HUMAN PERSPIRATION

By

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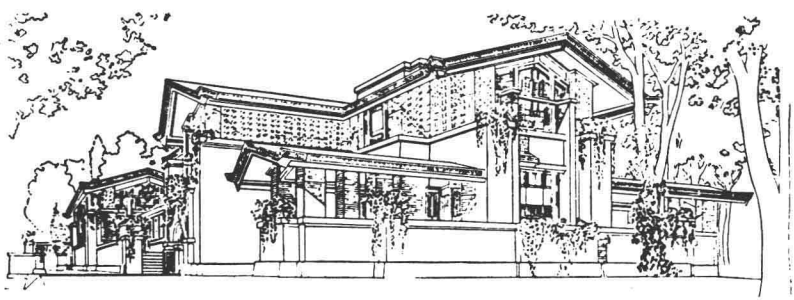

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PREFACE

Since the publication of my monograph *The Physiology of Human Perspiration,* in 1934, the knowledge of perspiration has been considerably extended. At an informal meeting on the physiology of heat and cold, held on the occasion of the Eighteenth International Congress of Physiologists at Copenhagen, in 1950, Dr. Eugene F. Du Bois, Cornell University Medical College, New York, asked me if a new edition of the above monograph could be expected. When informed of the financial difficulties involved in such a publication, Dr. O. G. Edholm, National Institute for Medical Research, London, took the initiative to consult with Dr. Du Bois, and the necessary arrangements were made by them. The publication of this monograph has thus become possible only by their kindness and assistance, for which I am deeply indebted.

In order to meet the required style of the Series of the American Lectures in Physiology, I have abandoned the style of my old monograph and have rewritten the entire manuscript, which is presented in this new monograph.

Y. K.

INTRODUCTION

Problems of perspiration are among the oldest in the history of medicine. Already at the time of Hippocrates, it was known that vaporous substances are given off through the skin. Scattered opinions about this phenomenon were brought into a system by Galen. He stated that, though insensible, perspiration (vapors dissolved by body temperature) is discharged continuously and uniformly from the whole body surface and that this discharge can occasionally be increased so that it takes the form of fluid, sweat. Fifteen centuries have since elapsed with no marked advance having been made in this knowledge.

Early in the seventeentn century, Sanctorius Sanctorio demonstrated to the great surprise of his contemporaries that insensible perspiration could be measured exactly by means of a balance. He constructed a large steel arm supporting a platform, on which he sat for hours and observed the gain in weight when he took food and the continuous loss of weight when nothing was taken. Such observations of his own body weight were continued throughout thirty years under various conditions of life. It is a surprise to present-day scientists also that the most important facts concerning insensible perspiration were correctly recorded at that time. Further studies were made by many later investigators, seemingly with the presumption that insensible perspiration has a great significance in indicating the health of man. But still there was no epochmaking advance in the knowledge.

After the discovery of the sweat glands by Purkinjé, in 1833, insensible perspiration and sweat secretion became an

inseparable subject. Insensible perspiration had so far been a matter of the whole body, but now the object of study was reduced to the skin, while the problem for study was tremendously extended by the advent of the sweat glands. The expected significance of perspiration to the health was, however, not fully recognized, and also studies on the skin encountered unexpected difficulties in the methods of observation. Research work along this line tended to decline: only some restricted aspects of the problem were studied and many of the interesting mysteries about sweating noticeable in daily life were neglected.

Some thirty years ago when we began our study of human perspiration, it looked like an unexplored spot in the field of medical knowledge. By the endeavors of my collaborators, sixty-five in all, and myself, I believe the knowledge of perspiration has been considerably extended. In the meantime, the number of investigators of many countries engaging themselves in research work on perspiration has increased, especially during the past ten years. This is due in part at least to the increasing interest in tropical life. Very many valuable contributions have been made by these investigators. With regard to the study of perspiration, therefore, these three decades may rather be looked upon as a period of renaissance.

One of the most important properties of water, insofar as it pertains to biological systems, is its high latent heat of vaporization. This property is fully utilized in perspiration, as it controls the body temperature by withdrawing heat from the body by vaporization of water. Water is produced over the skin both through the epidermis during insensible perspiration, and from the sweat glands during sweating. The former is a steady process taking a share of the heat loss of the body in ordinary life, and the latter is an extremely mutable process

dramatically preventing increases in the body temperature according to urgent necessities.

The body temperature is controlled successfully by sweating only when the sweat glands are capable of discharging a large quantity of water over the skin. Sweat glands with a secretory function similar that of the ordinary glands seem to have first appeared in the skin of certain mammals. In the course of evolution, their rate of secretion increased until at last they have come to outclass all other glands in the activity of producing an enormously large watery secretion. This is a unique development in the evolution of glands.

It seems strange that only some species of the mammals are endowed with well-developed sweat glands. The development of the sweat glands and of the associated nervous apparatus has been most highly attained in man so that human beings stand at the top of the animal kingdom in their ability to keep body temperature constant. Actually, sweating is the only process which makes human life comfortable during hot weather and therefore human existence possible in the torrid zone. It is peculiar that this value of sweating is recognized only by anhidrotic patients who suffer greatly from heat and not by ordinary people who usually complain about too much sweat. Sweating seems to deserve more physiological and social significance than is commonly attributed to it.

Besides control of temperature, sweating has a few other functions which seem to have once been important for our ancestors, but which are of minor significance in human life. These functions are fulfilled by a few special groups of sweat glands, which seem to be undergoing evolutional degeneration in the human body. On the other hand, there are signs indicating further development of the evolved sweat glands and their nervous system in some human races and during acclimatization of the subject. Such mixed evolutionary trends

are to be found in every organ, but the sweat apparatus seems to be one in which they can be seen most plainly.

In this monograph, we have endeavored to give an account of the present knowledge of perspiration. Instead of presenting a cumbersome review of the literature, we have drawn extensively on personal observations.

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HUMAN PERSPIRATION

CHAPTER I

INSENSIBLE PERSPIRATION

The term "insensible perspiration" has often been used to mean the insensible loss of weight of the body. The insensible loss of weight is equal to the weight of the water given off from the respiratory passages and the skin, plus the weight of the carbon dioxide given off, minus the weight of the oxygen consumed. The magnitude of the loss of weight due to the gaseous exchange in the lungs depends upon the respiratory quotient. The amount of water discharged from the respiratory passages is conditioned by the volume of respiration and the amount of moisture contained in the inspired air. The water elimination from the skin seems to depend on certain internal conditions of the skin and also on several environmental factors. The factors governing these three processes are therefore not at all identical. From a theoretical point of view, it seems unreasonable to treat such different processes as one subject.

In practice, however, the total amount of water discharged from both the respiratory passages and the skin is important for consideration of heat regulation and water loss of the body. Since the weight loss due to the gaseous exchange is very small compared with that due to the water loss, the former may be neglected in rough estimation. The total insensible loss of body weight, which can be determined simply, is therefore useful in practical medi-

cine; this is why the terms, insensible perspiration and insensible weight loss, are often used identically.

With regard to the mechanism of water elimination, the respiratory and cutaneous perspirations differ a great deal from one another. The mucous membranes of the respiratory passages are always very wet. The inspired air becomes saturated with water vapor as it passes over these moist mucosal surfaces and during expiration this vapor is given off from the body. The surface of the skin is comfortably dry, but the water contained in the skin tissue is discharged continuously from it. The mechanism is therefore much more complicated in the skin.

In the skin, the epidermis must be supplied with water originating from blood in the skin vessels in order that water can evaporate from its dry surface. For understanding the mechanism of cutaneous insensible perspiration, knowledge of the structure and properties of the epidermis, especially its state of hydration, and also of the structure of the minute blood vessels in the skin is of vital importance.

THE EPIDERMIS AND THE MINUTE BLOOD VESSELS OF THE SKIN

Epidermis

The epidermis is a stratified epithelium. It may be divided into four, or three, layers. In the *stratum germinativum* or *rete Malpighii*, the deepest layer, the columnar cells proliferate continuously, showing presumably the highest metabolism among all the elements of the skin at rest. The superficial layers are constantly replaced by the growth of the cells which gradually flatten as they approach the surface. In the process some of the protoplasm of the cells becomes transformed into granular eleidin which characterizes the *stratum granulosum*, but gradually the cells clear to form the *stratum lucidum*,