As regards personality, the indigenous elements of the Arctic regions display apathy, slowness, and inefficiency just as in the Tropics. But the Eskimos and the northern Siberians are said to improve considerably in activity when transferred to a more habitable climate, as in the United States.

The conclusion would seem to be that climate *per se* can at times be held responsible for personality changes, and that it

may precipitate neurotic or even psychotic breakdown in certain predilected individuals; that it influences the pattern of the resulting clinical picture; and that it may, as Montesquieu taught, be one of the factors in determining the characteristics of the native population.

From a Service point of view there are certain practical lessons which will serve to avert breakdown of mental health in climatic extremes. These comprise the principles of (1) selection of the suitable and rejection of the unsuitable candidates for Arctic and tropical service; (2) determination of the most desirable limits of stay in such regions; (3) periodic leave periods in equable and agreeable environments; and (4) a complete welfare service in the fullest sense of the term, to maintain the comfort, spirits, interests, and morale of Forces serving in these exceptional circumstances.

Selection of Personnel Best Fitted for Tropical or Arctic Service

Artificial acclimatization has the incidental merit of directing attention to those who are unlikely to endure climatic extremes. Service requirements demand that the question of selection and rejection should be considered more fully. It must be realized that this practice does not yet stand upon the firm basis of an exact science. Further work in this direction is sorely needed not only for Service purposes but also for post-war Colonial development.

Some of the circumstances which cause an examiner to look askance at a candidate for foreign service are more significant than others. The contraindications for tropical and Arctic service may be regarded as either relative or absolute.

Contraindications

State of Physical Health.—Nothing is gained by listing the diseases which would afterwards preclude service in the Tropics or the Arctic, nor those minor and chronic maladies which are apt to flare up and become troublesome under extremes of temperature. This aspect of the problem is fairly well established.

Age.—The elderly do not tolerate heat or extreme cold as well as younger persons, especially if submitted to such a climate for the first time. Many would like to enforce an upper age limit of 35, or even of 30, upon those to be drafted to the Tropics or the Arctic. This may be too drastic, for the older sailor may have endured a hardening process in climates of another sort which may prove a good training for the immediate task. Scott's Antarctic expedition illustrates how well the rather older subjects can fare. His final Polar party consisted of five men, their ages ranging from 28 to 43. In his last letter Scott wrote: "*I want to tell you I was not too old for this job. [He was 43.] It was the younger men that went under first.*"

Body Build.—Tropical exigencies are less well tolerated by those of pyknic habitus than by the spare or by the tall lean types. When working in humid atmospheres a big man is perhaps at a disadvantage compared with a small one, for both will produce heat in proportion to their weight and dissipate it according to the ratio of body weight to surface area. Such was the case in S. Robinson's comparison of two subjects, but J. Weiner's analysis of over 200 miners showed only a slight correlation between heat tolerance and surface area. A poor musculature is not a handicap. In the case of cold climates, a generous amount of subcutaneous fat is of benefit, short of a pathological obesity with its attendant circulatory strain. Apart from the factor of fat-insulation, big persons on the whole tend to endure cold better than the small, just as the larger mammals are the ones to survive in the Arctic. Exceptions occur, of course, as in Scott's party, where they found "strength of will" more significant than physical constitution.

Physical efficiency tests might be most helpful if standardized. A step test has proved useful in the selection of recruits, and correlates well with subsequent performance in the heat. The virtues of any selection procedure which reproduces closely the actual conditions of work are obvious, and should be developed further.

Pigment.—There is some relationship between the pigmentation of an individual and his tolerance towards tropical life, though few would go all the way with Woodruff, who said that recruits for tropical Service should be limited to brunettes of

short stature—the Mediterranean type, in fact. This same author tried to demonstrate a predominance of the blond in cooler climates and of the dark-skinned in the heat. Regarding sailors as essentially encompassed by a low-temperature environment (which of course is not the case), Woodruff has written: "*The blond type of man is now and always has been the best sailor. He takes to water like a duck . . . he is the yachtsman of the world, the boat-builder, and rules the sea at the present time.*" For Arctic service, cutaneous pigment is unlikely to influence the selection test, despite Woodruff's beliefs.

But certainly tropical Service is not for those who have such congenital defects of pigment as leucoderma. Albinos fare very badly in hot climates, and those rare cases of albinism in coloured people seldom attain adult age. Vitiligo, if sufficiently extensive, is a handicap. Persons who are of excessive or "platinum" blondness, especially if showing a tigroid fundus on ophthalmoscopic examination, are doubtful candidates for the Tropics.

Even the red-heads are suspect by virtue of their cutaneous intolerance towards the sun's rays. It has been said that the French Foreign Legion used to debar such candidates, but considerations other than photosensitivity might have been in mind.

Possible Biochemical Factors.—Experience both in the Tropics and in the far north shows that there are certain rare persons who are conspicuously intolerant of the heat, and others of the cold. Such heat-sensitive and cold-sensitive subjects are not conspicuous to ordinary medical tests; nor do they stand out by virtue of any feature of age, build, or colouring. It would be a convenience, at the very least, if it were possible to devise some test or criterion whereby these rare cases could be identified at home. No such hall-mark is known as yet, though a close physiological study is projected of all naval ratings who are invalided from the Tropics to the United Kingdom as being heat-sensitive. Alterations in the blood lipid-phosphorus level and in the suspension stability test have been suspected, but not demonstrated, in such cases. It is possible that some inherent dysfunction of the sweat glands or of chloride metabolism, or both, may be a feature of the heat-sensitive. A fairly wide variation in the chloride content of the sweat is known to occur, but no serious attempt has yet been made to correlate the biochemical with the clinical data. The proportion of eccrine to apocrine glands may be significant in this connexion, as suggested by the known racial differences. Still more likely is a link between the total number and distribution of eccrine glands and heat tolerance. Unreadiness to sweat in hot atmospheres may be a factor in determining heat sensitivity. Thus Borchardt closed up 15 subjects for two to three hours in a hot room at 33° C. (91.4° F.), with a relative humidity of 90%. Seven of them sweated much less than the others, and these developed various distressful symptoms, their body temperatures rising considerably. Kuno regards those hypohidrotic persons as probably unsuited for tropical residence.

There are several possible causes of constitutional deficient sweating; there may be a relative insensitivity of the sweat centres in the hypothalamus, the medulla, or the spinal cord; or the sweat glands themselves may be abnormally sluggish in action or too few in number. With regard to the last point, it is important to note that those very rare persons with congenital absence of sweat glands should be absolutely precluded from the Tropics.

Sensitivity towards high temperatures may increase as the result of a previous attack of heat-stroke. For this reason, firms usually transfer an employee to the United Kingdom permanently on his recovery from such an illness.

The phenomenon of cold sensitivity exists in a small proportion of the population. Such display considerable distress and even syncope when exposed to low temperatures which would not incommode the average. B. T. Horton and G. M. Roth believe they can detect such cases in the laboratory. Five minutes' soaking of the hands in water at 8 to 10° C. (46.4 to 50° F.) will bring about flushing of the face, rapid pulse, and a fall in blood pressure. They believe that such can be desensitized in either of two ways: (1) by immersing the hands in water at 10° C. (50° F.) for one to two minutes twice a day for three or four weeks; or (2) by the subcutaneous injection of 0.1 mg. of histamine twice a day for two to three weeks.

An acquired sensitivity to cold may develop in those surviving severe exposure—as, for example, sailors who have been immersed for long periods in the sea or who have been adrift in waterlogged boats. A local hypersensitivity to cold is, of course, one of the characteristic sequelae of immersion-foot.

Psychological Factors.—It is certain that both tropical and Arctic regimes impose a psychological burden which may prove too heavy for some. On the whole, one would prefer the volunteer to the impressed man, though there may of course be a psychopathological motive for electing to serve in adverse climates. The psychopath and the unstable do not withstand the hardships of foreign service so well as those of placid and equable disposition. Those of poor intelligence or educational resource do not tolerate the boredom of some isolated tropical and Arctic appointments. Ratings with a bad crime record either in the Service or in civil life are most unsuited. The older practice of transferring the persistent offender to some remote and uncongenial station in the Tropics has proved intolerable. A previous severe neurotic breakdown is a relative disqualification, while any alcoholic tendencies should be regarded as an absolute contraindication both to tropical and to Arctic service.

Peacetime Implications

Warfare in hostile climatic conditions has compelled scientists to direct their attention towards protecting personnel against the exigencies. The lessons of war medicine hold out considerable promise for the post-war period. One has in mind the enormous expanses of our Empire which are at present underpopulated. The extension of air routes over the North Pole, the mineral resources of northern Canada and the Antarctic, the development of desert Australia and of the West Coast of Africa are problems for the future.

Tropical and Arctic disease are capable of control, and the way is open for further advances along these well-trodden paths. But there still remain the hazards and discomforts of extreme cold and heat. If men must fight in such environments it should be made possible for them to live and work there and raise families without the fear of swelling the "poor white" community.

Of the polar wastes we have the opinion of the explorer, Cherry-Garrard, that the Antarctic "is not half as bad a place for public service as the worst military stations on the Equator." But serious doubt has been expressed as to how far the Tropics can be developed. Balfour has said that under existing circumstances the white man in the Tropics is never more than a wayfarer or a sojourner. The Tropics, according to Carthew, are peopled by only three classes of European—the adventurer, the missionary, and the beachcomber—of which only the last makes the grade. While Dill believes that man can be made to thrive in desert wastes, the hot humid regions near the Equator have been suspected by such writers as Castellani, Huntington, Anderson, and Balfour as being wholly unsuited for European occupation in the present circumstances. Contrary views have been expressed by Cilento, Rohrbach, Gorgas, and others. The last believes that if malaria and sleeping sickness were stamped out, then the Congo could be colonized by the white race. The significant phrase is "in the present circumstances," because the eradication of disease, the new insecticides and repellents, air conditioning, and the free use of refrigeration have quite altered the problem of tropical habitability.

We can discern the need for a central Academy of Geomarine or Climatology, wherein all research—medical and scientific—could be undertaken concerning both extremes of temperature. The fighting Services, colonization, geographical survey, agriculture, industry, communications, housing, would all be concerned. The first function would not be a study of disease states but of the physiology and psychology of performance, growth and fertility, vital statistics, textile research, protection of material against tropical and Arctic deterioration, and a fuller inquiry into ventilation, with a study of the influence of air conditioning upon human oecology. The Admiralty has under consideration the formation of a Tropical Research Unit, which could be regarded as the first move in this direction.

Conclusion

Let us conclude with two quotations as to the possible future development of unpropitious regions. Johnson in 1813, believ-

ing that man is better adapted than any other animal for migration from a northern to a tropical region, or the reverse, wrote: "For this boasted prerogative, man is perhaps more indebted to the ingenuity of his mind than the pliability of his body. . . . Man, by the exertion of his mental faculties, can raise up a thousand barriers round him, to obviate the deleterious effects of climate on his constitution." The second quotation is from the geographer, Huntington: "I want to know beyond question whether white man can live permanently in a tropical country, conquer the diseases, and make progress, without the help or hindrance of any coloured race. . . . I do not doubt the ultimate triumph of the white man over the Tropics, and much less do I despair of a white Australia. The process of selection for climate has never been really tested. All that has happened thus far has been purely fortuitous. The hope of the future, I believe, lies in an orderly and far-sighted selection of the right types of people, as well as in the further development of tropical medicine and hygiene."

To these ideas we would now also add the elaboration of an artificial climate in which to live and work.

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BIBLIOGRAPHY TO LECTURE I

- Annual Medical Report, 1936, Anglo-Persian Oil Co.
Bernan, W. (1845). *History and Art of Warming and Ventilating Rooms and Buildings*, London, Vol. I.
Blane, G. (1789). *Observations of the Diseases of Seamen*, 2nd ed., London.
East Indies Station Orders, 1871-1936.
Fonssagrives, J. B. (1856). *Traité d'Hygiène navale*, Paris.
Gagge, A. P., Burton, A. C., and Bazett, H. C. (1941). "A Practical System of Units for the Description of the Heat Exchange of Man with His Environment," *Science*, **94**, 428.
Guild, W. J. Forbes (1940). "Some Observations on the Potentialities of Air Conditioning for H.M. Ships on Tropical Service," *J. roy. nav. med. Serv.*, **26**, 262.
Hill, L. (1942). "Clothes and Fuel Saving," *British Medical Journal*, **2**, 524.
Houghton, F. C., Olson, H. T., and Suci, J. (1940). "Sensation of Warmth as affected by the Colour of the Environment," *Illum. Eng.*, **35**, 908.
Lind, J. (1774). *Essay on the Most Effectual Means of Preserving the Health of Seamen in the Royal Navy*, new ed., London.
Macdonald, J. D. (1881). *Outlines of Naval Hygiene*, London.
McDonald, R. (1944). "Principles of Ship Ventilation and Warming in Theory and Practice," *J. Inst. Heat. Vent. Eng.*, **12**, 234.
Mayer and Fittz. Quoted in the Annual Medical Report, 1936, of the Anglo-Persian Oil Company.
Méricourt, A. Le Roy de (1867). *Rapport sur les Progrès de l'Hygiène navale*, Paris.
Mills, C. A. (1945). *Climate Makes the Man*, London.
Oppenheim, M. (1896). *History of the Administration of the Royal Navy and of Merchant Shipping in Relation to the Navy from 1509 to 1660*, London.
Physiologic Principles Underlying Naval Ventilation (1942). Dept. Atmosph. Hyg., U.S. Naval Med. Sch., Bethesda, Md.
Preliminary Report of the Committee on Uniform Clothing of Seamen of the Fleet (1890) H.M.S.O., London.
Reid, D. B. (1844). *Illustrations of the Theory and Practice of Ventilation*, London.
Report of Committee apptd. to Investigate and Report on the Best Methods of Ventilating Modern Warships (1914). H.M.S.O., London.
Sims, A. J. (1945). "Habitability of Ships under Wartime Conditions," Paper presented to Institute of Naval Architects, April 17.
Siple, P. A. (1942). "General Principles Governing Selection of Clothing for Cold Climates," Address to Amer. Philos. Soc., June.
Trotter, T. (1979). *Medicina Nautica*, 2 vols., London.

BIBLIOGRAPHY TO LECTURE II

- Anderson, C. L. G. (1908). "The White Man in the Tropics," *J. Amer. med. Ass.*, **50**, 1780.
Armstrong, R. (1843). *Influence of Climate and Other Agents on the Human Constitution*, London.
Balfour, A. (1923a). "Sojourners in the Tropics," *Lancet*, **1**, 1329.
— (1923b). "Problems of Acclimatization," *ibid.*, **2**, 84.
Barcroft, J., et al. (1922). "On the Relation of External Temperature to Blood Volume," *Phil. Trans. roy. Soc.*, London, B, **211**, 455.
Bartlett, F. C. (1943). "Fatigue following Highly Skilled Work," *Ferrier Lect.* (1941), *Proc. roy. Soc. B*, **31**, 247.
Bazett, H. C. (1927). "Physiological Responses to Heat," *Physiol. Rev.*, **7**, 531.
— (1938). "Some Principles Involved in Treatment by Heat and Cold," *Med. Rec.*, **147**, 301.
— (1941). "Blood Volume and Cardiovascular Adjustments," *Amer. Heart J.*, **21**, 423.
— Sunderman, F. W., Doupe, J., and Scott, J. C. (1940). "Climatic Effects on the Volume and Composition of Blood in Man," *Amer. J. Physiol.*, **129**, 69.
Bedford, T. (1937). *Modern Principles of Ventilation and Heating*, London.
Borchardt. Quoted by Kuno (1934).
Brunt, D. (1943). "Reactions of the Human Body to its Physical Environment," *Quart. J. roy. met. Soc.*, **69**, 77.
Burdon, J. F. (1944). "Foreign Service Neurosis," *J. ment. Sci.*, **90**, 746.
Caplan, A. (1943). "Critical Analysis of Collapse in Underground Workers on the Kolar Gold Field," *Bull. Inst. Min. and Metall.*, p. 1.
— (1944). *ibid.*, p. 13.
Castellani, A. (1938). *Climate and Acclimatization*, London, 1938.
Castronuovo, G. (1935). "Irritabilità, psicosi e neuropatie tropicale," *Rif. med.*, **51**, 1180.
Cherry-Garrard, A. *The Worst Journey in the World*.
Cilento, R. W. (1933). "Conquest of Climate," *Med. J. Austral.*, **1**, 421.
Cooper, J. M. (1934-5). "Mental Disease Situations in Certain Cultures: A New Field for Research," *J. Abn. Soc. Psychol.*, **29**, 10.

- Culpin, M. (1935). "Neurasthenia in the Tropics," *Practitioner*, **135**, 146.
- Fleischer, W. L., Stacey, A. E., Houghton, F. C., and Ferderber, M.B. "Air Conditioning Industry," *A.S.H.V.E. Jour. Sect.* (No date.)
- Huntington, E. (1924). *Civilization and Climate*, 3rd ed., New Haven.
- Johnson, J. (1815). *Influence of Tropical Climates, more Especially the Climate of India, on European Constitutions*, London.
- Kuno, Y. (1934). *Physiology of Human Perspiration*, London.
- Lamprell, B. A. (1941). "Discussion on Tropical Neurasthenia," *Proc. Ann. Gen. Meeting Assam and N. Bengal Branch of Brit. Med. Ass.*, Calcutta, p. 25.
- Levick, G. Murray (1945). "Physical Preparation of Commandos," *Proc. roy. Soc. Med.*, **38**, 97.
- MacKinnon, M. (1923). "Education in its Relation to the Physical and Mental Development of European Children of School Age in Kenya," *J. trop. Med. Hyg.*, **26**, 136.
- Markham, S. F. (1942). *Climate and the Energy of Nations*, Oxford.
- Orenstein, A. J., and Ireland, H. J. (1922). "Experimental Observations upon the Relations between Atmospheric Conditions and the Production of Fatigue in Mine Labourers," *J. indust. Hyg.*, **4**, 30, 70.
- Petersen, W. F. (1935). *The Patient and the Weather*, vol. 1, pts. 1 and 2; vol. 4, pt. 1, Ann Arbor.
- Robinson, S., Turrell, E. S., Belding, H. S., and Horvath, S. M. (1943). "Rapid Acclimatization to Work in Hot Climates," *Amer. J. Physiol.*, **140**, 168.
- Sundstroem, E. S. (1924). "Some Studies in Tropical Acclimatization," *Comm. Austr. Dept. Health. Serv. Publ. (Trop. Div.)*, No. 6.
- Vernon, H. M. (1928). "Industrial Fatigue in Relation to Atmospheric Conditions," *Physiol. Rev.*, **8**, 130.
- Weiner, J. S. (1936). "Report on Heat Stroke, Heat Collapse, etc.," Central Mining-Rand Mines Group, Health Dept. Report, Annexure 2, p. 74.
- Woodruff, C. E. (1905). *Effects of Tropical Light on White Men*, New York and London.
- Wyatt. Quoted by Vernon (1928).
- Yaglou, C. P. (1937). "Abnormal Air Conditions in Industry: Their Effects on Workers and Methods of Control," *Symp., Environment and its Effect upon Man.*, p. 82, Harv. Sch. Publ. Health, Boston.

PRESERVATION OF HUMAN SPERMATOZOA AT LOW TEMPERATURES

BY

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Several experiments have been carried out, in the last few years, on the preservation of spermatozoa at low temperatures. This work is clearly in its early stages, but already very significant observations have been made on human as well as on avian and amphibian material. Luyet and Hodapp (1938) reported that a large percentage of frog spermatozoa showed motility after being partially dehydrated in 2 M-sucrose, spread in a thin film on a mica slip, immersed in liquid air, and thawed rapidly by plunging into medium warmed to 20° C. The technique of these authors was similar to one which had been successful with plant tissues, and was based on the assumption that the essential condition for survival of the spermatozoa was instantaneous freezing, to secure vitrification rather than crystallization of the water, and instantaneous thawing. Partial dehydration, by the addition of laevulose, was also used by Shaffner, Henderson, and Card (1941), who found that about one-third of fowl spermatozoa could be revived after freezing at -79° C. Duration of freezing, up to 14 months, was not an important factor in survival rate. Spermatozoa revived after one hour at -79° C. were capable of effecting fertilization, but there was very early embryonic death (Shaffner, 1942).

In view of these results the discrepant experiments recorded in the literature dealing with human spermatozoa are of great interest. As long ago as 1897 Davenport recorded that human spermatozoa would survive freezing at -17° C. This interesting observation received little attention for many years, but in 1938 Jahnel found that a proportion of human spermatozoa could be revived after freezing in glass tubes for 40 days at -79° C., or for shorter periods at -196° C. and -269° C. Jahnel does not state the diameter of the tubes used, but he did not apparently take any special precautions to ensure the utmost rapidity of freezing and thawing. Shettles (1940) froze human semen in glass capillary tubes 0.2 mm. in diameter, and obtained a low percentage revival of the spermatozoa from -79° C., -196° C., and -269° C. A few spermatozoa revived after 70 days at -79° C. Shettles emphasizes the importance of the freshness of the specimen. Hoagland and Pincus (1942), following up the premises of Luyet and Hodapp and using liquid nitrogen, tried an elaborate series of devices to facilitate the instantaneous vitrification and thawing of human semen. However, except in one or two isolated experiments, the revival rate was very poor. No spermatozoa could be revived after vitrification in fine capillary tubes.

The results of Hoagland and Pincus are in strange contrast to those of Jahnel, whose work is not cited by the American authors, and the discrepancy shows that other factors than mere rate of vitrification and thawing have to be considered. From a practical point of view, the question is of some importance. Jahnel's results suggested that the prolonged storage of human semen at low temperatures might be possible; the results of Hoagland and Pincus, on the other hand, offered no such prospect. The experiments described below were therefore carried out on the low-temperature preservation of human spermatozoa.

Technique

Semen was obtained from several different donors; all specimens were rated normal by the usual seminological examination. No marked difference in resistance to freezing was noted between the different samples. The semen was allowed to liquefy before being used, and was not diluted. In experiments with capillary tubes the semen was allowed to rise in the tube and the end was then sealed. Unless otherwise stated, immersion in the freezing medium was always for one minute, thawing being done by transferring the film, tube, or ampoule as rapidly as possible to medium or water at 37° C. Freezing fluids, other than liquid nitrogen (-195.8° C.), were made by cooling ethyl alcohol with solid CO₂. Quart-size vacuum flasks were used as containers.

Results

In a preliminary experiment a comparison was made by immersing semen in liquid nitrogen (a) as a thin film in a platinum loop, (b) in a very fine capillary tube (internal diameter approximately 0.15 mm.), (c) in a coarse capillary tube (internal diameter approximately 0.5 mm.), (d) in thin glass tubing (internal diameter approximately 1 mm.). After thawing, no motile spermatozoa were seen in the semen from (a) or (b); they were abundant in that from (c) and (d). A repeat experiment gave similar results. It seemed, therefore, that the results both of Jahnel and of Hoagland and Pincus were reproducible, and considerable doubt was cast on the idea that speed of freezing and thawing was the primary factor in the survival of human spermatozoa. A more extended experiment was carried out in which the temperature of freezing as well as the bore of the container was varied. The results are given in the accompanying Table. Although survival at -20° C. was not

Table showing Revival of Human Spermatozoa After Exposure to Low Temperature for 1 Minute or 5 Hours

Temperature	Freezing for 1 Minute in Capillary Tubes of Diameter of			Freezing for 5 Hours in Capillary Tube of Diameter of 1 mm.
	0.15 mm.	0.5 mm.	1 mm.	
- 20° C.	0	+	++	0
- 79° C.	0	+	++	++
- 196° C.	0	++	++	++

0 = No revival. + = Some spermatozoa revived. ++ = Abundant spermatozoa revived.

prolonged, these results give little support to the view of Luyet that freezing under conditions leading to the formation of ice crystals is incompatible with the survival of the spermatozoa, but they confirm the previous result that some inimical factor is associated with freezing in a very fine capillary tube. The nature of this factor is not clear, though a surface effect of some kind seems to be indicated. Pressure as such is not likely to be involved, since Marsland and Rugh (1940) showed that spermatozoa are unaffected by hydrostatic pressure.

In view of the successful results obtained with comparatively wide tubing attention was turned to the use of ampoules, and 1 c.cm. of semen was frozen at -196° C. in an ordinary 5-c.cm. pyrex ampoule. On thawing out, numerous active spermatozoa were seen in the sample.

Consideration was then given to more prolonged storage of the vitrified material. Maintenance at -196° C. for any lengthy period was clearly impracticable with the apparatus available. The results given in the Table, however, do not suggest that when 1-mm. tubes are used there is any advantage in vitrifying at -196° C. as compared with -79° C. An experiment extended this conclusion for larger containers, and further showed that transference from -196° C. to -79° C.