Experimental induction of vitamin-C deficiency leads after an interval of several months to perifollicular hyperkeratosis and later to petechial and perifollicular skin haemorrhages. Gum changes are slight.

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The *Danish Foreign Office Journal* (No. 3, 1949) contains an illustrated account of recently invented Danish scientific apparatus. The country that gave the world the Finsen lamp has raised the construction and design of these lamps to an extremely high standard. A new haemometer gives a direct reading on an electrically controlled scale of the haemoglobin in any sample of blood which is compared with a standard colour in an illuminated observation window. The lighting is adjusted until the tints of the two are identical. A new audiometer, with a frequency range of 20 to 20.000 kilocycles, has a built-in microphone and masking oscillator, and two insulated loud-speakers mounted on an adjustable stand. A new all-purpose electric water-bath, heated by an infra-red lamp, can be raised to a temperature of 400° C.

DISABILITY PRODUCED BY EXPOSURE OF SKIN TO MUSTARD-GAS VAPOUR

BY

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For a period after the introduction of mustard gas (2,2'-dichlorodiethyl sulphide) in the 1914–18 war "casualties" were produced as a result of ocular and respiratory lesions. Later, when adequate measures were taken to protect the eyes and respiratory tract, the skin burns came into increasing prominence as a cause of disability. The introduction of effective respirators and good gas discipline also had a considerable effect in reducing the incidence of disabling systemic poisoning.

In the interval between the wars the disability produced by the action of mustard gas on human volunteers was studied by various workers, and these investigations were intensified during the 1939–45 war, particularly with respect to tropical conditions. There was, however, no generally accepted classification of this disability, and, further, in most cases no practical test was applied to its assessment, which therefore depended solely upon the personal opinion of the investigator. In 1944 a system for the practical evaluation of disability in terms of the results of standard physical performance tests was evolved in Australia by Ennor, Gorrill, Legge, and Sinclair. In an attempt to evaluate the factors concerned in the production of disability in the field a modification of this system* has been applied to the analysis of disability in men exposed to mustard-gas vapour in the Tropics.

Material and Methods

Over a period of two years 179 men were under observation following exposure to various dosages of mustard-gas vapour under tropical conditions. All the subjects wore fully effective respirators throughout exposure; 147 wore ordinary tropical Australian battle-dress and 32 wore additional clothing which denied access of mustard vapour to the genitalia and buttocks.

On each day after exposure a standard physical performance test was carried out, consisting of two runs over a specially constructed assault course and a six-mile (9.6-km.) march in full equipment. In certain cases the capacity of the subject to defend himself by firing an automatic weapon was assessed On the basis of his performance in these tests every man was placed each day in one or other of five categories. Table I sets out these

TABLE I.—*Classification of Disability*

Category	Criteria for Inclusion
1. Unaffected	No objective sign of exposure
2. Injured, without disability	Performance test satisfactory; no treatment required
3. Injured, requiring treatment	Performance test satisfactory; treatment required
4. Partially disabled	Failure on any part of performance test
5. Totally disabled	Failure on any part of performance test, plus inability to use any weapon in self-defence by reason of: severe burns of the hands, loss of vision, gross systemic intoxication, or pain requiring morphine

categories, together with the criteria for inclusion in each. (The subsequent use of the terms "disability," "disabled," etc., without qualification, should be taken to refer to categories 4 and 5 of Table I taken together.) So long as

*The Ministry of Supply wishes me to make it clear that this system has not been officially accepted by the Medical Directorates of the British Armed Forces.

disabled men retained the capacity to fire a weapon effectively they continued to be classed as "partially disabled" even when they were sent to hospital on account of their injuries. The justification of this procedure is that from a military standpoint such men, whom it might not always be possible to evacuate, could be of considerable value to the defence of a fixed position. All disabled men were encouraged to remain ambulant for as long as possible, even though they were unable to complete the daily performance test.

Men with lesions of apparently identical severity were often classified in different groups as a result of differences in morale. No attempt was made, however, to modify the findings on clinical grounds, since it was considered that this factor would be equally operative in the event of chemical warfare breaking out. Though the stimulus of battle conditions was lacking, it was to some extent compensated for by the presence of a strong competitive spirit among the volunteers. Indeed, the whole-hearted co-operation of these men cannot be adequately acknowledged.

The system of assessment described above takes account of the fact that variations in the degree of disability may occur from day to day and also makes it possible to record the *actual* time of incapacitation instead of making an estimate.

Detailed daily records of the clinical condition of the volunteers were also kept (Sinclair, 1949b), and prognostic indications in respect of disablement were derived from them. An attempt to ascertain some of the factors responsible for the production of disability was made by asking each disabled man the reason for his failure to complete the performance test. This interrogation was carried out daily in conjunction with the routine clinical examination, and in every case it was found possible to attribute the disability to one or more specific causes.

It is convenient to classify the disabled subjects in terms of their maximum disability at any time after exposure; Table II shows the result of such a procedure. In 45 men

TABLE II.—*Incidence of Disability*

Maximum Disability	Skin Protection		Total
	None	Partial	
Totally disabled	1	1	2
Partially disabled	34	9	43
Injured, requiring treatment	24	—	24
Injured, without disability	84	19	103
Unaffected	4	3	7
Total	147	32	179

The subjects are classified according to the maximum disability occasioned them at any time after exposure.

there was some degree of interference with military performance.

Cause of Disability

Since respirators were worn by all subjects, skin burns (Sinclair, 1949b) and systemic poisoning (Sinclair, 1948) constituted the only means by which disability could be produced. Table III shows the various causes and the number of men who attributed the whole or part of their disability to them. It will be seen that the aetiology is very different in the two groups of volunteers, and these differences may be correlated with the protection afforded to the skin.

Unprotected Group

In this group by far the greater part of the disability was attributed to burns of individual regions of skin, and systemic poisoning was mentioned by only one man as contributing to his condition. A study of the individual

TABLE III.—*Aetiology of Disability*

Cause of Disability	Skin Protection		Total
	None	Partial	
Burns of scrotum	33	—	33
,, ,, penis	11	—	11
,, ,, axillae	5	5	10
,, ,, buttocks	1	—	1
,, ,, other regions	—	1	1
Generalized burns	1	5	6
Systemic intoxication	1	4	5

The figures indicate the number of men in each group who mentioned the items listed as being wholly or in part the cause of their disability.

regions of the body incriminated leads to the conclusion that in unprotected men burns of a few special areas—the scrotum, penis, axillae, and buttocks—become severe enough to produce disability at dosages which are not sufficient to give rise to incapacitating systemic poisoning. In other words, *at low dosages* most of the disability produced in unprotected men will be due to skin burns.

It follows that the development of disability should, in this group, be expected to run parallel with the development of the skin burns—that is, it should be delayed for several days (Sinclair, 1949b). This statement is borne out by a consideration of the number of men disabled on any given day after exposure. It was found that 50% of the eventual group disability was manifest by the fifth day after exposure, that the 90% level was attained by the ninth day after exposure, and that the maximum occurred on the eleventh day. It is interesting to correlate this finding with the fact that the eleventh day was also the day on which the maximum number of regional raw surfaces were present (Sinclair, 1949b), and to note that in only three of the 56 regional burns incriminated in Table III were raw surfaces not present at some stage in the case history.

It may also be mentioned that several of the men in the unprotected group were disabled initially by a burn of the scrotum, lesions of which tend to develop early, and that by the time this cause had ceased to operate they suffered a prolongation of disability due to deterioration of the condition of the penis (Sinclair, 1949b). Further, most of the men passed through several different classes of disability during the period of assessment. For example, the man who became "totally disabled" was classed in this category for 20 days, and spent a further 20 days classified as "partially disabled." The 34 men who became "partially disabled" spent an average of 15.7 days in this category and an additional 5.0 days classed as "injured, requiring treatment."

Partially Protected Group

In this group the picture of disability is quite different. Since the genitalia and buttocks were completely protected there is no mention of these regions, which were responsible for a great part of the disability in the unprotected group. On the other hand, it is interesting that burns of the axillae, which was the region third on the list of the unprotected group, were incriminated in five cases. These cases were all exposed to dosages similar to those administered to the unprotected group, but a further five men became disabled after being exposed to a considerably higher dosage, the cause being generalized burns in one case and generalized burns plus systemic intoxication in the remaining four. The conclusion may be drawn that as the dosage is increased not only do the burns in many regions of the body attain disability-producing status, but incapacity from systemic intoxication, due to the greater amount of mustard derivatives absorbed from the skin, becomes much more important.

There is of course no doubt that if the genitalia had not been protected a major factor in the production of disability in these men would have been the condition of the scrotum and penis, if only because lesions of these organs are slow to heal compared with the rest of the body (Sinclair, 1949b). Nevertheless, even if this had been the case systemic poisoning would still have played a leading part in their incapacitation. Potentially disabling systemic symptoms are at their height on the day after exposure, and it therefore follows that the time of onset and the development of disability in this group should be quite different from the results obtained in the unprotected group. In fact, it was found that all those in whom systemic poisoning was an operative factor became disabled within 24 hours of exposure, and that by the time the systemic symptoms had subsided the skin burns had developed enough to make the period of disability due to the two causes a continuous one. It should also be noted that severe burns seem to become manifest rather more quickly than more moderate burns. In consequence, both the subjects classified as "totally disabled" (Table II) became so on the day after exposure. Total disability in the first subject was due to severe genital burns requiring morphine, and in the second to severe systemic poisoning and generalized burns.

Admission to Hospital

Table IV gives some details regarding admission to hospital. The figures emphasize again the effect of the different aetiology of incapacity in the two groups. The severe

TABLE IV.—*Admission to Hospital*

	Skin Protection			
	None		Partial	
	Partially Disabled	Totally Disabled	Partially Disabled	Totally Disabled
Total No. of cases	34	1	9	1
No. admitted to hospital	19	1	2	1
Mean time of admission (days after exposure)	7·7	1	4·0	1
Mean duration of stay in hospital (days)	15·6	32	8·0	12

burns of the genitalia which occurred in the unprotected group were responsible for the high proportion of disabled cases requiring admission to hospital in that group, as well as for the relatively long time which they spent there. In the partially protected group the corresponding figures are much smaller, owing to the shorter course of burns of regions other than the genitalia (Sinclair, 1949b) and also to the relatively rapid disappearance of the systemic symptoms which were responsible for a proportion of the disability in this group.

Prognosis

Men protected only by respirators can be disabled within a few hours as a result of systemic poisoning if the effective dosage is high enough. In all such cases severe burns will develop rapidly, and the factor of surgical shock may also come into play. For these reasons the severity of the injuries quickly becomes apparent and there is little difficulty in arriving at a prognosis.

In the lower range of dosages, however, it has been seen that the onset of disability may be considerably delayed, and it is in cases exposed to such dosages that the value of an early and accurate prognosis will be greatest. An attempt was therefore made to correlate the subsequent disability of the volunteers with their clinical condition during the first 48 hours after exposure. Two main factors were considered—the presence of symptoms of systemic poisoning and the condition of the skin. The first was analysed in relation to both groups of men, while the second was used only in the unprotected group.

A total of nine men vomited within 24 hours of exposure, and all of these subsequently became disabled on account of skin burns. Twenty-nine became nauseated within 24 hours of exposure, and it was found that 83% of these eventually became disabled, while a further 10% required treatment. It must be noted that these indications are valuable only in a positive sense, since many men who did not vomit or become nauseated at any time became disabled subsequently. The occurrence of other symptoms of systemic poisoning—e.g., headache—was found to be of no prognostic significance.

In the group protected only by respirators, 11 men developed erythema within four hours of exposure. All these later required treatment, and 64% of them became disabled. Owing to the fact that most of the disability in this group was due to lesions of the scrotum, penis, axillae, and buttocks, particular attention was paid to the early development of burns in these regions. Table V

TABLE V.—*Prognostic Table, Based on Condition of Skin*

Condition of Scrotum, Penis, Axillae, and Buttocks Within 48 Hours of Exposure	Chance of Requiring Treatment	Chance of Becoming Disabled	If Disabled, Probable Duration of Disability
No damage visible	Nil	Nil	
Any damage less than general erythema in all four areas	3 to 2 against	4 to 1 against	1 to 2 weeks
Erythema in all four areas, with subcutaneous oedema in one or more	Over 10 to 1 on*	2 to 1 on*	2 to 4 weeks

* If the scrotum is one of the areas oedematous, these odds are substantially increased.

gives a summary of the prognostic indications obtained in this way, and it will be noted that the condition of the scrotum is the most important single factor.

In the group with no skin protection there was an almost exactly 10-to-1 chance that oedema in any region would be followed later by either desquamation or vesication. It could thus often be inferred, some days ahead, that a given area would require treatment later.

Several factors complicate the formulation of a prognosis. The characteristic irregularity in the development of vapour burns, even on the two sides of the same man, renders prognosis in the later stages of development of the skin burns extremely difficult. The effect of treatment must also be considered, particularly the striking results obtained in the prevention of disability by the use of elastic suspensory bandages for burns of the scrotum (Sinclair, 1949a). Again, the toxaemia of severe sepsis might be a potent disabling agent. This factor could not be evaluated, since very few lesions in this series became infected.

Discussion

Though all the findings in this paper properly apply only to volunteers exposed to mustard vapour under tropical conditions, there seems to be no prima facie reason why similar considerations should not be applied to troops exposed in temperate climates.

The necessity for an objective method of assessing disability in an investigation of this type has already been stressed, and it is submitted that the procedure adopted, however imperfect, does represent a step in that direction. By its use the term "disability" can be accurately defined and graded in a manner which bears some relation to the requirements of military situations. Further, the

employment of a daily performance test makes available a considerable amount of information on the manner of development of disability, as well as on its causes and duration.

The respective parts played by skin burns and systemic poisoning in the development of disability has already been pointed out, and it has been suggested that with high dosages subjects protected only by respirators would rapidly become disabled by a combination of systemic intoxication, generalized burns, and surgical shock. With moderate dosages, however, skin burns play the major part in the production of disability in such men, and the most important areas of skin in this respect are the genitalia and the axillae. Owing to the delay in the full development of burns in these areas there was in this series a corresponding lag in the development of disability, the overall group disability not becoming maximal until the eleventh day after exposure. Because of this delay, the ability to formulate an early and accurate prognosis becomes of considerable importance. It has been pointed out that in unprotected men it seems to be possible to make such a prognosis from the skin condition in the first 48 hours after exposure. A rough prognosis may also be based, irrespective of the skin protection afforded, on the occurrence of nausea and vomiting within 24 hours of exposure.

The possible prevention or reduction of disability is naturally a most important aspect of the subject. With moderate dosages it seems unnecessary to protect the whole body, and the prime object of any defensive measure designed to prevent disability should be the safeguarding of the genitalia and axillae. The provision of effective protection for the genital area and the buttocks would itself reduce the incidence of disability to a very large extent. It has also been remarked that the treatment of scrotal lesions with suspensory bandages has a considerable effect in reducing the incidence of disability due to burns in this region.

Summary

An account is given of the factors responsible for the production of disability in a series of 179 men exposed to the vapour of mustard gas in the Tropics.

The influence of dosage on the type of disability produced is discussed, and the importance of protecting the genitalia is stressed.

It seems to be possible to formulate a reasonably accurate prognosis on the basis of the skin condition within 48 hours of exposure. The occurrence of nausea and vomiting within 24 hours is also of value in this respect.

The kindness of the Australian Chemical Defence Board in permitting publication of the work carried out under its direction is gratefully acknowledged. Permission to publish has also been received from the Chief Scientist, Ministry of Supply. The work of assessing and recording the disability which is the subject of this paper was done by a team, to the other members of which my grateful thanks are due, in particular to Dr. F. S. Gorrill, Dr. A. H. Ennor, and Mr. J. W. Legge.

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A new unit, the Radiological Health Branch, has been formed in the United States Public Health Service to investigate and advise on risks to health due to the increased use of radioactive materials. It is under the direction of Dr. Edwin G. Williams. The unit will develop a training programme for public health workers and collect information on possible dangers to health from radioactive isotopes, *x*-ray apparatus, cyclotrons, betatrons, and other atomic-particle accelerators.

POSITION OF THE APEX BEAT AS A CLINICAL SIGN

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Previous Standards

Palpation of the apex beat is one of the commonest physical signs to be elicited, yet reference to various authorities reveals considerable divergence of opinion regarding its normal limits. There is no agreement even upon the three most important criteria concerning its definition and position—namely, (1) the point of cardiac pulsation to be regarded as the apex beat; (2) whether the limit of normal should be taken in relation to an anatomical landmark; and (3) the distance from the midline to be taken as the limit of normal where direct measurement is used.

Price (1927) gives one of the most useful definitions, "as that part of the area of pulsation, distinctly palpable, which is lowest and farthest to the left." This is supported by Lewis (1946), who describes an area 1 in. (2.5 cm.) in diameter, the outermost limit of which "is the best clinical guide to the heart's size," provided that there is no displacement. Bramwell and King (1942), although regarding this as the theoretical limit of the left border of the heart, for practical purposes prefer to take the centre of the area of maximal impulse. A third view is expressed by Carlisle (1934), who states that "the apex beat is not the point of maximum impulse, but is at the point farthest down and farthest out that the beat of the left ventricle is felt."

There is similar lack of unanimity regarding the anatomical point within which the apex beat should lie. Bramwell and King, since they consider that the size of the chest is one of the chief causes of variation in position of the normal apex beat, bound it within the mid-clavicular line. Parkinson (1936), however, holds that the mid-clavicular line is difficult to apply, especially in women. The nipple line is strongly advocated in men by various authorities, Parkinson regarding it as fairly constant and an "indispensable guide"; Noble Chamberlain (1947) states that the normal cardiac thrust is "almost invariably within the nipple line." These views are supported by Lovatt Evans (1945), Price (1927), and Carlisle (1934). However, Grassmann (1921) firmly denies the value of the mammillary line in determination of the size of the heart.

A fixed anatomical line is not upheld as more than a rough guide by Campbell and Conybeare (1942), who state that the apex beat should always be given as a distance from the midline. It must be emphasized, however, that there is a wide variation in the outermost distance from the mid-sternal line which is regarded as normal. Thus Gray's *Anatomy* (1946) states that as a general rule it will be found 3½ in. (8.9 cm.) from the midline; Noble Chamberlain gives it as up to 4 in. (10.1 cm.), while pointing out that where an abnormal apex beat is found the chest structure must be examined for scoliosis, etc., to exclude cardiac displacement. Lewis put 3–4 in. (7.6–10.1 cm.) as the usual limits of normal, and goes on to say that "a well-defined maximal impulse, the outer border of which is situated 4½ in.