Preface

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The magnificence of the submarine as a naval weapon system is almost overwhelming. It is the axis about which much of the United States Navy’s tactical and strategic roles revolve. In recent times the central Navy missions of control of the seas and projection of forces across oceans have depended unequivocally on the superiority of our submarine force. A major portion of naval aviation exists solely to support that concept. Our doctrine regarding logistic use of the sea surface and projection of marine amphibious units requires meticulous attention to the submarine as both a threat and a counter-threat. As a strategic weapon, the ballistic missile submarine is the only system whose fire power can be measured in megatons of TNT and that is also completely undetectable. Its destructive capability is unmatched in the history of warfare.

The critical limitation on this weapon system in the past, present, and future is human biology, a fact poorly perceived and even more poorly articulated by military planners and historians. Just as the living cell and the intact organism have homeostatic requirements (described by Claude Bernard and Walter Cannon), so the submarine requires an internally consistent system. The limits within which the system must operate are narrow; if they are exceeded, the entire system becomes dysfunctional and then inoperative.

Before the advent of the nuclear-powered submarine, the submarine’s final defense against attack by depth charge bombardment was to remain silently suspended above the ocean floor. The deeper, longer, and quieter the submarine could remain, the more likely it was to survive hostile surface forces. This was especially true in the shallow North Sea and South China Sea. What limited a submarine’s ability to remain under water was not metallurgy, weapons, or engineering, but the limited anaerobic power available to remove the waste of aerobic metabolism emanating from the occupants of this temporarily closed system. It is fair to say that in submarine warfare in the first half of this century, the single most decisive factor in the survival of a submarine under attack was its ability to control the level of carbon dioxide caused by human respiration.

One would imagine that the limitations imposed by atmospheric waste gases would be completely overcome by the unlimited anaerobic energy available from the control of nuclear fission. Such is indeed the case, but only with a heavy investment in carbon dioxide scrubbers,
carbon monoxide catalysts, mass spectrometer monitors, and unrelenting and meticulous attention to materials and practices compatible with living in a completely closed environment. Even with the abundant power and technologic sophistication undreamed of a generation ago, there continue to be limits on this true submersible. Currently, nuclear power plants can operate for years without overhaul, oxygen can be generated from seawater, and metabolic wastes can be removed as the engineer and designer desire. Yet the submarine patrol has a time limit. At present the limit is 60 days, set as a tolerance limit for human endurance. The cynic, the technical planner, and perhaps even the peacetime-oriented public might counter that 60 days is an arbitrary limit that certainly could be exceeded if exigency required. Perhaps so, but can we be certain? What are the limits of human tolerance to the monotony of days without sunrise and sunset? What are the cumulative effects of low levels of atmospheric contaminants on the ability to produce the maximum performance that may be demanded suddenly by battle or a damage control crisis? What is the behavioral impact of being deprived intermittently and for prolonged periods of normal societal interactions? The answer at this time must be: we do not know.

These collected papers clearly indicate that a closed environment is an artificial one. Even levels thought to be tolerable for prolonged periods produce measurable effects on physiological and behavioral processes. In a sense, then, this entire volume is an introduction to the future challenges in submarine medicine. Although the nature of some of these challenges is clear, that of others is blurred. The temptation to speculate on the direction of these challenges is therefore irresistible. The past 30 years have demonstrated that morbidity and mortality have not generally posed mission-abortion threats to submarine patrols of up to 60 days’ duration. Increasingly, however, the United States Navy and the society it serves have become aware of and even alarmed about diseases characterized by long asymptomatic latent periods, and which may also be associated with exposure to Navy operational environments.

The problems of ionizing and non-ionizing radiation, low levels of toxic gases and dusts in the air we breathe and the food and water we ingest, vibration, heat, light, and sound are being increasingly scrutinized and implicated as etiologic factors in accelerated aging, carcinogenesis, chronic lung disease, heart disease, arthritis, deafness, and maladjustment. The closed environment of a modern submarine is subject in varying but admittedly small degrees to these kinds of environmental hazards. As many of the papers in this issue point out, there are small but measurable physiological and behavioral responses. Could a submariner who spends 50 percent of his career in the artificial environment of submarine patrols eventually contract diseases characterized by long asymptomatic latent periods? Could such a relationship, if there is one, be detected by retrospective evaluations of morbidity and mortality patterns? Will public concern for such matters exempt the submarine community any more than citizen concern has exempted those responsible for exposure to nuclear weapon testing in the late 1950s or to asbestos in the naval shipyard? It follows that a major contribution of Dr. Schaefer’s work may be to prepare us for the prospective studies required to answer these questions better. Such studies must not be restricted to a display of morbidity and mortality patterns in submarine personnel alone, but must couple that display with a rigorous analysis of many environmental parameters so that issues of synergism and antagonism of several low level hazards may eventually be explored.

Even if future submarine medicine efforts are able to exclude a cause and effect relationship between prolonged exposure to an abnormal environment and altered patterns of morbidity and mortality, the effect of multiple low level environmental hazards on individual and crew performance requires further study. It is well known that our ballistic missile submarines can release an explosive force greater than that released in all previous wars. The cognition,
alertness, sensory-motor coordination, and man-machine interactions required for the controlled and timely delivery of such destructive capability must be the subjects of continued and more intensive study. Psychophysiology, psychology, and toxicology are each in their infancy. Their interrelations are largely unexplored, particularly in the range of threshold effects. As increasingly refined techniques of observation and measurement are made available, they must be increasingly applied to the field of submarine medicine. An environment that can be tolerated for simple existence may not be acceptable for the performance of either tactical or strategic missions. This challenge can and should be met by applying scientific methods to these operational problems of human biology.

Finally, aside from the speculative cause and effect relationship of low level environmental hazards and performance and behavior, I believe that the impact of monotony, sensory deprivation, and alteration of diurnal biorhythms require future study. These stresses are not entirely fixed and dissectible, but are closely linked to the attitudes that constitute the cultural fabric of the society from which the submariner comes. It is generally recognized that our cultural and societal mores are changing at a rapid rate. With these changes there will be changes not only in attitudes, but also in performance. Our tools to measure, analyze, and predict these correlates are weak and—some might say—non-existent. Therefore, the challenge is to meet the need for better methodology.

The editor of this volume is a scientist and a physician who has lived submarine medicine for almost 40 years. His experience and keen insight into both the gross and subtle problems of submarine medicine have been reflected in nearly 130 papers, articles, and books, and a well-deserved reputation as a world authority on the toxicology of carbon dioxide in closed environments. He was largely responsible for establishing limits for carbon dioxide on United States Navy submarines from the USS Nautilus to the present. He has directly or indirectly influenced the efforts reflected in each paper in this issue.

The past quarter-century has demonstrated how a biomedical team with the excellence that Dr. Schaefer's leadership reflects can contribute directly and indirectly to the national defense. This past is but prologue. This monograph is correctly a salute not only to Dr. Schaefer but to all who have shared the excitement of submarine medicine. In addition, it is an invitation for physicians and scientists of all free world navies to reach for the challenges and extend the contributions that have thus far been so ably presented.