distant, control. This is contrary to the nature of man which seeks adventure, progress and personal dignity. The medical profession has surely a duty to repay to the community for its privileges by offering example and guidance to assist man to contribute successfully by means of service, of co-operation and of tolerance in his new role as a citizen of a widening world.

REFERENCES


THE PHYSIOLOGY OF TEXTILES AND CLOTHING: A HISTORICAL NOTE

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HIPPOCRATES ON CLOTHING

The science of textiles and the physiology of clothing are often accepted as recent innovations, but close examination of the literature takes us back to early periods and to investigators whose works have been in some instances forgotten.

Nearly twenty-three centuries ago the Greek physician Hippocrates (460-370 B.C.), traditional father of Medicine, made some pertinent though obscure remarks in his essay on “Airs, Waters and Places” concerning the effect of the sun on sweating by the clothed body. We are told that “... as a strong proof of this, when a man walks in the sun, or sits down having a garment on, whatever parts of the body the sun shines on do not sweat; for the sun carries off whatever sweat makes its appearance; but those parts which are covered by the garments or anything else, sweat, for the particles of sweat are drawn and forced out by the sun and are preserved by the cover so as not to be dissipated; but when the person comes into the shade, the whole body equally perspires” (1).
"INSENSIBILIS PERSPIRATIO"

Some two thousand years later Santario Santario (1561-1636), commonly known as Sanctorius, Professor of Medicine at Padua, devised the earliest clinical thermometer and pulse clock. Sitting for long periods fully clothed in his steel-yard armchair, he weighed for the first time the "insensibilis perspiratio" or invisible perspiration of the skin (2). He may be regarded as the earliest investigator to measure quantitatively this variety of body water.

John Arbuthnot taught mathematics in London, later took a doctorate of medicine at the University of St. Andrews and became in 1705 Physician Extraordinary to Queen Anne. He tells us that he measured the temperature of the human skin with a thermometer made by his friend Stephen Hales, scientist and curate of Teddington (1677-1761). From various experiments Arbuthnot concluded that "the chilling effects of the wind are due to the dispersion of the warm and moist air which invests our bodies" (3). Many of us may feel chastened that this remark was made over two hundred years ago.

In classical periods a high level of hygiene prevailed, but in Europe during the Dark Ages, bathing of the body and washing of the clothes became a luxury of the few. Although the use of soap was well known to the Romans, it remained a rarity during the Dark and Middle Ages. The common people used as substitute wood ashes, nettles or even cow dung. It is therefore no small wonder that clothes were washed as infrequently as possible and that the outer garments and bedding were passed from one generation to another without being cleaned. Pungent perfumes were commonly used as a necessity.

In 1752 the German physician Joseph Zaccharias Platner wrote that the movement of the "insensibilis perspiratio" through the clothes was essential for health, and as a consequence he advocated frequent washings of the body clothing and bedding, an almost heretical doctrine in his day (4).

PHYSICIST, PHILOSOPHER, PHYSICIAN

The first scientific data gathered during the slow development of the science of clothing were due to another medical man, Joseph Black, Professor of Chemistry, and later of Medicine, at the University of Glasgow. He taught his students much, and published little. Nevertheless in verbal communications to the Newtonian Society of Edinburgh, on the subjects of Specific Heat (1760) and Latent Heat (1762), he produced conclusions from his careful work (5) which laid a path for those laws of thermodynamics upon which some of our modern ideas on body heat and the functions of clothing are based.

About this time Jean-Jacques Rousseau decried against the ponderously magnificent garments of the period before the French Revolution, stressing that it was more healthful to wear summer clothes in the winter. The critical Voltaire raised his voice against the coddling of infants with heavy clothes which he believed could lead to deformities. Alexander Pope, himself the son of a linen draper, wrote as follows in his Moral Essays:

"'Odious! in woollen! 'twould a saint provoke'  
(Were the last words poor Narcissa spoke)."
After the French Revolution there was a strong movement in France towards the clothing simplicity of classic periods, and in imitation of the ancient Greeks and Egyptians it became the fashion to wear little but the finest and most transparent muslins. This may have satisfied the esthetic inclinations of the gentlemen of the early Empire period, but it was followed by an epidemic of chills, catarrhs and phthisis. Diligent physicians were much disturbed by this vagary of the new freedom, and referred to the illnesses as "Muslin Disease."

COUNT RUMFORD AND TEXTILE SCIENCE

During the eighteenth century several monographs were published on various aspects of fabric and clothing by Schwartz (6), Kiesling (7), and Vaughan (8), but these did not add much to the scientific knowledge of their day.

The turning point in the history of textile science may be said to be due to a remarkable American, Benjamin Thompson, Count Rumford (1753-1814). In early life he considered embarking on a medical career, but instead became a teacher in the village of Rumford, New Hampshire, and studied physics in his spare time. His marked English sympathies attracted him to England before the War of Independence, and his remarkable gifts guided him into the Colonial Office, and afterwards to the post of Secretary of State. Although he received a knighthood from George III, he left his service and soon entered that of the Prince of Bavaria, to whom he became Minister of War, of Police, and Grand Chamberlain.

Despite much travel and many varying public commitments, Rumford found time not only to study but also to carry out investigations into diet and clothing, and on fuel, stoves and ventilation (9). He appears to be the first observer to stress the importance of convection in heat transfer, and to carry out research on what would nowadays be termed textile technology. In Munich, he performed experiments on the thermal insulation of clothing materials, wrapping them round a polished brass cylinder containing hot water and noting the time taken for the water to fall through a given temperature range as measured by a sensitive mercury Réaumur thermometer. In 1787 he recorded the unexpected fact that two thicknesses of cloth did not give appreciably more insulation than one. He clearly realized that air is the important insulator in clothing and stated that "heat is incapable of passing through a mass of air to penetrate from particle to particle."

Rumford's experimental work also led him to believe that dry air is a better thermal insulator than moist air. Later, in 1792, he demonstrated that more sunlight is reflected from a white than a black surface, adding that "white clothing is more fit to wear in a hot summer climate than is black clothing," a fact confirmed by his contemporary, Benjamin Franklin. Believing erroneously that a white surface was a poor radiator of the body's heat, he also advocated white clothing for cold weather, and was sometimes seen driving round Paris wearing immaculate white garments in the winter-time. He stressed the moisture-absorbing properties of wool, strongly recommending its wear near the skin, and was impatient with those who complained of its heating effect and skin irritation.
The ideas of the great Rumford dominated thought in the new science for about a hundred years, and his data were often used as a final court of appeal even late into the nineteenth century. He founded the Rumford Medal of the Royal Society. We may regard him as the founder of textile science.

HEAT LOSS AND WIND

Early in the nineteenth century when “trowsers” were beginning to replace breeches, a French physician, Clairain, wrote on the medical aspects of such clothing apparel (10), but his arguments did not greatly advance the knowledge of the day.

John Leslie, Professor of Mathematics and later of Natural Philosophy at Edinburgh, was a claimant of the Rumford Medal. He tells us that “moderate wind will quadruple the waste of heat, and a vehement hurricane is capable of increasing the rate of dissipation fifteen or twenty times; hence the keen impression of frost winds on our feelings” (11).

Leslie’s remarks on the cooling of radiating bodies were to be repeated almost a hundred and fifty years later by Siple of America, in the form of graphs of “Wind Chill” (12).

In 1833 a Scots physician, John Stark, reported to the Royal Society his work on the influence of the colour of fabrics to heat and odours (13), and his conclusions have been much quoted by many hygienists who followed him.

The French physicist Péclet carried out careful investigations on the heat loss from cylinders and spheres (1860) (14), and his data are still referred to by modern workers concerned with the dynamics of heat loss from the cylinder-like extremities of the human body. This observer repeated the work of Rumford on heat loss of fabric-coated metal cylinders, but his results suggested that thermal insulation was independent of thickness or weave of cloth.

VAL-de-GRÂCE: LÉVY AND COULIER

From this time onwards we note in our review an abundance of military hygienists, many of whom were medical men. Michel Lévy, Physician to Napoleon III and Inspector of Military Health, was Director of the Imperial Medical School at Val-de-Grâce; his excellent text-book of Hygiene first appeared in 1844 (15), and the third edition in 1856 contained a chapter of some fifty pages devoted to the Science of Clothing—De l’action des vêtements.

Coulier, Professor of Military Chemistry, and colleague of Lévy at the Val-de-Grâce, repeated in 1858 the work of Rumford and Péclet on the thermal insulation of fabrics (16), using much the same technique as that of his predecessors. We are told that he employed “un vase de laiton mince (thin brass) cylindrique de 500 cm., suspendu par des cordons de soie, dans un air tranquille, et fermé par un bouchon qui maintient un thermomètre très sensible.”

This careful observer was greatly interested in the relation of water to textiles, and his observations led him to the conclusion that water vapour was absorbed into the fibre itself—l’eau hygrométrique—to condense as liquid with the evolution of latent heat: much more liquid water could, however, be taken...
up into the interstices of cloth—l'eau d'interposition. We may read in our modern text-books similar statements concerning fabric water, but it is difficult to realize that the facts are almost a century old.

Lévy himself carried out investigations on the effect of impermeable garments on the marching soldier, and came to the conclusion that such clothing was unsuitable as the man became a "wet stove" (17).

We may accord honours to Val-de-Grâce as the first School of textile science.

**Later Hygienists and Pettenkofer**

About the same period, Surgeon-General Hammond of the American Army published a text-book on Military Hygiene (1863) (18) in which he quoted freely the investigations of Lévy and Coulier. It is worthy of note that most text-books of hygiene of this period already gave good descriptions of the microscopic appearance of textile fibres.

Hammond repeated Rumford's and Coulier's experiments with a heated brass cylinder, and confirmed that wool was a better thermal insulator than cotton. He also discussed the value of light coloured materials for keeping off the rays of the sun.

During the Indian Mutiny of 1857-8, lack of scarlet coats for native regiments led to the introduction of local cloth of a less vivid colour (khaki, Hindustani—dust coloured). Having been found suitable, khaki was used later by British troops serving in hot countries, but the tactical and physiological advantage of a drab colour were not generally realized for some time.

In 1864 appeared the first edition of an important text on Military Hygiene by Edmund Alexander Parkes (19), first Professor of Military Hygiene at the Army Medical School, Fort Pitt, Chatham. He made no remarkable contribution to clothing science, but repeated the earlier observation of Stark concerning the absorption of odour by coloured fabrics, and wrote at length on the value of socks for the soldier. Parkes' detailed work on military equipment, however, played a most important role in the development of accoutrements both in England and on the Continent. He speaks in his text of the work of Troubridge, first Director of Army Clothing (1857), who was employing up-to-date machines for testing fabrics in the new Army Testing Establishment in Pimlico. Discussing malaria, Parkes notes that since the poisons undoubtedly enter by the lungs or stomach, there appears to be little object in wearing special clothing as a precaution against the disease. We accept this statement with understanding, for Parkes' military colleagues, Laveran and Ross, had not yet discovered the parts played by the parasite and mosquito.

It is often assumed that scientific work on textiles began with Pettenkofer, Professor of Dietetic Chemistry and later of Hygiene in the University of Munich; but by 1865 when his investigations were published (20) the budding science was already well rooted and fast growing. Pettenkofer, poet, actor, medical man and scientist, was greatly interested in all aspects of human hygiene, whether of air, living rooms or garments. He contributed numerous quantitative tests for air- and water-permeability of clothing, and most succeeding authors
freely quoted his results. Perhaps the most valuable function of this great Bavarian was to popularize knowledge of clothing science by means of public lectures (21).

Dr. Joseph Krieger, a friend of Pettenkofer, repeated the earlier work on thermal insulation, but used a cylinder of iron instead of the traditional brass (22). In 1877 he published his studies concerning the relationships of clothing properties to chills, inflammations and fevers (23). Morache, Director of Army Health to the French 18th Army Corps, in his work on Military Hygiene published in 1874 (24), devoted some fifty pages to all known aspects of clothing science as applied to the soldier. Roth and Lex produced in 1877 their massive work on Military Hygiene, and with usual German thoroughness dealt with the subjects of textile science and military garments in no less than one hundred pages (25).

During the next few years Linroth (26) and Hiller (27) wrote on water in fabrics and clothing, and of the effects of wet uniforms on chilling the soldier. Several other books and reports of importance enriched the literature. Pommay (28) and Schierbeck (29) were interested in air permeability of fabrics and the ventilation of garments; Würster (30) described a small hygrometer for use under clothing; Berthier and Kolb (31) described an artificial rain test; Holbein (32) carried out early work on the bacteriology of undergarments, and Lang (33) and Schumburg (34) reported on the scientific background of underclothing which began to be generally used only towards the end of the nineteenth century.

THE "SANITARY WOOLLEN SYSTEM" OF JÄGER

About this time a certain Dr. Gustav Jäger was very active in attempting to introduce a new civilization by his "Sanitary Woollen System" (35). However, long before his time many had pondered on the advantages or otherwise of various fibres and weaves. Before the end of the eighteenth century, Rumford and Gibbons (36) had written on the value of wool for garments, and Tual in 1838 discussed at length its various advantages (37). Johnson favoured cotton for underclothes (1861) (38), Augustin discussed the use of flannel (1874) (39), Gerster inquired into the relative values of linen and wool (1891) (40), and in the same year Rutherford declared for the "Sanitary Woollen System" (41).

Dr. Jäger, although a physician and zoologist by training, based many of his arguments on unsound principles. He wrote that wool stimulated the skin and in some way prevented the absorption into the body of a hypothetical "noxious principle" present in sweat. Only by wool, he said, could health be maintained. According to Jäger, woollens kept away the "ubiquitous flea and microbe" and attracted fragrant odours! He added that vegetable fibres such as cotton and flax had the opposite properties and should certainly not be used in clothing! The "Sanitary Woollen System" of Dr. Jäger is now forgotten although some of us wear clothing with which his name is still associated.

RUBNER AND CLOTHING PHYSIOLOGY

The unscientific verbiage accumulated by Jäger and his colleagues was removed by an important near-contemporary, Max Rubner, who, like his pre-
decessor Pettenkofer, was a Bavarian. Rubner was a medical man and physiologist, and in 1891 became Director of the Hygienic Institute in Berlin. His first text-book on hygiene (42) was published in 1890, and his monumental Handbuch (43) which appeared in 1911 includes a chapter on clothing which to the casual reader appears quite modern. Rubner continued the work of his predecessors, and produced careful quantitative techniques for the measurement of air, water and vapour permeability, and for measuring the compressibility of fabrics. A number of his methods, in modified form, are still in use by some laboratories. He repeated the work of Coulier and Krieger on thermal insulation, using a Stefan calorimeter and recording the results in absolute units (44). Rubner found that insulation increased in proportion to thickness and came to a conclusion, new even today, that thickness is a fundamental property of fabrics—"Die Dicke der Stoffe ist ein Fundamentale Eigenschaft." Rubner extrapolated air permeability values to a thickness of 1 cm., a strange oversight on his part since all the fabrics used by him were much thinner. He formulated the principle that most natural fibres have similar physical properties which become modified in the weaves that can be produced from them. Thus we have his "primary" properties of the fibre and "secondary" properties of the cloth. He also stressed that air and moisture properties are closely linked characteristics of textiles. Continuing the researches of Coulier, Rubner again demonstrated the existence of two levels of water equilibria—that of vapour in relation to the fibre ("hygroskopische Wasser") and that of liquid in relation to the interstices ("zwischengelagerte Wasser"); he pointed out the latent heat value of the former, and the marked effect of the latter on thermal insulation by displacement of air.

But it was as physiologist that Rubner contributed most greatly to the science of clothing, and he showed firm conviction that much truth is missed if one limits investigations to a piece of cloth without considering the whole garment worn under realistic conditions. Rubner's work on metabolism had shown the importance of body surface area in relation to heat loss, and it was to the surface that he directed much of his energies (45). Measurements of skin temperature and of temperature gradients through the layers of clothing were recorded under a variety of environmental conditions, using thermocouples—"feiner Neusilber-Eisen Thermoelementen"—which were just beginning to be used in physiological work. In assessing the relative value of woollen and cotton socks, he took measurements from subjects wearing one type on each foot. Many of his contemporaries were highly suspicious of his interest in the human body and of his "tomfoolery with feet."

Rubner stated a fact not generally realized even today; a human when wearing clothes is not always a reliable judge of his own comfort. We claim Rubner as the leader of the new science of clothing physiology.

**The Modern Period**

During the early twentieth century, work continued sporadically on problems of hygroscopic heat and thermal insulation. Rodevald had shown in 1897 that the heat of hydration of starch was not entirely explained in terms of surface
condensation phenomena (46), and suggested the possibility of a chemical mechanism. Masson and Richards in 1907 demonstrated that dried cotton wrapped around a thermometer bulb absorbed water from the atmosphere with a concomitant evolution of heat which could not be explained as due to liquefaction alone (47). Leonard Hill in 1920 referred to the schoolboys’ trick of blowing up the sleeve or placing the head under the bed-clothes as a means of getting warm (48). With these earlier studies as background, the recent work of Baxter and Cassie (1941) on “sorption” heat (49) and its practical application to the human by Nelback and Herrington (1942) (50) is perhaps not unexpected.

From the heat flow cylinder of Rumford, Coulier and Krieger, and via the calorimeter of Rubner, emerged the wet Kata thermometer of Hill (48). Later was developed the oil-containing copper cylinder of Floyd and Baker (1925) (51); and the constant temperature copper plate of Sale and Hedrick (1924) (52), of Cleveland (1934) (53), and of Rees (1941). With Rees came the concept of the TOG value of a textile (54) as a measure of thermal insulation. Finally we arrive at the engineering feat of the “Copper Man” of Burton (1944) (55) and Hall (1946) (56), with its associated CLO unit of thermal insulation of the complete clothing ensemble. Excellent reviews on the present state of knowledge of the physiology of textiles and clothing are given in the publication of Newburgh (57) and in that of Winslow and Herrington (58).

CONCLUSION

Looking back on the path that has been traced it seems clear that from earliest times man has reflected much upon himself and the nature of his garments.

We sometimes smile indulgently at the efforts of our predecessors, but unless prepared to read what they have written, we may well lose time in going over ground already well trodden. It is perturbing to realize how much was known a century ago, and what a grasp of the principles of clothing physiology was held by Rubner over fifty years ago. It may be difficult, and at times impossible, to draw valid conclusions from the work of earlier investigators, partly because specifications of textiles were unknown to them, and partly because design of experiment and analysis of resulting data had not been evolved. Nevertheless, the principles laid down by Rubner and his predecessors have laid the foundation of the science of clothing physiology, and only by the close integration of physicist, engineer, textile technologist and applied physiologist or hygienist will the interrelations of fibre, weave, garment and body be made more clear.

The wranglings of the men of cotton, wool, and linen have long been forgotten, and we have learnt that for many conditions it matters but little what we wear near our skin. But for the soldier and for those exposed to extremes of climate, to wind and to rain, operational garments will for long be of prime consideration. Here lies work for the future.

ACKNOWLEDGMENTS

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**STUDIES ON URINARY CARRIAGE OF ENTERIC GROUP ORGANISMS**

VII.—THE VALUE OF DIFFERENT CULTURAL METHODS FOR ROUTINE CLEARANCE TESTS AND FOR FOLLOW-UP INVESTIGATION OF CARRIERS

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Methods of urine culture for enteric group organisms and for the concentration of organisms of this group in specimens of urine were quantitatively evaluated by Archer and Ritchie (1950) in the first paper of this series. It was concluded that enrichment was probably unnecessary and could not be used exclusively, that direct plating, oxalate precipitation and primary fluid culture in an indicator medium ("MacConkey-mannite") should be used in carrier investigation work, and that assessment of the best methods for future routine use should be based on the results observed.

Williams Smith (1952) found selenite and tetrathionate superior to liquid desoxycholate-citrate, liquid Wilson and Blair, cacotheline broth and brilliant green peptone water for isolation of Salmonellae from faeces. The use of either selenite or tetrathionate might reveal the presence of ten Salmonella organisms, while it was necessary to add several thousand Salmonellae to faeces before they could be recovered by direct culture on desoxycholate-citrate-agar or Wilson and Blair solid medium. In general, isolation was easier from human and animal than