PRESIDENT'S ADDRESS
THE ECOLOGY OF THE SOLDIER IN WORLD WAR II

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Each president of this Society must have felt as I do the golden glow of satisfaction and pleasure in being deemed worthy to be for a time conductor of the proceedings of this wonderful association of people. I am greatly gratified as well as grateful. But we all know that the president is just the front man for the proprietor, Josh Billings.

The one thing the president of our Society cannot claim in introducing his comments is that his talk took him by *surprise*. When, last year, there were some sly preliminary queries as to whether I would accept this office, none could say that my response waited for arm twisting. My reactions then and later may be described by an analogy with a grammarian's view of tensions and tenses. My first thought was one of commingled incredulity and bliss. The tense was *future perfect*. Then came the realization of obligations. It neutralized much of the pleasure. The tense became *future imperfect*. As the novelty wore off and my need for preparing an address seemed for a while to recede, it became a simple *future tense*. Too rapidly this merged into the approaching deadline stage of subclinical panic which characterizes the *gerundive* or "to be about to be." You are all too painfully aware *now*, that things are *tense* in the *present tense* as my pretensions intensify. As time flows by, when mercifully this is over, my memories will be *past imperfect* and then *simple past*. Ultimately the halo which our conveniently selective memory puts on even the most evident collection of blunders will allow me to recall that things were *pluperfect*—past, that is.

Bidding a captive audience "Come With Me" for a little retreat into the mountains of antiquity, I am supported by the notion that I might provide a repast for the spirit of our communion of fair people both interesting and significant. This illusion, I am afraid, has been responsible, I hope elsewhere, for much pompous cant. As befits climatologists, I discuss with you environment and ecology as it became known to me during World War II in field studies, laboratories and ultimately tests *in situ*, right in combat.

Over and above the perils engendered by the usual hostile deployment of all man's devices of destruction, World War II saw new stresses and strains imposed on soldiers by their equipment and machines, in the air, on land, in, on and under the water, in a bewildering variety of climates

and places. The designers often forgot the critical matter of the men. Clinical investigators en masse poured out of their ivory towered laboratories to study normal young man, his inherent capacities and his abilities to adjust to the changes of changing environments. They studied how to put him into machines, and the harm done by physical agents and forces beyond his native tolerance or adaptive ability.

In the summer of 1942 I joined the Armored Medical Research Laboratory at Fort Knox, then being built under the direction of Col Willard Machle around a nucleus from the Kettering Laboratory and College of Medicine at Cincinnati. We were palpitating, worried in the urgency of the suddenly recognized calamity of our endemic unpreparedness. Our group of young physicians, chemists, physiologists, engineers, and public health people had the heady stimulation of working on common problems viewed from many angles. Many of our group have since had careers of distinction in academic medicine.

Mercifully we were spared much military ritual. We saluted. We never had to drill. Immediately we all learned how to drive tanks, for our first job was to find out what troubles were inherent in the equipment or in current usage "the hardware." My scrambling around later under barbed wire, with live fire going over, was not to make a soldier out of me but to find out, if I could, why, occasionally people felt obliged to stand up in such unpromising circumstances. This experience, by the way, never provided insight, evidence or even testimony. With strong motivation and with our collective experience which gained volume and momentum exponentially, we took off on a series of problems. We found that one problem grew into many, and many into myriads. Only later I realized that we had been working on ECOLOGY. Ecology is climatology spelled with capital letters.

Let us concentrate on the work on acclimatization, mostly to heat but also to cold, how we tried to measure fitness and performance, how much atabrine was needed to get any level in the blood that might prove suppressive against malaria, and the care and feeding of an army getting its emergency ration out of cans and boxes.

Here is a stark list of other things we worked on. Our physicists designed all around greenhouse vision for tanks, using bullet-proof glass blocks; goggles for dust; sunglasses, periscopes, binoculars, fire control from all sides, and the size and location of escape hatches for ease of exit rather than convenience of the manufacturer. Physical characteristics of men were guides for crew selection. Tanks could not be changed—we collected dozens of anthropometric measurements on tens of thousands for preselection—extensive measurements of many dimensions of human feet showed us that average soldiers did much better with shoes

two sizes larger than the accustomed ones. Though there had been no change in the standard last in the United States for many decades shoe sizes were erratic and meaningless. We measured the shifting distribution of weight on the foot of a marching man on a checkerboard grid with a multitude of small strain gauges a long time before computers could digest the data we collected. Clothing for desert, jungle, and fireproof characteristics, we studied. The addition of iodine to purify drinking water was subject of an extensive test.

Almost every possible phase of military activity—infantry, artillery, and in and around tanks—was studied to see how many calories were required for various kinds of work in many environments. A long study of the antiquated method of artillery fire control indicated that much accuracy could be added to the Civil War system with forward observers calling or phoning back to the gunners. Night vision, noise, vibration, deafness following repeated gunfire, and claustrophobia were studied in detail. Infrared gas analyzers were used to get instantaneous records of the amount of moisture lost in sweat. Tank casualties resulted from inability to see. The head stuck out of the turret was an easy mark. Fires caused by a penetration and burning of the propellant charges caused even more casualties. Seat design, head room, hatchways, fatigue, flash burns, and flameproof clothing occupied our attention. The muzzle break to dampen sound when the main weapon fired, particularly for men outside a tank, was studied in detail. We also worked on harness, suspenders, field packs, ambulance coolers, refrigeration and individual crew air conditioners in tanks as well as electrically heated gloves, and other equipment in the cold. Statistical help was available for all problems such as finding the least number of subjects needed for any degree of accuracy.

Part of the success of our several ventures stemmed from the fact that we worked under brilliant men—Hugh Morgan, Johnny Youmans, Bayne-Jones, Steve Simmons, and Jim Shannon. Not the least of the many characteristics they had in common was the capacity to use Occam's razor on snarly tangles of red tape in perfect execution of the law of parsimony. The crepitus of released tensions reminded one of the pleasant sound of hot air issuing from punctured stuffed shirts.

Tanks

It was not so much surprising as distressing to find that the vast automotive know-how of the country, camouflaged by much ballyhoo from Willow Run via Madison Avenue, had sort of overlooked the fact that if men used tanks they had to be fitted into them. The thousand errors, ranging from almost total lack of useful vision to the anthropological

impossibilities of managing some of the equipment were all too evident. For example, in a long line of idling tanks, each processing exhaust from the tank ahead, there was serious danger from carbon monoxide. This could be corrected by changing exhaust vents.

Heat

We learned what could be found about acclimatization to heat. Heat in the African desert was not as bad a problem as keeping thinly clad men warm when the temperature suddenly dropped 20 or 30 degrees after sundown. We studied heat casualties in California deserts. In a series of experiments in which a light tank company was followed during four days of maneuvers, enforced reduction of drinking water caused deterioration which paralleled the water deficit. It could be corrected almost instantaneously by supplying water. Heavy consumption of alcohol, gastrointestinal disorders, the jaundice then abundantly present from the yellow fever vaccine, lack of sleep or failure to eat, each increased the physiologic cost of work and other difficulties produced by heat.

In the hot room at Fort Knox we demonstrated that the major features of cardiovascular and thermal adaptation were nearly completed during the first few days of active work in heat. The urine became "salt free" in a few hours. Slowly the adrenals learned to conserve salt which disappeared from the sweat after about 10 days. We studied a predictable form of orthostatic hypotension occurring for the first few days after work in the heat. It resulted from pooling of blood and the reduced venous return to the right heart.

Much military tradition hinged on the notion that to drink water was unsoldierly, at least during the daytime, a notion probably as modern as the Mexican War. This myth was responsible for a multitude of casualties when the first armored divisions were moved into the desert training area in the southern part of California. Emphasis on salt had resulted in soldiers taking salt tablets even when there was no water, thus compounding their troubles. We found that when healthy soldiers regularly ate a good diet, salt tablets were not needed and even did harm. Nausea was induced when a tablet touched the lining of the stomach. The sharpest limiting factor for man in desert operations, then and always, was water.

By the time we had mastered the practical environmental problems of deserts, the war was well out of north Africa so we concentrated on moist heat. We found that the wet-bulb thermometer, the capacity of air to accept moisture, was the best gauge of heat load. Varying combinations of heat and moisture were studied. The heat load of a temperature of 150°F, as dry as we could get it in the laboratory, was the equivalent of 95°F with the air saturated. Acclimatization was needed for work under

each higher heat stress. What had been called heat exhaustion turned out to be mostly dehydration exhaustion. Heat stroke, usually associated with illness, fatigue or protracted exposure to hot night environment, could be prevented by acclimatization and enough water.

The failure to find any sign of deterioration, except as it reflected illness, lack of sleep, or a week-end pass, was our first clue in dispelling the old myth of tropical deterioration.

Individual human thermostats are set with consistency but there are extremes at either end. Certain subjects reacted to heat with a very rapid pulse and relatively low temperature. Others tolerated much higher temperature without symptoms or evident handicap in performance. They had less cardiovascular burden as measured by blood pressure stability and slower pulse rate. Recently investigators have found that women have a different manner of adjusting to heat. Bless them, but this is their ecology.

Observations I made in Guadalcanal late in the war demonstrated a significant difference between temperatures in various parts of a jungle and Henderson Field, the weather station, a few miles away. Within the jungle itself, swamps, streams, and rotting debris produced humidity significantly higher near the ground than at eight feet up. Such records of actual jungle temperature seem never to have been made before.

Clothing

Clothing in any hot environment is a real problem. Its solution may vary from the total nakedness of aboriginal natives to drapery which looks like a collapsed tent in which Arabs lead a tolerable existence in desert heat. In the hot desert, protection from solar and ground radiation is important in designing headgear and clothes. Shoes must reduce heat gained by contact with hot surfaces. In some tanks, the buttons on coveralls got extremely hot and produced blisters, a minor but annoying difficulty.

Water and Thirst

Men working in unaccustomed heat do not drink enough water. Our soldiers ended each day about a liter short. They made it up overnight. The amount drunk during work increased with experience but thirst never became an accurate gauge of water need. Performance was much better if fluids were forced to replace just what was lost. After a week's exposure a subject restricted to the amount of water he drank voluntarily the first day complained bitterly of thirst. There seems to be no reason to restrict drinking water in many athletic exercises.

Cold

Acclimatization to cold was hard to measure. The important adaptation to cold environments is learning to use clothes. Their insulation is proportional to thickness. An outer shell provides windbreaking. Sweating in frigid regions may lead to cold injury when sweat freezes. Dehydration may lead to problems much like those in hot climates. The physical discomfort and disadvantage caused by wind in cold has been worked out mathematically. The subjective coldness felt at around freezing with a 30-mile wind may be similar to that at 20 degrees lower with no wind.

Physical Fitness

The continuing belief that there is an abstract entity "fitness" which applies to a multitude of activities is correct only within sharp limits. Rigorous training for boxing may improve one's performance in swimming but not as much as training in swimming does. It is still necessary to specify fitness *for what*. In addition to cardiovascular capacity, fitness depends on innate strength, on size, on past experience, on current health, on adequate sleep, on hygienic regimen, and on training. Most tests of physical fitness are influenced by learning. Improved score may indicate acquisition of skill as well as improvement in fitness. This may be true even for what in bygone days used to be an acceptable function—walking. Tests of fitness cannot measure or keep motivation constant. No adequate measure of physiologic cost exists.

We studied hundreds of soldiers performing several different fitness tests under different conditions. Comparing ten components of three tests, we found, to our sorrow but not dismay, that no test or combination measured the chief components of fitness. The scoring systems were inadequate. The distribution of performance and achievement scores was abnormal. Reproducibility was uncertain. Stress on all subjects was not equal. Certain knacks and readily acquired skills enabled shrewd subjects to "beat the test." There was no correcting factor for different environments or variations in physique. Innate and learned skills were not taken into account.

But still the tests gave an estimate of general fitness, permitting comparison of groups and secular trends in scores. A battery of fitness tests was much better than a single test but a good noncommissioned or line officer was a better judge of fitness than all the tests put together. This fact dazed and depressed our mathematical colleagues, eager with their slide rule computers. A curious and valuable by-product of our efforts was the demonstration that fitness testing was an incentive to a group of men to improve fitness by exercise, by training, and by acquiring skills. Inadvertently soldiers became more fit.

A study of orthostatic post-exercise syncope gave us insight into its mechanisms in hot and cool environments. An example of asystole for 19 seconds in one subject, proved by an electrocardiogram, was a source of solace and satisfaction to colleagues with a strong fear of exercise and effort.

Atabrine (*quinacrine*)

Those who remember the early days of World War II vividly recall that the Japanese had cornered the world's supply of quinine. Germans were sending out rumors about atabrine's anaphrodisiac effects, as groundless as the mythical canard about saltpeter which still haunts the hallowed halls of school, barrack, and camp. A good malaria suppressing agent was vital. At Fort Knox, using a thousand soldiers, we tested many dose regimens with or without priming doses to see how quickly we could get various plasma levels. Suppression could then be tried in the field and the necessary level reached.

In our study no toxic reactions occurred. With a fixed daily dose, the blood level rose progressively for about eight weeks and reached an equilibrium proportional to the daily dose. Time to reach the characteristic equilibrium could be greatly reduced by a large priming dose. The plasma level at any time depended on daily dose, preexisting level, and time since the last dose. The net change in plasma level was a daily gain of about 30 micrograms per liter for a 1-gram dose balanced by a daily reduction of 10% of the existing level. The results were the same in simulated tropical conditions.

Ration Tests

I had been in the Army three weeks when I was driving a light tank on maneuvers in the desert in California under strict blackout. The psychological problem of driving a tank is a complete reversal of that of driving a car. One looks at a tree, estimating whether the tank can knock it over, rather than avoid it. Driving a tank with its skidding metal cleats on a concrete highway near automobiles was about as calming as riding a bicycle on ice, but much safer for the driver.

My first assignment was to look at emergency rations. Dr. Ancel Keys had preceded us in the desert. He reported favorably on K rations. But we followed the path of a maneuvering unit by the trail of discarded K biscuits. Even small desert rodents avoided them. After a few days' steady use, food which tastes fine as an hor d'oeuvre or at a taste panel becomes monotonous. Its high satiety value is too much. Experts who designed the ration must have thought in terms of animal husbandry. They concluded that each ration each day should have the liberal allow-

ance of vitamins, etc., recommended by the Food and Nutrition Board. To get such constituents within the physical requirements for an emergency ration, brewer's yeast, soybean flour, and liver extract had to be added. This was not what one would recommend offhand for flavor. The Surgeon General of the Army commanded me to write a critique of Army emergency rations.

The resulting document had all the earmarks of genius. I emphasized two prime discoveries. First, a ration is no good if it is not eaten. All the vitamin king's horses and all the food procuring king's men can't feed an Army if soldiers won't eat the food. The second radical discovery was that soldiers are people and eat things they are familiar with more readily than exotic ones, and variation, not monotony, encourages eating.

In the nature of our military arrangements, the Quartermaster Corps was responsible for procuring and delivering rations. The Medical Service had some responsibility in designing rations late in World War II. My comments were upsetting. Serious difficulties in the field and in combat had been so disturbing that I was ordered to run a ration test to see how foolish my ideas were. There was no convenient desert island to insure isolation, but in the Pike National Forest in Colorado we could plant the six companies, 1000 soldiers, isolated from each other and from outside "contamination." A test area with an entire program was established. The design of the 10 weeks' test, the questionnaires and their immediate transfer to IBM cards (more than 250,000 were used with nearly instant processing at the Corps Area Center in Omaha) enabled us to write a book about the ration test which was distributed less than 10 weeks after the test was over.

We had to interpolate an additional fitness test of the effect of a moderate change in altitude in those adapted to an altitude of approximately a mile above sea level when we moved from the 6,000 foot level at Camp Carson to the 9,000 foot level. Another effect of altitude was that our estimate of the gasoline needed for the test based on our experience at Fort Knox turned out to be exactly half what was required. This logistical lesson which might have been disastrous had I not had a priceless document signed by Adjutant General Ulio in Washington. It began with the formidable military injunction, "You will assist," and it enabled a mere Major to turn a red-faced General livid in 30 seconds.

We compared K Rations, C Rations, 10-in-1 Rations, Canadian Army Mess Tin Rations, and Field Ration B, switching them around at fixed intervals issued either as a ration or in isocaloric quantities. To half of one company we gave a vitamin; to the other half an identical appearing placebo. We introduced many new components and some entirely new rations.

The new rations, with common American foods and some variation, were highly acceptable. Physical fitness improved throughout the test period. No nutritional deficiency developed. The subjective element in the evaluation of nutrition was important, particularly in doctors not very experienced in clinical medicine or in clinical nutrition. The tendency was to overestimate the significance of minor variations from the normal. In short, for an emergency, the rations as improved would get soldiers through. What one needed was variety with ample and acceptable calories. For the short emergency, forget vitamins, forget proteins, forget fat and carbohydrate as such. Remember calories. Finally, an emergency ration should never be used for routine feeding.

Tests in Action

In the last year of the war we went to the Pacific, where we were able to study garrison troops and those in combat. This was the first time such a test had ever been done. We found that the ration we had improved was high in acceptability and the performance of the groups using the rations was excellent. They had been in serious combat for four and a half months of almost daily fighting. The improved C Ration had been the only food they had. They were the fittest group we tested anywhere. Some 30 biochemical determinations were made on selected groups of 50 soldiers. Physical examinations and fitness tests were done and the general quartermaster problems of food supply of the island or command were evaluated.

Our studies in the Pacific on healthy young American men largely protected from infection, who had lived in the tropics for more than three years and had an adequate diet, bore on tropical nutrition and deterioration. They were well protected from malaria, typhus, typhoid and major dysenteries. Doctor Kark, with the British Army in the Burma-India Theater, used exactly the same techniques and biochemical supplies. He found Indian soldiers with riboflavin levels which would have indicated severe deficiency in our soldiers. They had no clinical manifestation of disease. Their military performance was excellent. Physical fitness test scores were conspicuously higher than in our soldiers. This underlines the necessity for individual standards for different populations.

Recently captured Japanese prisoners of war in Burma had many positive physical signs, especially weight loss and low levels of hemoglobin and serum protein, very low excretion of riboflavin and chronic calorie deficiency. Anemia, ariboflavinosis, and pellagra were observed.

Our data from the Pacific and Burma-India Theater exploded the figment of a specifically tropical deterioration. There was no peculiar

nutritional requirement for the tropics. Vivid descriptions of mental, moral, and physical deterioration in lush surroundings had conjured up a picture of a pleasant morbid putrefaction of body and spirit termed tropical deterioration or tropical neurasthenia. It had no nutritional or physiological basis. Such deterioration exists, associated with homesickness, nostalgia, and the loss of usual social structure and supports. Commonly, but not invariably, it is connected with alcoholism. But it is not specifically tropical.

There was a close correlation between the calculated average daily intake of ascorbic acid, thiamine, riboflavin, and the amount excreted in urine collected before breakfast. Low or normal biochemical findings in individual soldiers were compared with the absence, presence or degree of various abnormal physical findings. With 20 items in the physical exam and 30 biochemical determinations, including vitamin load tests, hemoglobin, serum protein and so on, 600 correlations could be made. Of those with statistical significance, most were backward, that is, a high vitamin level with the presence of a physical sign or a low vitamin level and the absence of a physical sign. The others had no known connection, for instance, vitamin C and neurological signs. The trivial abnormalities were the normal variations of a well-fed group. We could find no need for extra vitamins or low-protein foods in the tropics. Thus we put to rest certain ancient traditions about the tropics which have flourished on the basis of highly imaginative literature rather than careful clinical observation.

Conclusions

In a laboratory established to study soldiers in tanks during World War II, my colleagues and I were able to find ways to study the physical, physiological, and emotional characteristics of young soldiers. We measured the adaptive changes to heat and cold, the vagaries of water and salt needs, of clothing and fitness. The biological rules for atabrine dosage, absorption and blood levels which we found permitted medical officers in areas of hyperendemic malaria to eliminate this disease as a military problem. Measurements of physical health and fitness as well as complicated field laboratories gave us the means for comprehensive testing of emergency rations. Statistical methods and the use of IBM processing had speeded up our work. Simple changes were recommended, introduced, and the rations tested in combat. By comparing studies in several tropical areas we were able to lay the ghost of "tropical" deterioration or a special food requirement. I have selected a few of the studies I participated in to illustrate the eternal relevance of climatology and its more comprehensive relative ecology. Pope's words still hold,

"The proper study of mankind *is* man."

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