The Physiological Dynamics of the Skin.

Graduation Thesis

By

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N. B. - The references to mistakes have been placed wrongly; the numbers refer to the notes on the back of every alternate leaf.
The human skin, which may be regarded as the external skeleton, the protecting and investiture envelope the wall of limiting membranes of the body, belongs to the connective-tissue series of structures, being composed of fibrocellular elements finished off by epithelium. It has its embryonic origin partly from the uppermost and most external layer of the blastoderm, the epiblast, from which the outer cellular covering is derived; but chiefly from the middle layer or mesoblast in common with the other connective-tissue formations, & a great part of the large glands & internal organs. It is built up of the same simple type which governs all the other secretory structures & ductory channels; — kidneys, liver, lungs, mucous & serous membranes — the analogy being perhaps especially marked in the case of the mucous membranes which line cavities communicating with the external surface, which have sometimes been named the "Internal Skin." Reduced to its simplest form, this common type consists of a delicate homogeneous layer to which Bowman gave the name of "basement membrane," having on one side a plexus of capillary blood-vessels, on the other algae of epithelial cells. This simple arrangement is eminently suitable for the work assigned to it, which is the transfer of certain materials from the blood-current onto to a free surface, either to be utilized in the system or altogether removed out of the body as of no further service or as prejudicial to its well-being. Equally, therefore, in structure & in physiological action, the skin possesses a remarkable similarity to the pulmonary, intestinal, & urinary organs. It becomes indeed continuous with the mucous membrane lining the cavities of these visceræ at their different external orifices. And this identity of structure is further emphasized by the occasional occurrence of hairs growing from the corneal conjunctiva; by the
fact that the intestinal and vaginal mucous membranes sometimes become converted into tissue closely resembling the cutaneous by its evisceration from prolonged exposure to the air and friction, in cases of prolapse; while the familiar instances of the dermoid cyst of the ovary furnishes yet another illustration of the allied nature of these tissues. Their common origin.

It is usual to describe the skin as divisible into two principal parts, separated by a thin structureless film or base-membrane. The upper or external portion is entirely cellular, and is called the Epidermis, Cuticle, or Scarf-Skin, by comparative anatomists, Epiderm. The deeper or internal division is the Corium, Seton, Cutis vera, or True-Skin, or Epiderm. It is both vascular and sensitive, and moreover contains various important structural elements.

The Epidermis, although apparently smooth, if closely examined, presents on its surface a series of elevations and depressions, ridges and furrows, which are either arranged in parallel rows as in the palms and soles, or form an interlacing network as is well seen on the backs of the hands. These are caused by irregularities on the surface of the subjacent corium to which the epidermis is so closely and perfectly fitted as to adapt itself to every prominence and depression, thus considerably increasing its surface area. Besides these are to be seen numerous minute apertures which are for the most part the openings of the sweat-glands, and may be also openings of the sebaceous ducts with issuing hair-shafts. It is very thick on the palms and soles, thicker in the feets, & becomes increased so with prolonged pressure or friction. Wilson found it to measure in the palm of an ordinary hand $\frac{1}{2}$ of a line in thickness; its thickness appears to be proportionate to the size of the subjacent papillae on which its formation or nutrition most depends. It may vary from $\frac{1}{2}$ to $\frac{9}{12}$ of an inch, being thinnest on the inner aspect of the limbs, the anterior surface of the trunk, the posterior surface of the feet.
Four layers are demonstrated to exist in it. 1st, the Rete Malpighii; 2nd, Mucous Layer, next to the membrane propria; 2nd, Stratum Granulosum, or Granular layer, a thin layer immediately above it; 3rd, Stratum Lucidum; 4th, Stratum Cornueum or horny layer, the most superficial. The deepest layer of the Rete Malpighii consists of columnar epithelium with distinct nuclei, having superimposed upon it several zones of cells clearly nucleated polyhedral cells which become more flattened the nearer the surface. The cell-contents, so-called, are fibrous fibrillar, granular, pigment, giving rise to the variety of complications found in different persons' races. In the intercellular spaces there have been observed very delicate terminal fibrils of nerves, or branches of nerve-tissue-corpseules. The Granular layer is formed of somewhat flattened epithelium with bright nuclei, having nodules of granules radiating from them. Nearer the surface, the Stratum Lucidum consists of a layer almost homogenous in appearance, but slightly striated, composed of still more flattened cells with very indistinct nuclei. Lastly, the uppermost is the horny layer, is an imbricated series of quite flattened squamous cells, their nuclei having totally disappeared, their substance having changed in its chemical constitution so as to have become transformed into keratin. The oldest and most superficial layer perfectly dry thin, are being constantly detached and thrown off. There is thus a constant cell-formation or secretion, a corresponding death and loss of strata epithelium. The Rete Malpighii contains the active cells of growth and reproduction, which, being constantly formed from materials in the papillary corium, gradually push the outer cells outwards to the surface where having lost their vitality they are cast off.

The corium, the deeper and more important subdivision of the integument, is the skin proper, indeed, of a different and more complete texture. It is much thicker than its cellular covering, measuring in the thinnest parts as in the eyelids, the penis
(1) "Diseases of the Skin", p. 14.
somewhat less than aline, while in the soles, the back of the neck, or about the nipples, it may amount to as much as aline or a half. The demarcation, however, between it and the subjacent muscular tissue is so ill-defined that a precise estimate cannot be made. It is dense, tough, elastic, consisting as it does mainly of fibro-cellular substance; it is highly vascular, rich in nerves and glands, more or less supplied with fat. The superficial portion is usually known as the Papillary, Vascular or Sensitive Layer, being characterized by very numerous little conical elevations or processes on its external surface, called Pil- pilae, which accurately fit into intimately adherent corresponding depres- sions or indentations on the under surface of the covering cuticle, which are so vascular as to be almost tenacious, being endowed with nerves as to convey an impression of the slightest touch. So vascular or sensitive is this layer that a needle can nowhere over the body-surface be introduced without drawing blood and producing pain. The ground-work by which these important structures are supported is a web of fine white fibrous tissue in closely packed whitish inter--spacing bundles, having between their wavy trabeculae narrow spaces which are the lymph canaliculi, wherein are found connective-tissue-corporcles, in many of which run the slender twigs of blood-vessel and nerves. In this portion of the corium there also exists a varying quantity of yellow elastic tissue, the bright fibre of which appear to run through or upon the white bundle. Their curled ends seem to be associated with the connective-tissue-corpuscles, in the lacunar canalicular spaces. This adds materially to the strength and elasticity of the structure. In the deeper strata of the corium—in the white fibrous bundles are larger, thicker, more coarsely organized, the areolar spaces becoming wider, frequently filled with fat-cells, lined with endothelial connective-tissue cells. The tissue ultimately blends with the subcutaneous areolar and adipose-layer with which it is continuous. Similar in character, the latter separating, more strictly, connecting the skin with the subjacent muscular and dense structures, constituting at once
a dense, soft, yielding medium for the transmission of blood-vessels, nerves, and lymphatics to and from the corium. It thus binds the integument firmly to underlying parts, and at the same time allows of very free and easy movements of considerable stretching.

The Papillae are simply prolongations of the connective-tissue of the Corium thrown up on its surface, thereby largely extending its superficiality. They occur irregularly but always in large numbers over the general surface, except at places which are highly sensitive as the palms, finger-points, & toes, where they are found in groups, arranged in parallel rows, as evidenced by the curved lines visible on the cuticle.

The columnar cells of the Malphigian layer invest them, following their outline throughout; but the Epidermis as a whole is slightly thicker at the inter-papillary spaces & thinner over the apices of the papilla themselves. They are largest & most numerous where the cuticle is thick & needs active reproduction as in the hands, feet & nails. Each Papilla contains one or more capillary loops projected perpendicularly from a somewhat dense horizontal plexus of minute vessels at its base, which come into close relation with the basement membrane. And similarly there usually accompanies the capillary loop a fine nerve-fibre derived from a sensory plexus almost the surface of the Corium. It would seem, however, that these are many papilla more exclusively vascular, others specially supplied with nerve structure, or more particularly so where sensation is most developed in which case peculiar arrangements are found in what are known as Tactile Corpuscles or the End Bulbs of Merkel.

There is reason to believe that these bodies, which are cells enclosed in connective-tissue, are the terminal endings of sensory medullated nerve-fibres. The nervous innervation in the Papillary layer is largely composed of nerve-fibres which have become non-medullated & which send out terminal fibres into the intercellular substance of the Rete Malpighii & the outer sheath of the hair-follicles. The Glands of the Skin constitute an element of
much interest and importance. They are of two kinds: the Sweat Glands, which are both more numerous and of more consequence than the others which are the Sebaceous Glands. The first are simple, convoluted, while the second are sacculated or tubulated glands. They are both in reality more involutions of the Epidermis or Corium, their membrana propria being formed by the common basement membrane, the secreting cells lining their cavities being mostly continuous with those of the Rete Malpighii, while capillaries and a certain amount of connective tissue form their walls. They are thus practically identical in structure.

The Sudoriparous Glands are generally situated in the deeper parts of the Corium, or in the Subcutaneous tissue. They are small rounded masses consisting of the coils of a minute tube which proceeds outwards more or less obliquely through the substance of the Corium in a slightly wavy course, becoming more and more spiral as it runs through the Epidermis, opens on the surface, commonly at the apex of a papilla, by a somewhat vascular aperture. A capillary plate closely surrounds the convoluted portion bringing the blood close to the membrana propria. A single layer of columnar epithelium lines here on the basement membrane but in many of the larger glands a delicate layer of unstriped muscular fibres is found interposed between them. In others, muscular fibres are placed outside the glomeruli. More superficially, the epithelium occurs in several layers derived from the Rete Malpighii, the cells are polygonal or cuboidal or squamous; whereas in the Epidermis there is no definable structure at all, the passage being simply formed by the cuticular cells themselves. Like the papillae they occur irregularly over the general surface, their number and dimensions vary much in different regions. In the palms and soles they are arranged in rows, the external pores may be seen in regular array on the papillary ridges: they occur also in the greatest numbers in these parts. Krause having counted as many as nearly 2,800 in a square inch on the palm, while on the back he could only make out
417 in the square inch. The largest are found in the axilla or groin, which are warmer and protected regions, and consequently more in need of their aid. Krause calculated, after many painstaking observations, that the whole mass of the perspiratory glomeruli in the body would amount to about four cubic inches of secreting substance, equal to about \( \frac{2}{7} \) of the area of the kidneys, but he stated that they did not possess so much secreting power in proportion. Wilson, however, goes somewhat further, by a simple computation getting the probably staggered result of 28 miles of perspiratory tubing in the body, this of course including the whole tube to the surface of the skin. These are somewhat fanciful and certainly only approximate statements, but the fact remains that the secreting substance constituting the mass of these Sudoriparous Glands must be vastly large of the greatest importance.

It only remains to refer briefly to the other structures contained in the Corium, namely, the Sebaceous Glands, the hairs, which are almost always found together. The Hair-Follicle is a pouch formed in the Corium by an involution of the Skin, usually a little over a line in depth, in which is lodged the shaft of a hair, at the bottom of which is the Hair-Root in close proximity to a large papilla from which the cellular elements of the Root of the Hair are constantly supplied. The hair is simply composed of modified Epithelium derived or elaborated from the Corium—in both, a horny secretion. Into the hair-follicle, frequently rather more than a half of a line below the surface, there open one or more small tubes, the secreting ducts of clustered vascular containing secreting cells; fat-globules in their branching pouches, which are the Sebaceous Glands. The Glands are merely sebaceous dilatations or processes of the hair-follicle, being lined with pigment-cells similar to or continuous with those of the deepest layer of the Binde-Malpighia, while their cavity is usually filled with fat-cells and debris of epithelium forming the oily secretion, which is known as Sebum. A minute bundle of unstriped muscular fibre proceeds from the outer layer of the corium near its external surface to be inserted
into the hair-follicle below the Sebaceous Gland; this muscle receives the name of Arrector Pili. There are occasionally two of these which surround the Gland, and not only serve to project the hair but assist the outward flow of the secretion. These actions are partly produced also by the contractile connective-tissue contained in the hair-sac itself, the contraction thereby causing the peculiar condition of skin familiarly known as "goose-skin" or Lat. 

...Fine nerve-endings are found in the part of the hair-follicle, which must have some share in the production of this appearance. Unstripped muscular fibres probably occur pretty freely in other parts of the Corium; it is certain known to be present in the Ducts of the Sebaceous Gland around the nipple.

Sebaceous Glands are present wherever there are hairs, that is, in all parts of the Skin, with the exception of the palms, the soles, the dorsum of the third phalanx, of the penis, which are absolutely devoid of hairs hence also of Sebaceous Glands. The largest are the Malarian Glands of the Eyelids, those situated near the external orifices of the body, where they are besides in large numbers. Some are found exceptionally to open directly on the Skin, independently of hair-follicles, but they are few.

The Nails, like the Hairs, are merely horny modifications of the Epidermis continuous with it, consist of dense layers of thick, hard, squamous Epithelium. The papilla on which they rest from which they are nourished, are especially large, vascular, sensitive...

When we consider the structure arrangement of the Skin we are at once struck with the obvious excellence of it as a Protection to the body. This is its most apparent and simplest function, that of guarding and tending as well as finishing or rounding off concealing the underlying textures. It exercises its protective influence both physically and vitally, both these in various ways. By the density of the Corium of horny cuticle, the fluids of the subjacent tissues are preserved against too active or rapid evaporation, the close Epidermis especially supplying an admirable check to...
Etherization. Were this removed, the tissues would soon lose that moist condition which is necessary for their vital activity, the various juices would then danger of becoming inactivated or inactive. Then, it is a safe-guard against mechanical irritation. In the skin, where friction or pressure act most constantly, the epidermis, if thick, is a means of protection and relief from shock. From the frequent injuries of certain parts of the integument, discomfort and injury would inevitably result, were it not that coincident with this a reparative and protecting process goes on by which the epidermis becomes so hypertrophied that the excessive irritation is less nocuous. This is particularly observed in the skin of the hands of the hammerman or boatman. Even the epidermis, thin as it is, allows of our handship objects with impunity or comfort; but in parts deprived of this, the mere contact of air arouses acute pain. While also from its thickness, pliability, the presence of fatty matter, the skin as a whole acts to a certain extent, especially in children, as a defence from the compact pressure of hard substances. From chemical irritants, likewise, if not too severe, its oil secretion somewhat protects the system; although the all-important fact of cutaneous sensibility certainly furnishes the economy with the best defence from external injury. Its very meagre absorbing power under ordinary normal conditions renders the handship of certain injurious substances to many people engaged in what would otherwise be most dangerous occupations, possible, comparatively harmless; may even arrest in every one many evil consequences which might result from the presence of injurious irritant atmospheres of any kind were the integument more permeable to the entrance of foreign substances. The danger of exposure to contagion must thus be materially lessened, although unfortunately not altogether removed; for the normally conditioned skin must undoubtedly act favourably as a barrier to the ready entrance of matter which, on account of the feebly permeable infectious nature of the healthy epidermis, added to the constantly operating tendency outwards of material
from the body, which greatly prevents & counterbalances the reverse process of absorption from without.

Besides possessing these conservative characters the human skin serves to bind down & unite the bodily structure into a compact & finished whole, furnishing a soft & smooth surface for pleasureable contact & imparting that agreeable form, colour, & outline which charm the aesthetic sense. It kindly conceals from view the underlying tissues, which would have been a perpetual discord to the eye, by throwing a veritable "veil of flesh" around them which, from its graceful flow of line & delicately varied flesh-tints & smoothness as of living marble, gives enjoyable satisfaction to the sight. I have been the im-

theatric delight of painters in all times. The contemplation of it inspired Shakespeare to the fine outburst of admiration in the word Utterly "what a piece of work is man! in form & moving how express & admirable! in action how like an angel! the beauty of the world! the paragon of animals!" It is only when this beautiful covering is diseased or injured or removed that we realize how hideous might have been the body's external aspect as Naaman the Syrian's skin, leathern with leprosy, was said when perfectly restored to be "like unto the flesh of a little child," expressive of its greatest contrast.

The extent, irrevocability, & value presented by the healthy skin in different persons & even the same person at different times, depends on the quality, amount, & oxygenation of the blood in the cutaneous capillaries, on the thickness & degree of translucency of the epidermis, on the quantity & kind of pigment especially in its deepest layer. The rosy hue of health, the blushing cheek, the pallor of fear, & anger, the sallow tints of the sun-burnt & weather-beaten traveller, are all due to the presence or absence of arterial blood in the cutaneous vascular planes, or to the development of pigmenatary matter in the Mal 

knightian cells. Different types of complexion are consequently thus met with, which have been considered by many as partly indica
of temperament and diathesis; and doubtless they do often furnish helpful hints in the treatment and prevention of disease.

While it acts as an investing envelope holding together and binding deeper structures, it nevertheless by its smoothness, elasticity, and lubrication, admits in all parts of the body of free and facile movement, of one portion over another, as well as of structures placed outwardly, such as muscle and tendon. By this means, also, it adapts itself almost without limit to the various changes in the dimension of subjacent parts, stretching without injury again the enlarged abdomen in pregnancy and in the second stage of labour, as well as in excessive obesity, ascites, ovarian dropsy, large tumours generally; or frequently returning almost unchanged to its ordinary condition on the removal of the disturbing cause.

The skin is pre-eminently a nervous structure, more abundantly supplied with nerve-tissue than any other organ. So completely is the surface furnished with nerves that the body may be said to be entirely invested with a sensory coat-of-mail, since a needle-point can nowhere be inserted without producing a more or less acute impression of pain. To provide for this enormous nerve-supply the posterior spinal nerve-roots are consequently found to be much larger than the anterior. Sensibility is thus a highly developed and important function of the skin. By means of this precious faculty valuable information is conveyed to our consciousness for our guidance and comfort, for we constantly depend upon it as the connecting link between us and the external world. By it we are enabled to feel the presence and contact of objects, to form a notion of the sensible properties of surrounding matter. Without it we would fail to feel the ground we tread upon, or the tools we handle in our bread-earning craft, or even the food we eat; we would be constantly liable to all kinds of serious injury from violence and accident. So that it is absolutely essential for the maintenance of our existence. By virtue of its
special arrangements in the papille, its tactile corpuscles, end-bulbs, or Pacinian bodies found in the subcutaneous tissue in the hands and other parts, it acts in the body as an organ of special sense, that of Tactile Sensation, which is strictly monopolised by it. The mucous membrane of the mouth and nose. But through these multiplied modifications of nerve-structure it conveys impressions which differ from mere touch. There are in addition, the specialised sensation of Temperature similarly limited to the same parts as that of Touch, the common sensation of Pain, all which appear to be distinct from each other or even generic. And the supposition is a plausible one that since there are several forms of nerve-ends in the Skin, each has its appointed kind of impression to convey, that along a special pathway in the nerve-centres — tactile, thermal, & pathetic. For when a warm body touches any cutaneous area, these are simultaneously produced, two distinct sensations, namely, the simple one of touch which would result although the object were cold, or neither cold nor hot; and also that of warmth, which often follows the impalpable impingement of merely heated air. And further, Weber proved by the simple experiment of placing the elbow in very cold water that a thermal impression results from the direct irritation of the end-organs by the sensory nerves of the Skin, while by the same irritation pain is referred to other end-organs of the same nerve, — in this case the limbic at the points of the fingers. He also found that difference of pressure is felt in a part by equal weights when they are of unequal temperature. Clinical observation, besides, seems to supply corroborative evidence of this differentiation. In certain abnormal nervous condition the tactile perception may be diminished or abolished, while thermal sensation is increased or intact, vice versa. Cleland, however, has stated his opinion that irritation from external stimuli, however, they may differ in character, proceed along the same nerve-fibres similarly, affecting their molecular arrangement, traversing the cord by the same route, but on reaching the Cerebral cells influences the consciousness in its own special way by bringing it into direct relation with the brain, a continuity of the impinged condition by the whole length of the nerve-fibre being established. The sensory nerves of all other parts of the body,
Excluding the organs of special sense, appears to be incapable of arousing any other sensation than that of pain in response to any unequal stimulus. It is in the skin alone that a variety of sensations is occasioned by different irritants, mechanical, chemical, thermal, pathological. Thus itching, tingling, creeping, tickling, smarting, shivering, burning sensations may all be recognized by the consciousness, and refer to particular parts of the surface affected. The irritation from intestinal worms is not felt in the bowel itself, but at the anus or in the rectum. However, when an ordinary stimulus becomes excessive, be it a very rough surface, or a strong chemical solution, or a very hot or very cold substance, the only feeling experienced is pain. And when the epidermis is abraded, the slightest contact or even mere exposure causes only pain. The epidermis is thus serviceable, by interfering non-sensitive matter, in blunting or modifying impressions, when much hypersensitive as in the blacksmith's finger, renders the skin of these parts relatively anaesthetic, useless in the practice of delicate manipulations. Nor are all parts of the integument equally sensitive. The detection of an impression is most delicate where the epidermis is thinnest, especially where the nervous end-organs are largest and most numerous. By Weber's illusory two-point test, with a space of 2 mm. between, can be recognized by the end-organs of the point of the finger, where they are especially developed, while on the back and outer aspect of the middle portion of the limb, a lesser distance than 0.5 mm. may produce an impression of only a single point. The sense perception is capable of great development and education; for the blind sometimes arrive at a marvellous keenness of cutaneous sensibility. The power of temperature perception seems to vary less, although Weber found it most acute in the eyelid, least in the trunk, especially in the middle line of the body. For the adequate and healthy action of the skin as a sense-organ, a plentiful supply of nerve apparatus and due circulation of healthy blood through the papillea, as well as normal sensory activity of the nervous system generally, are absolutely necessary. A state
(1) Quoted by Hermann, p. cit. 6459.

(2) "Evolution, Expression, Sensation", p. 111.
Either of anemia or hyperemia of the skin diminishes sensibility to tactile impressions; while anemia increases, the thermal sensibility; hyperemia diminishes it, which is natural and explicable by the fact that thermal sensation is comparative, not an absolutely constant thing; for what would be cold at one time will be felt as warm under different physiological conditions, as cold hands will feel lukewarm water hot, which to hot hands will have the impression of cold. Prolonged exposure to severe cold gradually produces cutaneous anesthesia, partly by acting directly on the nerve-endings, and partly by diminishing the amount of oxygenated blood in the superficial arteries; active exercise or friction, by increasing respiration, filling the skin with warm circulating blood most effectively restores sensibility. This action of intense cold is taken advantage of in medicine for producing local anesthesia & reducing pain: i.e., cooling evaporating liquids like ether, ammonium chloride, & the like, having been successfully applied for these ends. The thermal perception is a valuable means of saving the body from harm; for by it notification of a chill may be made, the evil of which may be timely guarded against by exercise or clothing or removing to a warmer atmosphere, when a feeling of comfort & well-being is at once experienced from the return of a free supply of warm blood to the investing sensitive covering of the body. Equally from the injurious effects of excessive heat & of corrosive irritants, the possession of this thermal sensibility provides a protection. Any degree of temperature between 10° and 47° C. can be appreciated as a normal sensation of warmth or cold, but beyond these extremes, pain is the only sensation recognized. The larger the area acted on, the stronger is the impression, as is proved by placing the finger of one hand & the whole of the other hand into the same basin of hot water. This is apparently from a multiplication of impressions when what may be called the field of thermal sensation, is common to all kinds of stimuli.

A sensory, as well as a sensory-motor reflex.
connection obtains between the Skin and internal parts and organs. Although
the mode of paths of this nervous process have not been clearly traced,
there is a faint idea that it cannot be doubted that such sympathetic
pathways exist. Mental emotion may create the consciousness of a creeping
feeling in the skin, just as it may fetch a blush to the cheeks; a prolonged
play of cold air on the back of the neck may be rapidly followed by pneumonia
which in its turn will produce herpes, or a burning may be succeeded by
diabetes; ovarian or uterine disorder is often seen to be associated with
acne, sebacea with pertubation. I have repeatedly observed urticaria alternate
with asthma; tickling the sole may end in convulsions; a
rush of cold water over the abdomen may arrest uterine hemorrhage; a
small slap on the back of a newly-born infant, or the application of cold to
the surface of an adult, will seize the respiratory act; while a warm bath or
cocainism may soothe intestinal spasm or gastralgia. Thus much is
known that it must be somehow due to the junction of fibers of the Sympa-
thetic Nerves with the Cerebro-Spinal Nerves. And it is further concluded
that in the Spinal Cord there must exist arrangements partaking of the
nature of independent ganglionic centres which receive impulses impelled
from to the Skin, which also receive and modify impressions passing between
the Surface and internal structures. (1) Dunontpalley. (2) Recent experiments
on Acupuncture, Mortimer Granville's Vibration process of treatment
might be said to prove this hypothesis. The former found that the local peripheral
irritation, of a hypodermic injection, simply of water relieved pain in a cor-
responding cutaneous area on the opposite side of the body. Brown-Segar.
(3) Thosigan discovered that a transmission from one side of the body to the
other of a local modification of temperature also occurs, the lowering of
temperature in one hand being reflected by a similar diminution in the opposite
hand. The beneficial action of Counter Irrigation may possibly re-
sult from a partial explanation by these observations, although some light
may be cast upon the nature of the effects produced by the local application of
cold and electricity.
The question of absorption by the skin has received much discussion and difference of opinion. Older writers such as Krause, Madden, Wilson, Carpenter regard the process as one of some importance and considerable activity; while later authors like Hermann, Foster, and Hurley, view it with comparative indifference as a thing of little physiological significance. The truth is, however, that the skin does absorb matters from without, but that the thickness of the horny epidermis or the cutaneous secretion with which it is more or less freely lubricated place a formidable obstacle to the process under ordinary conditions. Besides, in the healthy skin secretion movement outwards of fluid and vapour are continually going on to a greater or less extent, which must so far interfere with the passage inward of any substance. Thus in a warm bath above 95°F. when the circulation is active in the skin secretion is proceeding proportionally little if any fluid is found to be absorbed by the integument, but in a temperate bath of about 80°F. absorption does take place, as proved by having baths coloured with solutions of logwood or fenugreek or pistachio causing the colouring matter to appear in the urine. It is particularly when the circulation in the cutaneous vessels is feeble and the amount of blood small, then, therefore, the exhalant process is languid, that substances lying on the surface, especially if the surface is moist, find most favourable means of entrance. This is the condition of things mostly met with in moist malarious districts, and it is more than probable that it is by the skin that miasmatic poisons in such instances most frequently enter for the use of woollen clothing very greatly lessens the risk of poisoning. Substances in solution as morphia, iodine, potassium, lead, alkaline salts, etc. similarly become absorbed if a piece of air-proof oilcloth is placed over the part to check evaporation; as I have myself found; it is very doubtful whether any substances in solution can to any appreciable extent be introduced through the cuticle except on this principle.
1) Vidé D'Alton's "Physiology."
2) "Sur l'Analyse Thérapeutique Locale" - 1879.
The epithelial cells imbibe moisture, swell up, and gradually get filled with fluid till the epidermis at length may become converted into a whitish moist animal membrane through which moisture may take place. The washerwoman's hands show this dermic imbibition. This seems to be a necessary condition for absorption of solid substances in solution which do not act chemically on or dissolve the epidermis. Substances, which contain alcohol do get absorbed to a small extent when simply applied to the cuticle, for alcohol has a slightly extractive action on the squamous epithelium. This probably explains the action of the secretions of iodine, rhubarb, opium, belladonna, &c. When the alcoholic preparations of these drugs are placed on the free surface of the skin, McClellan of Aylesbury, it is well known, succeeded in causing vaccine vesicles without puncturing the skin at all, but simply by covering a little lymph with a coating of blood. Shipwrecked sailors are said also to have relieved their raging thirst by wrapping their bodies in their soaking shirts, in which case the osmotic action would probably be feasible. The contained blood in the vessels under the cuticle gives them a moist appearance which would favour sublimation; or possibly the water may have partly traversed the epidermis in a state of vapour. For the unaltered epidermis does allow the passage of vapours inward as well as outward, & Krause indeed considers that this is almost the only method of skin absorption. He considered it impossible for any liquids to penetrate the squamous epithelial covering in its liquid form, that is, if it did reach the vascular layer it must be through the perspiration and sweat pores. It was his opinion that the serous fluid of a blister disappeared as vapour escaping through the cuticle. If a piece of epidermis be fixed over a glass containing water, the water will very gradually disappear without the membrane exhibiting the least degree of dampness, which shows that water when in a state of vapour can successfully traverse the tissue. The efficiency of mercury, mercurial, carbonic acid, & other hot-air vapour baths is further evidence
of the possibility, if not the facility, of different vapourised substances invading the system through the skin. The more volatile substances as Chloroform, Ether, Turpentine, Carbonic Acid, Ammonia, Mustard, & perhaps Iodine, more readily make their way to the papillary layer of the corium, the fewer experiences less resistance in its passage between the cells or through the duct of the glandule. But even solid substances can be introduced through the natural epidermis by being mixed with an oily medium. By forcible pressure the solution, being in this manner pushed into the ducts or perhaps through the cells themselves, till they reach the capillary layer. Where the cuticle is thin, many active substances, as Mercury, Belladonna, Morphia, Iodine, &c., can be somewhat freely thus forced upon the circulation; pressing can in this way be fairly supplied with nourishment when sufficient cannot be taken by the ordinary channel.

It is clear, therefore, that absorption by the blood-vessels or lymphatics of the corium is altogether impossible until the epidermis has been removed, or in a measure dissolved, or in some way penetrated; & as we have seen, there is much difficulty normally attacking this, both from structural & vital causes. Hence, as a source of physiological pain to the healthy organism it must be admitted that the skin takes a very subordinate place. M. Paré's 4th came to the conclusion after a series of observations on newly-born infants, that is a bath of simple water found entrance only by the epidermis of the hands & feet, as these are the parts devoid of sebaceous secretion, but there is no doubt that when subjected for a sufficiently long period to its application, other parts can also absorb water. M. Felon 5th believes that all substances soluble in water can be taken up by the circulation through the skin, but that this action is too irregular for any important use; though solutions when alkaline, alkaline, or otherwise much more readily get absorbed on account of their solvent action on the sebaceous matter or epithelium. The oxygen of the air at least, & other gases, action, volatile, or finely-divided matter, do also gain access into the system through the epidermis, probably however only in very minute quantities.
reached the dermal vascular layer, substance are rapidly and freely taken up by the capillaries and beginning of lymphatic vessels, then carried off into the general blood-current. This is now utilized by physicians in the familiar therapeutic procedure of the hypodermic injection of drugs.

In close connection with this absorbent property of the skin is its action as a respiratory structure. There also most of the modern physiologists differ from their predecessors in attaching little importance to it, for the same reason that the thickness of the epidermis renders an interchange of gases between the blood-external surface a very feeble insignificant process. But that it does occur, that incessantly, is undeniable, and to this extent, however small, it works as a constant aid to the lungs. These organs and the skin are associated by a general typical resemblance in structure, by a common function of elimination and interchange. They act and react on each other through sensory reflex nervous stimulation. What respiration is required by plants is carried on secretly through the epidermis of their leaves; frogs can sustain life for some time after excision of their lungs by absorbing O and holding CO₂ through their integument. The human skin, however, possesses this faculty of breathing only in a very limited degree. If the body is enclosed in an air-proof bag, the air contained in it ultimately exhibits all the characters of truly respiring air, having lost all its O which has been replaced by CO₂ + H₂O. The average total amount of CO₂ thus removed by the skin in 24 hours is estimated by Schaarling as 10 grammes. *Dalton's estimate of 4 02 nearly approaches it; but it is often much less, though it may also be augmented by a rise of temperature and active muscular exertion, as well by the digestion of a generous diet, particularly if vegetable — whatever, in short, to increased pulmonary activity. The amount of O absorbed is supposed to be slightly less, so that the share of respiratory work falling to the skin is by no means small, the proportion of CO₂ exhaled to that by the lungs being about 15 30. Still, this apparently unimportant but continuous respiratory interchange must surely serve a useful purpose in the economy.
(1) Comptes Rendus, 1863.
(2) do.
especially in giving occasional help to overtaxed or debilitated lungs. It is probable that this amount of CO₂ is not only removed as such in its gaseous form directly through the epidermis & in solution in the sweat by the glandular ducts, but likewise partly in combination with various salts as carbonates; dissolved in the perspiration which may be decomposed on reaching the surface. Schönhase states that he has found more CO₂ in the06 moisture of the urine when the skin was defective in action. "It is a noteworthy fact also that in health the arterial blood of the cutaneous capillaries does not become venous in the skin, which indicates a constant supply of O₂ to the surface as well as an absence of tissue-change in the cuticle. It is only when there is an excess of CO₂ in the blood from any abnormal cause that the integument becomes of a livid or venous hue. Helv. throws out the suggestion that possibly in these cases of dark-blue skin in feeble persons exposed to cold in whom bright-red vermilion spots are occasionally seen, comparable in appearance to the impure spots, inflated lungs of newborn infants, the skin makes a special, but not partially successful effort at respiration. The not-infrequent occurrence of diaphoresis & cutaneous eruptions in the course of lung disease, sometimes alternating with cough & paroxysms of dyspnea as I have seen, reveals a certain functional reciprocity between lungs & skin, as does also the normal activity of the skin with the quickened respiration resulting from muscular exercise. And last, the familiar experiment instituted by Fourier, repeated by Breschet & Berquel, Bernard, Raschke-Luschke, in which the shaved skin of dog or rabbit was covered with a thin impermeable varnish, lends additional probability to the connection of the skin with respiration. In all, or even the chief, effects produced certain cannot be attributed to non-aeration of the blood in the cutaneous blood-vessels, yet the fact that the skin becomes gorged with venous blood, that dyspnea & convulsions supervene with fast-falling temperature, that the heart thumps are found to be full of dark blood, render the similarity to death by asphyxia very close. Moreover must be thrown on the lungs.
deprived entirely of aid by the skin; the mass of abnormal tissue products increasing in the body, the lungs and kidneys get overpowered and gradually cease work, while the enormous loss of heat by radiation from the exposed integument through the varnishing brings an end to the creature's sufferings in about an hour or a half. Farcy denies that this is death by asphyxia, as asserts that non-aeration of the blood through the skin is too insignificant to have any share in its production; and undoubtedly the rapid heat-loss from the surface, the double source of blood-poisoning in retained or re-absorbed matter which ought to find an outlet by the skin, precisely also some amount of pyretic internal metamorphosis of the tissues, are sufficient to explain the results. But that the complete loss of cutaneous respiration must have somewhere in developing aggravating these conditions, so pronouncedly dyspneic, worthy an actual loss of 0. Retention of CO₂ in the skin itself, or after evolution or thanation of the respiratory centre, or both, presents to my mind some degree of probability. Fournoult by leaving parts of the skin unvarnished, observed that these parts retained their natural colour; so that it would seem as if the varnish produced a local accumulation of CO₂ from a kind of stasis of the capillaries, cessation of oxidization, such as is sometimes produced by cold. Death may thus be regarded as resulting from a true CO₂ poisoning of the brain. Roy Brown, from some recent experiments, think they have shown that diminution of 0 increase of CO₂ in the skin causes dilatation, congestion, stasis of the cutaneous capillaries by a purely local influence on their walls; it is just possible that even the small amount of 0 excluded by the varnish of CO₂ retained may be sufficient to initiate the engorgement of the skin which is a leading factor in the fatal result. Carpenter, in referring to this question, remarks, "the aeration of the blood through the skin is a function of no trifling account in man;" Wilson says, "the importance of this function in man is not sufficiently estimated."

However, it is a great compound secreting organ that the skin presents of highest interest; in this aspect no
(1) Wilton, "Healthy Skin", 1858.
(2) Hutley, ibid.
(3) "Diseases of the Skin" - Syd. Soc. Vol. 1, 1864.
phisiologist ignores its importance. When it is remembered how large a collective mass of glandular glomeruli it is which occupies the cutaneous tissue, and that an enormous volume of circulating blood the skin may at one time accommodate, there is little difficulty in believing that a vast amount of eliminative work is accomplished by this arrangement. Kirke considers that this, of all the functions of the skin, is the most necessary to maintain life. It provides an extensive area for the escape of a large quantity of superfluous water from the blood to the tissues, as well as of a comparatively small but really important amount of solid matter, organic and inorganic, being the waste products of tissue metabolism. It is indispensable for the continued existence of the healthy organism that a free outlet should be furnished for the continuous removal of these poisonous effete materials; although the body is provided with other widely active channels for this purpose, each having its own appointed quantity to eliminate with its own defined capacity of work, whenever however the equilibrium is seriously deranged, disease is the inevitable result. A certain limited degree of interdependence therefore obtains between all the secretory organs, between some more directly than others, which is natural, seeing they have all one common anatomical basis, are engaged in the common task of withdrawal of waste. Now the skin in a special manner is morphologically correlated to the kidney, to the sweat to the urine. Both structures are composed of a large tract of tubing, through which, by a combined secreting and filtering process, they permit between them by far the largest quantity of water in which are dissolved saline compounds of organic products, notably chlorides of sodium and urea. Both secretions normally are slightly acid in reaction, and to the taste. When re-absorbed or suppressed they produce analogous effects. And it is matter of common experience that in summer, when the skin is usually flushed with blood (Secreting actively, the urine is markedly diminished, in winter, just the reverse is observed. That on leaving a warm room after an evening party, the cold night air almost instantaneously checks the surface circulation.
the kidneys forthwith act vigorously. It is only within certain limits, however, that auxiliary or vicarious to each other. For if the kidneys be removed, the skin, with the help even of the other excretory organs, is totally unable to expel the fatal waste which ultimately kills, for if the skin is varnished, as we have seen, the kidneys fail to preserve life.

The elimination action of the skin is a mixed process, being partly a transudative escape through the epidermis in the form of invisible vapours of fluid containing volatile matter, and partly a true secretion by the epithelial cells of the sudoriferous gland tubules. The first is entirely physical in its nature, the natural consequence of physical laws and conditions, while the other is a purely vital phenomenon, and moreover regulated by the nervous system. It has been either impossible to define the respective parts which these two different methods take in producing the general result. It is observed that ordinarily, when the healthy body is not surrounded by any exceptional influence, in the absence of all disturbing conditions, elimination is unconscious, but continuously proceeding through the skin as invisible vapours containing various materials in a gaseous, volatile, or atomized form. This exhalation, or invisible perspiration as it has been called, may be easily demonstrated, has been frequently measured, for handling a cold smooth surface such as an writing-plate at once produces a skin dampness upon it, the careful and ingenious experiments of Sanctorius, Seguin, Valentin, and others, have enabled them to express, however approximately, its amount in figures. When the surrounding air is dry, only moderately warm, and especially if it is in motion, when atmospheric pressure is diminished, when body and mind are quiet, when the amount of fluid in the blood and tissues is not large so that the general blood-pressure is not at all raised from normal, there is usually no sensible moisture on the surface. Now, seeing that the skin, as Huxley says, is comparable to a moderately thick and permeable bladder filled with hot blood to a greater or less extent, there seem just precisely the conditions favourable for simple atramatic action, for exhalation of vaporous matter into the external atmosphere, and for active
evaporation. But this uninterrupted passage of vapour through the epidermis by the sweat-ducts is so slow and gradual that in these conditions the evaporation of the body is carried off at once as such, and not condense as watery sweat on the surface. It is therefore reasonable to suppose that in this steady, slowly insensible form of elimination, the physical exhalant action through the epidermis must take a not insignificant share; but that it should form more than $\frac{2}{3}$ of it as both Krause and Valentin calculate, seems to be highly improbable. These physiological investigators proceed on the assumption that only the mouth of the gland forms any part of the exhalant or evaporating surface, forgetting that the lengthened tubes themselves, being free to the atmosphere in some measure, must also act not only as filters but as evaporating surfaces as well. That such a large proportion of the fluid of the solid material daily secreted by the skin should be so separated through the dense epidermis, while so extensive an arrangement as the gland-tubes possessing no less favourable chances for carrying out vaporous exhalation & evaporation should effect so little, seems scarcely tenable. For it must be remembered that many persons may for weeks together, even months, never sensibly perspire. That the glands only act during emergencies or to meet special requirements, as Krause & Valentin assert, would render the epidermis necessarily still more vital in its powers of separation, an inference which I think is unanswerable. Further, if the epidermis alone permitted such abundant removal of material, it is strange that even with the aid of the lymphatics the fluid of a blister should not sooner disappear; one would expect that at least some impression would be made on the amount of fluid in cases of general edema by this extensive operation of epidermic exhalation. We must, therefore, come to the conclusion, as indeed Foster very judiciously does, that the perspiratory glands are the principal channels of elimination, even when that is only insensible. Autonomic secretion is to be regarded, like all the other eliminating processes, as a vital function, aided & influenced no doubt, as the others are, by physical & mechanical conditions.
There is reason for believing that the sweat glands are constantly at work, as the conditions necessary for their secreting action are always present, namely, blood holding impurities which they are fitted to separate, vitally active cells in close relation to it, a certain amount of nervous influence, ducts for the removal of the separated material. And since the body is furnished with these glands in such prodigious numbers, there seems no more reason to suppose that they remain inactive until specially called upon than that the kidneys do so, although Hermann states that the main almost only difference between the sweat and the urine is that it is not, like the urine, constantly secreted. Krause & Valentin, or bestested, are also of opinion that they are only occasionally called into requisition. Carpenter, however, confidently asserts that even although the skin be wet the air full of moisture, even in hot baths, secretion still steadily goes on. The activity of the ceruminous gland of the external ear, whose secretion is only a modification of the sudoriparous, at least appears to be uninterrupted. However, it is probable that in the repletion or exhaustion following their over-stimulation, their activity may for a time be in abeyance, but in health this must be infrequent exceptional.

The demand upon them varies greatly, but it is probably never altogether absent. In ordinary circumstances the amount of the secretion is comparatively small and gradually formed and evaporated during its transit through the ducts or surfaces; or even if the quantity happens to be actively increased, the dryness of the favourable conditions of the external air may accomplish its evaporation at once on reaching the surface. In still, moist air, with a low barometer, or when the body is encased in water-proof garment, even a feeble secretion will manifest itself on the skin as moisture, the overcharged medium being unable to evaporate it sufficiently, we may easily imagine we are sweating rather profusely when only a relatively small amount of secretion may be going on, which, however, at once becomes converted recognisable on the surface. And this condition of things really does lessen the
Secretion action. But secretion is distinctly stimulated by a very hot atmosphere, which may even be perfectly dry, but the amount of secretion may be largely increased that even this dry hot air, even though it also may be in motion, may not succeed in vaporizing and carrying off the whole of it. Hence the skin perspires. This is quite a common experience in hot summer weather or in warm climates or heated rooms even when the body is at rest. Heat, in the form of warm baths or poultices, muscular exercise, copious draughts, especially of warm fluids, intoxicated use of certain kinds of food with condiments, alcohol, thick woollen clothing, mental or emotional excitement, as well as physical pain, not to speak of medicinal or poisonous substances, or certain diseased conditions, have each efficient power of stimulating the sensible fluid secretion, as well as mere heat of surrounding air; the increase may be to an enormous amount, particularly if there be a combination of several of these factors. Now, when all these causes of hyper-secretion are intently examined, it will be seen that they depend on three leading conditions. Firstly, increased blood-pressure, which may be brought about either by a large addition to the whole body of circulating fluid by the ingestion of foods especially liquids, or by an increase in the internal temperature as in the heat of the external medium, which augments the circulation in the cutaneous capillaries; Secondly, an accumulation in the blood of materials which have peculiar properties of exciting these glands to effect their secretion, which are either the waste compounds from tissue metabolism, or substances introduced directly into the system; Thirdly, the direct or indirect action of the nervous system alone.

It is certainly the fact that the most frequent phenomena which is associated with perspiration is a more or less flushed appearance of the skin from fullness of the superficial arterioles, accompanied by a sense of surface warmth. A brisk walk on a hot day supplies familiar and striking evidence of this. There is free circulation of an increased supply of oxygenated blood in the dilated capillaries surrounding the gland cells, while at the same time there is a short of congestion. The blood-pressure in the minute vessels is raised,
which furnishes at the same time material for mechanical stimulus to the activity of the secreting cells; for whenever the pressure is lowered, the secretion proportionately diminishes, whatever is found increasing the cutaneous blood pressure apparently produces sweating, unless indeed it be extreme. Cardiac stimulants such as hot air or bath, muscular activity, warm drinks, alcohol, ammonia, almost invariably induce cutaneous vascularity; far enough the glands at the same time are stimulated to more vigorous secretion. How far this process of secretion is the results of the increased heart-action, capillary blood-pressure, accelerated circulation bringing to bear a fuller stream of living warm blood on the vital gland-cells; how far it may be physical pressure seeking relief by filtration; or how far it may depend on stimulation by the motion of abundant warm fluid, of the fibrils of nerves in connection with these gland-cells, it is hard to determine, although probably all of them have an associated influence. But facts seem to point to the abundant presence of hot blood & the action of nerves as commonly the most potent factor in perspiration. It will be seen that in all those mentioned examples of stimulants, the increased circulation is produced or accompanied by a certain elevation of temperature of the tissue. The blood-current, either from heat induced from within or acting from without, so that increased production or presence or circulation of heat in the body, at once stimulating the heart's action & dilating the arterioles, combined with some special nervous excitation, must be regarded as the most usual & prominent factor of the cutaneous secretion. The application of cold water or air to the body-surface checks sensible secretion speedily; this is accompanied by a sense of chill or palpable condition of the skin, indicating a diminished supply of warm blood to the sensory layer of the integument & to the glands, from contracted arterioles & a disturbed condition of the nerve structures unfavourable to secretion. So, when the heart's action is foible, as in the weakly, underfed, or thin child, especially in cold weather, there is frequently found an anemic, dry, or cold surface. Prolonged cold slows the heart's action, paralyses cutaneous
circulation, diminishes surface sensation; it is then that perspiration is at its minimum. The ingestion of a large quantity of cold water, if the body is kept cold, both pass more readily by the kidneys; but even cold drinks taken when the body is warm in bed or in a warm room, elect rather to be secreted by the skin, perspiration may be protracted. The raised pressure in the vessels of the heat combined approach usually to be sufficient stimulus, but if necessary conditions, to the activity of the sweat glands in health. Then, however, the skin is in a state of compensatory hyperemia or partial stasis, the result is different. In the hot flushed skin of Scarlet Fever, Syphilis, Erythema, or other diseases we find, instead of the natural moisture accompanying an increased cutaneous blood-supply, either a dry, pungent condition of the surface, or possibly a physical exudation of fluid here there under the cuticle in the form of vesicles, like what occurs in a burn. So also we meet with that purple venous engorgement in cases of Cardiac obstruction or failure, where the skin may be cool, dry or only very faintly moist. An explanation of this anomaly may be found by supposing that there is too great bulk of blood in a more or less motionless state, overwhelmingaret the secreting cells or blocking the tubules, that it is charged with material which poisons both the gland-cells and their nervous supply, while also abnormal temperature may seek a similar parasitical influence. There is locally a want of tone & vitality in the vessel, probably from defective oxygenation & excess of CO₂, as well as an abnormal condition of the nerve-centres; whatever restores these by removing the morbid cause, brings the circulation & temperature nearer to normal, as cold baths in fever, iron in syphilis, & Digitalis in cardiac inadequacy, will have some chance also of reviving the glandular activity of the skin. The converse likewise occurs, as in the pale, cold, moist skin of Syphilis, or the morbid, the hot, flushed, & equally pale surface in Phthisis. Secrétion must in these cases depend solely on nervous change acting directly on the gland-cell, although the amount of blood in the arterioles is much diminished, yet find sufficient to effect secretion. But all these are purely
pathological & exceptional conditions, do not affectthe general truth that in the increased flow of warm blood through the dilated cutaneous capillaries, especially with the influence of heat co-operating, is the normal & never-failing stimulus to secretion of sweat.

Another condition speaking to perspiratory secretion exists in the constituent of the secreted fluids which are contained in the blood being brought within reach of the operations of the Gland-Cells. As is the case also with the Kidneys, the preponderating element of the secretion, as it is also of the blood itself, is Water, & the separation of this from the blood is greatly a process of filtration through the walls of the capillaries, being less or greater according to pressure within the vessels. But besides water, which itself apparently acts as a stimulus to true secretion, there are several substances which it holds in solution, or are mixed with it, which the metabolic changes in the tissues have ultimately transferred to the circulating blood, which it is absolutely necessary should be cast out. Here these effete product of the oxidation of the various tissues, nitrogenous compounds, carbo-hydrates, &c., organic salts, permitted to accumulate in the blood, the organism would surely sooner or later come to grief. On the activity of these Gland-cells, therefore, their special affinity for these particular substances depends the deliverance of the blood from their dangerous increase. During vigorous muscular exertion, for instance, the muscles by their augmented contraction & oxidation, rapidly generate heat, which add to the circulating blood an amount of CO₂ & nitrogenous waste materials, notably, ammonia, urea. This reaching the lungs, the respiration is quickened to relieve the blood-stream of the accumulated heat, CO₂ + H₂O, this exalted action in its turn increases the force & rapidity of the heart. It sends an accelerated fuller flow of still imperfectly purified & overheated blood to the skin, which demands of the perspiratory gland-cells the effective removal of their share of the waste, by sweating, &c.; & to the economy soon forcibly resort a refusal or failure. There is, in truth, a real besoin de transférer as a besoin de respirer; for whenever an over-supply of CO₂ in the blood induces the slightest approach to dyspnea, as can be demonstrated by holding the breath; or if we other nitrogenous waste compounds accumulate
so as to overload the Kidneys, the Skin glands at once receive the hint to act, and a certain amount of increase of sweating is the natural result; if this does not subside, the organism is in much the worse. It is unknown how these substances are attracted by the gland-cells, or to what extent they are chemically elaborated by them. Some must pass through in simple solution with the filtered water; but a considerable amount of it is separated and elaborated by chemical or vital means. The fat is certainly formed in the cells, even where there are no Sebaceous Glands, as in the palms; it also in the external ear. The presence of O in the blood seems, in normal conditions at least, to be necessary for the action of the cells; for continuous secretion does not take place unless a constant supply of oxygenated blood is furnished to the gland capillaries. And that heat is an invariable product of secretion favours the idea that oxidation has at least always something to do with cell-activity. 

But after all, the Nervous System is the master influence in the production of the Perspiration process. And yet it is only recently that this fact has been clearly established, though it had long before been inferred and recognized. Such a connection must exist, from the familiar effects of excessively mental or emotional conditions, increasing the appearance of sweat. For how otherwise could these purely nervous phenomena be accounted for? If a man is placed in a position of painful suspense, or his mind is strong to a high pitch of tension by some great fear or anxiety or responsibility, he has a moment of that nervous excitement or enthusiasm — the Skin is found to become moistened or even wet with perspiration. And on the other hand, sudden emotional shock, a state of mortal terror, or maniacal fury, where there is an excess of nervous action, is coincident with a dry unperspirable Skin. But that secretion of sweat is impossible without the aid of nervous action was only, within the last few years, experimentally demonstrated by Naurocki and Luchsinger, who finally proved that secreting nerve fibres are furnished to the glands. That special nerve-centres exist somewhere in the Cord or Medulla, for the
(1) Celsus says, liber I, cap. ii: "Ssecutatis autem plenamque finis
control of this function of the skin. In 1837 C. Bernard first distinctly demonstrated the existence of a controlling power in the Sympathetic Nerve over the vascular system, which indirectly involves also an influence on the production of perspiration. By dividing the Cervical Sympathetic, hyperemia, increased temperature, and perspiration were induced in the head and neck, while the contrary effects appeared after its stimulation. This Vaso-motor mechanism has been further elucidated by Czon, Ludnig, von Regold, and more recently by Dastre & Morat, whose investigations prove that these nerves contain both Vaso-constrictor and Vaso-dilator fibers, that the head-center or their nuclei, in the medulla, or that subordinate centers exist in the Cord or the course of the vessels themselves. This sympathtetic dilatation & constriction of the vessels, however, can act directly only on the circulation, merely supply favourable conditions for the action of the glands. Acting on the depressor nerves of the heart which are closely analogous to them & perform often a powerful & benign part, they modify the amount of blood-pressure in the arteries of the skin. But this, as Hermann points out, can only influence the transudation of fluid in the glands & the degree of concentration or dilution of the secretion, not the vital part of the secreting process. Vaso-motor dilatation unquestionably favors naturally accompanies secretion, but does not produce it except indirectly. Nicot, for example, in his observations on the Cervical Sympathetic, says that in paralysis of that nerve, after the lapse of some time the hyperemia disappears entirely, while the hyperemia & raised temperature remain. Lachmacher found that after the injection of adrenalin no sweating could be produced on the hind-paw of a cat by stimulating the Sciatic nerve, although all the necessary Vaso-motor phenomena were present. Nevertheless, numerous cases proved to be connected with paralysis of the Cervical Sympathetic, especially cases, recorded by Vernède, Osle, Ritgen, Elstein, & some others, clearly indicate that hyperemia & congestion go together with singular constancy, that irritation, but short of paralysis, of that nerve, is followed by constriction of the vessels,
Naurocki also states that reddening of the skin of the cat's paw always preceded the breaking out of perspiration on applying the faradise current to the Sciatic nerve.

That true, vital secretion of the glands is not dependent on the blood-supply of the capillaries brought about by neuro-motor influence, nor even upon the O carried thereby to the secreting cells, is evinced by various facts. It has been found by Bernard and Ludwig that other glands, such as the Salivary, can be made to secrete when their blood-supply is shortly intercepted, even when they are removed from the body; the analogy may therefore be fairly applied to the Sweat glands. The occurrence of Sweating in condition of the circulatory system which renders the Skin anemic in Syncope, Shock, whether mental or physical, for example, where the Skin is certainly pale, devoided of moisture; in Sweats of Pithicus and similar sweating diseases, of the Dying, of the weakly, anemic, or hysterical; on the other hand, the non-perspiring condition of the flushed skin in the eruptive fever, breaking out spontaneously into sweat as the fever attains its crisis, so markedly observed in Agra, these facts force us to look for some other factor in the perspiratory process than vascular changes. And this has been found in Special Nerve-fibres, probably running in the cutaneous branches of the Spinal Nerves to the Sweat glands. Netzelard has pointed out that Sweating is governed by both Sympathetic & Spinal Nerves; while the researches of Lacheza, Haurowitz, Valvian, Ostrovsky, & other workers, have plainly shown that the vital secretion of the Skin is under Special Nervous agency. Naurocki in an interesting paper describes his own Lacheza experiments on young cats, with the conclusions derivable from them. When either the abdominal sympathetic or the Sciatic nerve was stimulated by the induced current, the Skin of the hind-paw of that side showed perspiration, even when the Aorta was clamped or the Curval vessels tied; when the peripheral end of the divided Sciatic was stimulated, even after amputation of the limb, the results were the same. No-sweating, however, could be brought about after atropin


3. Centralblatt für die medicinischen Wissenschaften. 1878. No. 1-5. 2.

had been injected. When the Sciatic was divided, the central end irritated, sweat appeared on the other limbs but not on the injured side, the irritation apparently affecting the sweat-centres or centres, reflected to other parts. To establish the fact of a central nervous action on the secretion, the Sciatic nerve was divided. The cat, enclosed in a bag, was placed in a stove heated to 60° C, when it was found that the paw of the injured limb remained dry, while sweating in all the other paws was in full progress. Heat and cold, however, appeared to affect locally the activity of the glands themselves; for electric stimulation of the Sciatic of a cat placed in a moderate temperature of about 31° C produced a larger amount of secretion than when the animal was placed to a lower temperature; or the application of very cold water to the limb almost froze the secretion altogether. Another method of demonstrating central nervous agency was by producing a state of dyspnea in the animal, by anesthetizing aspiration, by which the "sweat of anguish", as Lachesis calls it, was brought on. Such is the condition found in the intermittent, in the asthmatic and phthisical. In a cat thus operated on, all the nerves were seen to be paralyzing except the one whose nerve had been divided, which remained quite dry. Lachesis also found that, after first "depriving it of the influence of the psyche," then anesthetizing the animal, the injury of the iliac into another, sweating resulted in the hind-paws, which indicated that it could only be through the Spinal Nerve Centres, most locally through the circulation on the terminal nerve-fibres or secreting cells, that the drug acted. In order to trace the course of the secretory nerve fibres, both Nosoko and Lachesis divided the Abdominal Sympathetic beyond its junction with the T2 to L2 Lumbosacral root, the Thoracic Sympathetic beyond its junction with the T2 dorsal root, or removed the Ganglion Stellatum, when they found that sweating could not be induced in the nerve-injured parts by placing the animal in sweat-producing conditions such as heat and dyspnea. They affirm, therefore, that the sweat-fibres for the hind-limbs arise from the Cord at the commencement of its Lumbosacral root, are dispersed in the Abdominal Sympathetic, finally distributed in the Sciatic nerve. So with the fore-limbs, they come from the cord about the L2-

(2) "Über Nervöse Hyperidrosis und Anhidrosis" - Jena, 1867.

(3) Centr. für die Med. Wiss. 1878 - Nov. 152. Also luebsinger in Pflüger's Archiv. XV. I and II.
dorsal vertebrae, are dispersed in the thoracic sympathetic & the ganglionic stellat:
curn, finally pass down in the median clavicular nerves. Valpioni, as the result
of his researches, considers that these fibres pass directly along the spinal roots to the
sensory-motor nerves, & that instead of containing any fibres derived from
the sympathetic, the latter act as inhibitory of sweat-secretion. Ott &
Woodfield have also thought that they have discovered in the corpora quadri-
gemina a special centre inhibiting the sweat-secretion; but these observa-
tions, as far as I know, have not been confirmed. Reaurooki, from ex-
periments in which he divided the cord at the upper part of the cervic:
region, thereby preventing sweating in the fore Thirsd and fourth parts, concludes, that a
common centre for sweat-secretion exists in the Medulla Oblongata; but
suchinger's more complete convincing methods seem clearly to prove that
at least an independent centre for the hind limbs resides in the upper lumbar
Cords.

From these researches, the following conclusions appear to be rationally established. There are special nerve fibres con-
cerned in the glandular secretion of sweat, which are probably distributed to act on the gland-cells. That they are contained both in the sympathetic
nervous system and sensory-motor nerves. That possibly a dominant centre of control
is placed in the Medulla Oblongata, but that most probably independent centres
exist in different portions of the Cord. That sweating can occur as a reflex
act, which may be demonstrated in ourselves by placing a very pungent substi-
tance in the mouth, or otherwise producing a sudden, unexpected painf ul impression.
When the face will readily perspire, that it is probable that heat, as well as pain,
may partly act in this reflex manner. That sweating is brought about by
means of the Central Nervous System, for heat & the accumulation of
CO₂ in the blood must act in that way. They, as well as pilocarpine have
a determinate in pneumonia & other febrile affections of the body, accompanied by diminishing sweat.
been shown to do so. A heat-favour the secretion, but will not alone reduce
it without the help of nerve action, & cold is distinctly unfavourable, though
within certain limits, nerve action can to some extent promote it.
That sweating occurs quite independently of blood supply, though increased vascularity usually accompanies it.

Different investigators have employed themselves in trying to define the amount of perspiration, both sensible and insensible; but their results, as might be anticipated, are variable and can only be regarded as approximations to the truth. Precise observations cannot possibly be made, for there is not only much variation in the normal amount secreted, depending on many conditions, but great difficulty attends the collection of accurate measurement of the secretion. Sanctorius[1] was perhaps among the first who gave himself to this investigation; as the result of 30 years' daily observations, he came to the conclusion that out of every 8 lbs. of food and drink daily taken into the body, 6 lbs. were eliminated by the skin, lungs, and other 2 lbs. by the bowels. Kidneys. Valentin's[2] result are different, though carried out with apparent care and precision. He took in 24 hours 9.48 lbs. of fluid and solid food, 2.2 lbs. were eliminated by the skin, lungs: 4.6 lbs. by the kidneys: 2.6 lbs. by the bowels. His estimate of the ordinary daily amount of skin elimination is about 1½ lbs. Seguin[3], who carefully collected the materials eliminated through the skin by excluding his entire body in a bag of water-proof muslin, calculates the average daily amount of loss by the skin to be 33 lbs. But changes in the amount secreted may be considerable; that Pindel, after excluding his arm in a cast-iron covering, could influence the secretion that he reckoned the whole amount for the body may be as low as 2 kilos. or as much as 20 kilos. or nearly 40 lbs. in the 24 hours. Jacot also states that sweat may be secreted to the extent of 1600 grams, or 3 lbs. in an hour. To observe and measure the variations in the secretion at different times and under different conditions, Valentin found that when at rest the hourly elimination from the skin weighed 32.8 grams or about 183

When he took exercise in the sun, fasting, the amount of loss per hour rose to 87.3 grams, or nearly 3 lbs.; that when he engaged in vigorous exercise after a meal, in a temperature of 72° F., he lost in an hour 132.7 grams, or about 1½ lbs.
(2) Gerhardt, op. cit.
by perspiration. Southwood Smith, in the course of his investigations into this
point, observed that among the furnacemen at the London Gas-Works, a loss
equal to 5-10 lb. an hour very commonly occurred more than once a day. On the
other hand, it is not an uncommon experience to find little or no visible perspira-
tion whatever on the skin even during a lengthened period. But even in this
case, the lowest quantity of cutaneous discharge by evaporation or inhalation
found by Seguin would probably be reached, namely, 20 oz. in 24 hours. These
extremely large amounts are of course exceptional; but they indicate the
enormous capabilities which the skin possesses for eliminating waste material
by its glandular activity. In comparison with the lungs, the loss in weight
to the body by cutaneous secretion is nearly three times as great, according to
Seguin; and the escape of watery vapour from the skin is generally stated to be
about double of that from the lungs. And it is certain that not infrequently,
even in health, the combined elimination from skin and lungs exceeds the com-
tribution intestinal and renal secretions. Usually, however, the kidneys re-
scribe more than double the quantity both of water and of solids waste which is
accomplished cutaneously. The activity of other secretory organs modifies
the amount of cutaneous loss: as well as differences of constitution, habit,
climate, season, surrounding temperature, muscular activity, mental
states, or other conditions formerly referred to.

The sweat, when it can be collected comparatively pure, is found to be a clear, colourless fluid like water, possessing no
structure, but usually containing minute flakes: which are composed of
epidermic cells, sebaceous substance. I have generally found in it,
in microscopical examination, some finely granular fatty matter, one or
two crystals, a few more or less disintegrated squamous epithelial cells,
sometimes bacteria. I have always found it salt to the taste. This
reaction I have also invariably found, even when freshly secreted or just after
a warm bath, to be distinctly acid to litmus paper. In these respects it is
similar to the urine, the alkaline preponderating element, chloride of sodium,
(1) Combe's "Physiology applied to Health" p. 29.


(3) Strader de Chemin X. C. p. 80

(4) Vide Foster & Herman, Op. Cit.
giving it the saline taste, while nevertheless its chemical reaction is
acid, from the presence of free acid or acid salts. Foster says that fresh
sweat, "is alkaline;" but I am not aware that there is any proof of this.
It may, indeed, be alkaline while undergoing decomposition of its albuminous
ingredient, which is very readily done, when ammonia is then present;
but when alkaline when alkaline is largely deflated, neutralizes proper acidified;
but, though the absolutely pure fluid can hardly be obtained, there is ground
for concluding that it is normally acid. Various methods have been adopt-
ed with varying success of collecting the secreted sweat as pure as possible
for examination, such as subcutaneous the body, placed on an inclined or propped
metal bed, to a vapour bath; inclining the body, or part of it, in air-tight or
water-proof bags connected with receivers; Amelung placed his arm in a glass
vessel, then with some sort out a piece of clean flannel soaked with
sweat in distilled water. The analyses of Grosp-Rosanes 4 of Faver
agree in the classification of its contents as follows:—(1) Water, 99.56. (2) Three
other Nitrogenous waste products, 1.92. (3) Inorganic Salts, consisting mainly
of chloride of sodium, potassium, earthy phosphates, sulphates, carbonate;
oxide of iron, 2.5. (4) Neutral fat, cholesterol, some volatile fatty acids
as acetic, butyric, formic, and other, 0.01.
The proportion of solid matter here given is lower than what is frequently estimated; for Foster states it as
1.81 per cent, 3 of which is organic matter, Carpenter observes that at
the very least 100 grains of nitrogenous material are eliminated daily by the skin.
It is now generally accepted as a fact that urea forms a minute but constant
constituent of normal perspiration; Turville affirms, as the result of his
method of experiment, that as much as 10 grains in the 24 hours may be
thus eliminated, which, however, must be quite exceptional, only the result
of occasional very effective sweating. It is increased after a very albuminous
sweat diet, in warm climates, and abundant in some diseases, notably cholera
and leucemic states, that after food-rich in albumen, the supamental Nitrogen
is passed off in the sweat; this may probably be in the form of urea or from
its decomposition. Faver makes no mention of an acid containing N, occurring
he also obtained lactic acid as well. Normally, which he calls, "hydrosic acid," pure N\(_2\) as such, does not seem to be normally given off by the skin; but it appears that in varnished animals, from portions of the surface which are left uncovered, a volatile alkali, which is probably N\(_2\)H, can be detected, while under the skin of the varnished portions, fumes and fumes occur in which crystals of the phosphate of magnesium, &c., &c., can be obtained. This is supposed to constitute the excrementitious substance known as the "hydroscopic carbonate," the accumulation of which in the blood partly gives rise to the symptoms. Langle is of opinion that it may be seen, that the N\(_2\)H is the result of its decomposition. Amid, in common with many other substances, is removed by the skin unchanged when introduced into the system.

In young persons during an attack, uric acid is frequently found in the sweat, Vignard, by applying solutions of N\(_2\)H to the enlarged joints has obtained large quantities of water; the acid sweat of rheumatism is, it is believed, largely impregnated with lactic acid; urates sometimes appear in the perspiration of gouty patients, while sugars in diabetes & bile in jaundice, are occasionally secreted by the skin. And in somewhat rare cases, blood has been seen to be mingled with the sweat; other matters, probably volatile, having a fecal odor, have been known to escape cutaneously in cases of long-standing constipation & intestinal distension. The fatty matter & cholesterol found normally in sweat is to a large extent to be accounted for by admixture of sebaceous secretion with it; but not altogether, as, quite independently, much of sebaceous fluid, which are absent from the palms & the soles, the sweat of these parts contains fat & fatty acids. And not only so, but the sebaceous cells, have been seen to be filled with fat-ferries, that in proportion to the quantity of fat & fatty acids, discovered to be present in the sebaceous fluid. And it is probable that the is capable of being greatly stimulated; to this action of the skin are probably due in some part the reducing effects, so long popular among very stout persons, which are said to be produced by long-continued or copious diaphoresis. For there seems to be a pretty constant ratio maintained
And according to Flüger's law that acids check acid secretion, when applied to the mouths of their gland ducts, the effect of sponging the skin with dilute sulphuric & acetic acids in preventing the sweat & phosphatic, should favour the probability that sweat is really an acid secretion.
between the water solution of the sweat, the greater the amount of secretion, there is commonly a proportionately increased amount of solid waste removed with it. If this is so, it follows that the skin presents a splendid field for therapeutic measures which have for their intent the withdrawal of morbid or toxic elements in the organism. And the hydrotherapy method of treatment, if wisely employed, offers to the physician most powerful means not only of rationally affecting the nervous centres through an extensive sensitive area, but of relieving the oppressed tissues of a vast amount of waste morbid material.

In close connection with the sweat-secretion, and partly dependent on it, is the other great function of the skin, that of regulation of body temperature, which must now as briefly as possible be considered. It is a familiar fact, but one sufficiently remarkable to strike every reflective mind, that men, whether residing in the tropics or wandering among the Arctic ices, whether passing their toiling lives under the glare of furnaces, or compelled to spend their days and nights passing from home to home, enduring now the scorching sun, and then the bitterness of winter storms, nevertheless, under all these diverse conditions, show scarcely any appreciable change of their body-temperature. This is a vital characteristic which man possesses in common with all mammals, birds, which are therefore termed warm-blooded, or rather, home-thermous, their blood being of even temperature under almost every variety of circumstance. Heat is generated in plants by oxidation and decomposition in their tissues; but it is so small in amount and so lightly that it is easily given out by transpiration and radiating. By radiation alone plants at night become even cooler than the air above them, and hence death is formed upon them. Very similarly all animals except the mammals and birds produce so little heat that it is easily given out by transpiration and radiating. By radiation alone plants at night become even cooler than the air above them, and hence death is formed upon them. Very similarly all animals except the mammals and birds produce so little heat that it is easily given out by transpiration and radiating. By radiation alone plants at night become even cooler than the air above them, and hence death is formed upon them.

(2) Hermann, Op. Cit. p. 120.
contact with a medium whose temperature is variable, commonly between 30-400 degrees lower than blood-heat. Heat is therefore incessantly formed in every part of tissue, with the exception of the epithelial, more or less actively, according to the amount of tissue metabolism, the heat being, as constantly transformed, like the other products of tissue oxidation, to the circulating blood, is distributed equally throughout the organism, thereby fulfilling a necessary of vital activity, or the maintenance of life. But it is also a necessary condition that this constantly generated heat shall be prevented from accumulating in the body under any circumstances, with the other tissue products being continually eliminated as heat, so that the temperature of the blood may not pass a point which would endanger existence; for it is absolutely necessary for the continuation of all the vital processes that the mean temperature be scarcely departed from. This indispensable dissipation of superficial heat, by inhibition both of abnormal rise or fall of temperature, by increasing or diminishing the heat-loss of the body, are effectively accomplished principally by the skin. Ordinarily just so much heat is generated in the tissues as can be perfectly removed by the cutaneous surface through secretory channels. But so fine an adjustment as this of opposing forces, so sensitive a balance between heat-production and loss, which maintains a rigid constancy of temperature under very wide extremes of condition, has led to the search for discovery of proof of the existence in the Central Nervous System of a distinct thermostatic mechanism. By an arrangement of special nerves overproduction of heat is inhibited when heat-loss is diminished, hence a high temperature prevented, while the skin at the same time is encouraged to exercise its eliminating function; and on the other hand, heat is more actively generated when withdrawal of heat from the surface is increased, while the conditions of the skin favouring heat-loss are at the same time reduced to the minimum. This knowledge is a distinct and valuable scientific advance, explaining much as to the physiological maintenance of fluctuations of normal temperature, while pointing the way to unravelling the mysteries of hypothermia.
Harnessing the most advantageous therapeutic procedure.

The internal organs, especially the muscular and glandular structures, are the great producers of heat, and, doubtless, heat with some of it to the cooler regions on the surface by more conduction or convection. The skin is the coolest tissue of the body, naturally, from its situation, but also partly because its extensive epidermic layer with hair, cooler, retains heat apparently, for oxidation has not been found to take place in them. But the circulating blood, warmed in the active heat-producing interior, finding its way uniformly to all the cooler superficial tissues to which it gives up much of its heat, returning its cooled stream back to the hotter parts, materially assist in equalizing the general temperature and maintaining it at the normal mean of blood-heat. This is evidenced by the fact that the venous blood derived from the skin is, unlike all other venous blood, cooler than the arterial. The skin, by its extensive area with vascularity, is surrounded as it is by a medium whose temperature is usually many degrees below that of the blood circulating through it, of the tissues of the body generally, constituting the main regulator of body-heat. And this it does by chiefly affecting the heat-loss, of the whole of which it can ordinarily account, according to Helmholtz, for 77% per cent. Heat is being constantly lost from the surface by simple radiation. It is likewise abstracted by conduction to colder objects in contact with the skin, commonly clothes or the surrounding air. The colder the air, the more it is in motion, the greater is the quantity of heat conducted off from the surface, as is painfully felt in a strong blowing East wind. Besides, the different secretions thrown out of the body withdraw some amount of heat, but much the largest share is removed by the sweat. And the evaporation of this secretion, continually going on to some extent, occasionally, in very serious measure, affects the greatest heat-loss of all. These physical causes of loss are always in operation, more or less, and may be such a degree as to endanger life, were not some vital action to come into play to save the organism. The heat-generation of the skin supplies a guide to us, informing
us of danger on the one hand from too great a loss of heat, when recourse may be had to thick clothing or a warmer air or muscular work; on the other, from too large an accumulation of it taking place in the blood, when thin clothing is also good heat-conductors, or cool air, or cold water, may be resorted to for the purpose of increasing surface loss. The tingling sense of warmth felt in the skin after muscular exercise tells us of the cutaneous vessels being dilated by a hot circulatory fluid, this of itself assumes us of an active cooling going on to cope with the felt increment of body-heat from increased muscular contraction and consequent oxidation. A compensating process is always at hand to preserve the wondrous balance of temperature; then, as in the beginning of fever, we experience a sense of severe cold in the skin which makes us shiver, while at the same time we are other wise conscious of a febrile heat, we know that this compensating power is in abeyance that we are in a state of disease. This powerful tonic contraction of the surface vessels from irritation of the vaso-motor centres as it appears to be, while body-temperature is rapidly rising, is an anomaly, not the rigor of sensation of cold in such circumstances, announces to us that it is so, treat once set about to rectify the abnormal process. Other means possessed by the body for so regulating heat-loss as to preserve the normal standard of temperature, are the changes brought about in the state of the circulation, especially by heat of cold. Increased production of heat in the tissues, ingestion of warm fluids, or high external temperature, stimulates the vaso-motor centres which excites the activity of the heart and dilates the blood vessels, thus send the blood in fuller quicker current through the arterioles and the skin. A vast sheet of hot blood occupies the cool and cooling area, for the heat as well as dilates the surface capillaries; when necessity demands, the skin may thus relieve the organism of a very large increment of heat by radiation and conduction. The flow of blood through the internal heat-producing areas is materially lessened, the volume of cooled fluid returning to them abstracts largely from their accumulating
heat, and helps to keep the temperature normal. In the healthy body, the integument, under the presiding control presumably of a nervous thermo-regulating centre, knows how far to go on with its heat-dissipating work. When the contrary necessity arises, when there is a diminished oxidative activity of the tissues, or a low surrounding temperature, the opposite conditions are found. The skin shrinks, or becomes pale, cold, the blood returns from the contracted surface capillaries to the heat-producing interior, and heat is thus conserved. In the case of the vanishing rabbit, paralysis of the superficial vessels allows a large accumulation of blood in them, and consequent rapid loss of its heat by conduction through the gelatious coating; while the poisoned condition of the tissues, in some way affecting the thermotactic nerve-centres prevents a sufficiently counterbalancing production of heat in the interior which could rapidly, if the animal died, like all homothermal animals which die from low temperature, with symptoms of asphyxia. Burdon-Sanderson concludes that there is hence an increased production of heat because there is an increased discharge of it; but it scarcely follows, for swallowing the animal in wood, or placing it in warm air does not prevent, though it retards, the fall of temperature. And besides, Seguier & Breschet found in the muscles a deeper part, from the very beginning, a steady and rapid fall of temperature till death. Whenever, therefore, from the demands of elevated temperature, the vaso-motor nerves, acting as I believe concentrically with a thermotactic mechanism, raise the general blood-pressure, increase the action of the heart, dilate the cutaneous arterioles, or in any way cause a greater quantity of blood to pass through any portion of the skin in a given time, that portion of the skin becomes redder and hotter, or thereby gives off a proportionately large amount of heat: twice over.

But besides this mode of operation of the vaso-motor thermotactic only the sweat-secretory nerves may be brought into action for further regulating the body-heat by loss; and indeed secretion and evaporation are often the most powerful of all these contrivances. As before, the ordinary phenomena...
...active muscular exertion supply a convenient physiological illustration for us: we find that the increased number of muscular contractions results in an active over-production of heat for the time, which has to be eliminated if the vital processes are to continue; that for this end the respiration and circulation are quickened; the blood vessels of the skin become full of blood (being also diluted by the temporarily augmented heat) which loses heat considerably by conduction. And if this does not suffice to remove the excessively evolved heat, a feeling of discomfort is experienced in the skin till the sweat-glands are stimulated to more active secretion. The irritation by the warm blood circulating in the dilated vessels around them, or by the secretory nerve-fibres, if not the sweat-centres as well. And hence sweat is poured out on the skin, which also carries away with it an additional amount of heat, further cooling the surface by simple contact. But this secreted fluid is more or less rapidly converted into vapour; the more rapidly it is so, the greater is the quantity of heat abstracted from the body in a given time, the heat used up in the process of evaporation becoming latent. Thus, after even continued violent exertion, however great may be the production of heat, it is fully met by a corresponding sweat-loss, the normal temperature is not in the least disturbed. But if, after prolonged severe exertion, when the nerve-centres of the heart are greatly exhausted or when heat is being steadily lost by sweat-evaporation, a sudden chill is received, such as by sitting on the damp and cold ground, or by drinking a copious draught of cold water, this added withdrawal of heat may depri...
to or even above blood-heat, the only means which the economy possesses within itself for maintaining its mean standard of body-heat is vaporization, by the skin, aided to a small extent by the other secretory organs, or by a diminished heat-production. And even this sometimes proves incompetent to remove the necessary quantity of the accumulated heat which overpowers the nervous centres, heat-shock or heat-stroke the result. But even in exceptional extraordinary high temperatures, such as the enormous amount of heat which cutaneous evaporation is capable of using up, by withdrawing from the organism, the body-temperature may still be preserved at or little above the normal point. The well-known case of Chalffin the "Fire-King," who in the last century in London exhibited himself in a chamber heated up to 600° F., who by drinking copiously of cold water, maintaining freely, vaporization in the dry heated air being rapidly effected, was able to remain in it two hours for some time, has an almost apocryphal flavour about it. The furnace men employed by Chantrey the Sculptor were sometimes exposed to a heat of 350° F. In these cases the enormous external heat must be expended in effecting evaporation which, to preserve life, must therefore be rapid; and when we consider the large quantity of heat necessary to evaporate to dryness a kettle full of water, these results do not appear so incredible. Lewis professes himself totally unable to explain the startling difference between the body-heat and the external temperature in these cases; I consider there must be some other factor than evaporation alone; but he does not apparently also appreciate the large mass of heat required for vaporizing liquids. The Besides overlooks the fact that in such conditions heat-production in the body must be extremely diminished, for he says it proceeds at the normal rate all the time. With warm surroundings heat is not only lost by evaporation, but generation of heat is diminished; the reverse is the case in low temperatures. The effect of cold weather is to stimulate the thermogenic centres by which the accentuation of the heat-producing processes is increased, at the same time the loss of heat from the skin is lessened by the contracted condition of its blood-vessels.
The complete absence of sensible perspiration: the heat is shut in, to some extent. Heat is co-quickly lost by conduction in frosty air, that even vigorous physical effort, while it may maintain the body warm, may hardly induce perspiration; for the heat-production may be just sufficient to replace the loss. The continuous complete evaporation of even insensible perspiration gives a cold, dry heat-wind its peculiar biting character; for it is not only chilling from its mere coldness, by its depleting the quick evaporation from the surface abstracts more heat and more rapidly than the heat-production is able with sufficient promptitude to supply. The cutaneous circulation being reduced to a minimum, the sense of surface warmth is for the time being almost lost. With rain, when the skin is moistened, it is absorbed to the face, evaporation resulting of course as. A moist heat-wind, on the contrary, is felt to be mild or warm, because the heat withdrawing process of evaporation is partially stayed. In moist air, a temperature more little raised above blood-heat soon proves fatal from the absence of the cooling action of evaporation. This was proved by the experiments of Delaerehe. In sultry, damp day, or a climate which is hot and moist, it seemed to be unequaled by coldly warm. And it is this that constitutes the danger to some persons of a Turkish bath, especially if their skin perspires with difficulty, or if their heart-blood-vessels are unequal to a considerable strain of tension. The mechanism of perspiration, then, provided there exist conditions favourable to effective evaporation, operates as a potent preserver of the balance of temperature where that is in danger of rising too great an elevation from whatever cause, be it increased production from tissue-oxidation through muscular work, mental emotion, or some abnormal state; or be it diminished loss from external heat, by dissipating just enough of the superfluous heat from the surface as to maintain the general body-temperature at its uniform level. Actually, happily, describes it, the blood is comparable to water distributed through many stems of hot-water pipes which can be cooled at pleasure by having damp cloths laid over them. And equally, when the temperature runs the risk of falling too low from an excessive withdrawal of heat by external cold, or from a feeble functional activity of the tissues, as during rest, or in state of starvation.
"Physiology of Common Life".
...cellulatation, the sweat mechanism ceases or greatly lowers its action, thus saving the organism from much loss by evaporation. This I believe is brought about by the stimulation of the thermoregulatory nerves of the skin, conveyed to a thermoregulatory nerve-centre which co-operates with the vasomotor system of nerves. For in winter we produce more heat & preserve it by loss less by evaporation & almost none by visible sweat, while loss by radiation & conduction are greatly retarded by the blanched integument; in summer we part with much heat by evaporation, sweat, & the congested skin, while we produce as little as is compatible with the performance of necessary vital processes. And yet all the time the temperature of the body practically remains at the invariant point of about 98.6°. The conclusion that this is the result of constant nervous control, unconscious & involuntary, seems inescapable.

The influence of the skin in regulating the body-temperature through heat-production is not so apparent nor so direct; but it is nevertheless real & of great importance. Placed as we are, in the temperate climate at least, in a medium usually many degrees below blood-heat, it is clear that a loss of heat from the surface, even when clothed, is constantly going on, & that it is indispensable for securing a fixed degree of bodily temperature so essential to life, that heat beast constantly generated to supply the loss. But since also we are continually exposing ourselves to temperatures of widely ranging degree, it is equally clear that the heat-production must be under incessant regulation so as just to meet the changing demands of heat-loss, no more. That this wonderful balance is held by the nervous system is now pretty fully established & generally recognised; there are reasons for believing that for the performance of this essential function, there exist special thermogenic & thermo-inhibitory nerve-centres & nerve fibres. The influence exerted by the skin on the production of heat is chiefly exemplified in the effects of cold, which, either in the form of cold air or cold-water directly applied to it, undoubtedly favours the development of heat in the body; that is, the loss of heat by the skin arouses the internal
This rise of temperature I have found repeatedly in myself to be very slight, not more than to a degree, and very temporary. I have once or twice conferred myself in a cold bedroom, naked, for 10 minutes, at 4 o'clock on a spring morning with East wind prevailing. Intense shivering and teeth chattering came on in a few minutes, but became somewhat less latterly. I roughly estimated the amount of CO₂ inspired by breathing into equal quantities of lime water, when certainly their appeared a greater milkyness during than before the experiment.

heat-producing processes to increased activity. The organism is thereby urged to a spontaneous act of self-preservation. Under the stimulation of this thermic impression conveyed from the sensitive cutaneous surface, the thermogenic centre is prompted to send an impulse along its calorific fibres to the muscular and glandular tissues which are the predominant producers of heat, exciting in them increased action and therefore increased tissue-oxidation formation of heat. It is a reflex nervous process. Tissue-oxidation is synonymous or co-extensive with heat-production, with degree finds pretty accurate expression in the amount of CO₂ therea eliminated.

Various investigators have repeatedly found that the application of cold to the surface of man or of homothermal animals in health invariably causes their temperature to rise, and augments the quantity of CO₂ secreted and O consumed. Senato[9] denies that there is anything more in this than the driving-in of the blood to the internal or protected parts of the body by the contraction of superficial vessels, while they state that increased heat-production accompanies an increase of secretion of CO₂ by no means regularly occurs. Liebmeister[10] and many more, however, insist that there is more than this; their numerous experiments certainly appear to substantiate their opinion. They found that the distinction between cold-blooded and warm-blooded animals consists in this, that tissue-oxidation increases with heat they become warmer, and diminishes with cold they become colder; while the reverse obtains in the latter as regards tissue-metabolism, their temperature remains always the same, or practically so. That this maintenance of an even temperature by the warm-blooded animal, despite an active loss, is the result of an increased production of heat within itself by means of nervous influence, was shown experimentally by Aflüger[11]. By abolishing the action of the nervous centres, or cutting off communication between them and the tissue by curarisation, section of the medulla, or other means, he found that these warm-blooded animals became affected in an exactly similar way as a cold-blooded frog or ottrums to heat or cold. Tissue-metabolism was markedly
decreased by cold, as evidenced by the lessened secretion of CO₂, while the temperature fell steadily. [Rohrig & Luntz] by wrapping uraemic poisoned rabbits in wet cloth after a cold bath, found the temperature continued to fall, proving that this resulted from the diminution of heat production, and not from increased loss of heat. And the same thing I have myself at least once observed in hyperpyrexia treated with cold bath, several others are recorded. And that this increment of heat from the stimulus of cold at the surface in some way originates largely in the muscular tissue through the operation of thermogenic nervous impulses directed to it is rendered probable by the investigations of Samuel. He found that healthy rabbits, when subjected to even severe cold, showed very little alteration of temperature; but that by ligaturing the main arteries of the limbs or dividing the motor nerve trunks, the temperature rapidly became as low as they died. The same inference may be drawn from the instance of uraemic poisoned animals, tales from clinical cases of motor paralysis; the function of the muscular nerve fibres being suspended, muscle meta- 

at once a consequent generation of heat in them fails to be effected when the cold is applied. The intense shivering, teeth chattering, and cholic movements observed when naked in cold air, or when cold water is applied. Colasanti: When experimenting on guinea-pigs, they found that they constantly eliminated a remarkably increased amount of CO₂ under the influence of cold; but he also observed the important fact that when pyrexia was produced in them, these results did not follow, a diminution rather than increase of heat production occurred. And pyrexia certainly affects the nervous centres; while the wasting and infectible condition of the muscular system after severe fever points to the probability of its being specially concerned in the febrile process. The muscular pains present at the commencement of many febrile conditions may possibly be similarly accounted for. It is possible that in pyrexia the thermo-inhibitory centre is paralyzed, that cold by withdrawing a certain amount of heat may proportionately restore it to functional activity, or as diminished thermogenic action. At all events, the thermogenic process in fever does not respond to the stimulus of cold in the normal way. Indeed, there are various features

(2) Archiv X, 1878.
of the febrile state process which strongly suggest not only a defect or heat loss but a persistent increase of heat production, carried out by virtue of some nervous mechanism temporarily deranged. The ordinary mode of catching cold points to nervous cutaneous impressions acting in abnormal nervous states; for usually only when the general health is deteriorated is the vitality of the nervous system centric reflected, when the surface chill from a prolonged spell of cold-air induces, as it is almost certain to do, a febrile process. Here the contraction of the cutaneous vessels and the irritation of thermic nerves by the chill not only shuts off heat, but seems to be followed by an excess of natural energy of the thermogenic nerves which overdo their work, the inhibitory centre being for the time overpowered; an over-production of heat unchecked, along with diminished loss, thence results in fever. And the welcome way in which many fevers critically & spontaneously change from the dry, hot condition of skin to a pleasant evaporating steaming moisture, can hardly be caused otherwise than by nervous influence. In this event, an inhibitory mechanism would appear to have re-established its sway, heat-production becomes restricted, while the hit-and-miss paralysed sweat nerves glands come to the rescue. But it is different in other cases, showing that in certain febrile conditions at least, heat production is even a more essential part of the process than diminution loss. In rheumatic fever or pericarditis we may find profuse perspiration which does not in any degree lower the body temperature which may, on the contrary, rise, although the abundant heat must at the same time be withdrawing heat considerably. And after injection of pilocarpin in the beginning of the cold stage of intermittent fever, Ringer found that cutaneous secretion of sweat may take place without afflicting or curtailing the attack. The same results were obtained in typhoid, scarlet fever with the artificial production of perspiration by acetic acid in hot-air bath. The perspiration at the onset of rising fever is comparable to the sensory temperature effects of cold itself; it is apparently a violent contraction of the cutaneous vessels from irritation of the vasomotor centre, as held by Traube, with a corresponding sensation of the loss of surface warmth, succeeded by increased heat-production as
evidenced not only by rising temperature but augmented secretion of CO₂. Hütter found that he produced septic fever in frogs that the cutaneous circulation was greatly diminished. Leyden & Fränkel, by inducing cutaneous fever in dogs, observed a regular increase in the secretion of CO₂ which kept pace with a similar increase in tissue-oxidation & in body-temperature. But they were convinced that increased temperature did not arise alone from increased metabolism in fever, but that the loss of cutaneous evaporation & a changed condition of the cutaneous circulation in some way affected the "regulator of heat," That as much heat was not removed in a given time by convection & radiation as would be the case in health with an equal production of heat. On the whole, then, it seems evident that the pathological phenomena of pyrexia, as well as the direct physiological effects of the application of cold to the skin, lend their weight to the presumption that a special nervous mechanism is concerned not only in the regulation of the body-heat by varying surface-loss, but also in the increased production of heat with control within specified limits. It is scarcely credible, especially in the face of all these facts, that mere contraction of the superficial vascular area or accumulation of warm blood in the internal tissues, even with the aid of clothing, food, & muscular motion, alone can adequately explain the maintenance by men used to a moderately warm atmosphere, of an even temperature throughout a severe Arctic winter. Besides, Renéé clearly proved, by his careful observations, that cold-bathing especially sea-bathing, in a variety increases the secretion of CO₂ & that the body-weight actually decreases unless more food is ingested; that, in fact, tissue-waste & therefore heat production are stimulated, which cannot satisfactorily be accounted for except through special nervous co-operation.

The existence of a differentiated thermo-inhibitory nerve apparatus has already been hinted at. It is reasonable to suppose that if there is some nervous mechanism actively engaged in the production of heat & its dissipation, there equally exists some arrangement for controlling its over-formation. And clothes or clothing in contact with the body-surface, appear in the first instance to stimulate, in the usual way the metabolism of the

(2) "Therapeutics" p. 395.
tissues; and if the organism is healthy, or if active exercise is maintained, the nervous system responds to the altered circumstances by not only ultimately encouraging the necessary dissipation of heat from the surface, but by checking also its over-production within, so that the organism suffers no harm. But in other conditions, this natural heat-producing process goes on to excess, the tissue-oxidation being allowed to surpass the heat-loss; runs on without hindrance, the temperature rises, a febrile process is established. This looks as if the effect of surface-cooling is not only an increased activity of tissue-oxidation, but also a certain degree of paralysis, or depression, of an inhibitory mechanism. \(^1\) In cases of hyperpyrexia, the withdrawal of heat by the cold-bath seems to arouse the inhibitory centre to action. The temperature remains lower and occasionally continues to fall for some time afterwards. Sanders-Evyn \(^3\) found not only that rabbits excreted more CO\(_2\) after sudden exposure to cold, but that they excreted less on exposure to heat; tissue-dilatation must therefore have been diminished by the latter, as it must also have been in the formerly quoted case of the "fire-king." \(4\) Tschetschelin, \(^5\) experimenting on rabbits, found that irritation of the spinal cord was respectively followed by a rise and a fall of temperature, while section of the medulla at its junction with the pons always resulted in a marked rise. Raumyn Zwenke \(^6\) obtained in dogs always a fall at first, followed immediately by a rise, after section of the cord: the fall they attributed reasonably to increased surface-loss from vaso-motor paralysis, and consequent dilatation of the cutaneous capillaries, by preventing which by wrapping the animal quickly in wool, the temperature began to rise sooner. The temperature rose the more markedly in proportion to the nearness of the section to the medulla. They explain the rise of temperature after section by an increased production of heat which soon more than counterbalances the surface-loss by capillary dilatation. They, as well as Tschetschelin, consider that section of the higher parts of the cord or the medulla removes the operation of an ethereal inhibitory centre situated in the cerebrum. External heat seems to excite this centre so as to cooperate with the vaso-motor centre in the medulla which increases surface-loss. Frankel \(^7\) endeavoured to prove experimentally that normally the CO\(_2\) produced in the...

2) Virchow Archiv Band 76.

tissues becomes a factor of heat regulation. Seeing that Haidenhain had first shown that the Medulla regulates the body heat by affecting
the nervous system, the superficial circulation—a fact further elucidated
by Ostroumov—he considers that the CO₂ stimulates the centres situated in the Medulla, its aid in restricting a rise in the general temperature, it may be by increased loss, or diminished production, or both. He cut the Sciatic Nerve of a dog, inflated its lungs with a varying combination of O₂ and CO₂ Mix. On the non-paralysed side, he found the superficial temperature raised, while the cutaneous area of the paralysed side remained at the same degree or fell.
He is therefore of opinion that the increased production of CO₂ which occurs in raised temperature is one of the factors which regulate the activity of the nerve apparatus that governs the extent of heat production. Bernard advances even further, he thinks he has proved by experiments on the Cervical Sympathetic, the Auricular Nerve, the Vagale Nervi, that the Sympathetic nerve is a preganglionic influence. These Sympathetic nerves contain special calorigenic fibres. He showed that an impression of pain conveyed through a sensory nerve produced a reflex lowering of temperature by the action of the Sympathetic, while a rise was observed in the part deprived of Sympathetic influence, without any proportionate vascular changes. This was also observed by Knoebel. And Lichtheim & Gultmann state that certain
paroxysms of skewing which sometimes occur in the paresis of hemiplegia are explained by reflex inhibition of the vasomotor centre in the Medulla. Haidenhain on the other hand states that irritation of sensory nerves lowers the temperature of the blood by reflex irritation of the Medulla, accelerating the circulation, or at the same time dilating the cutaneous vessels, according to the observation of Ostroumov, this cooling the blood by surface loss by rapid distribution.
(1) Foster Hermann

(2) Contr. Dr. Med. W. H.
The irritation of external heat may, does, bear this out; but the phenomena attending the equally irritating action of cold militate against it, as I think, as a complete explanation. Brunton, in his declaration that irritation of a sensory nerve, as in conjunctivitis, produces dilatation of vessels in that part, but a contraction of all other vessels throughout the body, diminishing the blood-pressure therefore in the surface, which would rather tend to shut in heat and raise the temperature of the blood, which inflammatory action from sensory irritation certainly does. However, from the complicating influence of the all-pervading vasomotor nerves, all such experimental observations have probably come with combined with error, so that it is difficult to arrive at results of results. The effect of activity observed by Ringer in certain cases, where temperature was greatly lowered without any apparent increase in the area of the skin, suggests either some depressing action on the thermogenic process, or a stimulation of an inhibitory centre. A deep-seated lesion of the spinal cord has frequently been observed to be followed by a persistent elevation of body temperature, even in the paralyzed parts, which favours the probability that a power restraining heat-production must in those cases have been suspended.

The application of severe cold or the prolonged exposure to a very low temperature may withdraw heat so rapidly as to such an extent that the tissue-oxidation is not able to keep pace with it. The vital activity of the tissues themselves may be gradually lost. The nervous responsive influence as well as surface sensation becomes interfered; the respiratory centre becomes interfered. The heart fails; consciousness and muscular power are abolished, oxidation becomes impossible, and death follows. The skin, as a bloodless and rigid hue, the heart, lungs, or brain are found full of venous blood, similar to the condition found in Apoplexy.
It is death by general depression and CO₂ poisoning. The narratives of Arctic travellers furnish us with cases illustrative of this. Even a cold bath, particularly in the open air, when one is exhausted with muscular exercise or in a feebly vital condition, may depress the nervous centres so much that once the sudden shock of heat-withdrawal acts to result in fatal syncope. The powerful effect of cold on the respiratory centres is familiarly seen in the deep panting, irregular breathing which commonly follows at first on getting into cold water. Inspiration is greatly deepened as if intentionally to obtain more O₂ for the tissues to use up i.e. increased heat. The physiological action of a Cold-Bath is twofold. There is a physical abstraction of heat which depresses the nerve-centres of the tissues generally, having an exclusively destructive tendency; there is a vital nervous stimulation by the sensation of cold which excites the centres to an increased saving functional activity. In proportion as these two factors predominate is the advantage derived from cold-bathing. It is often observed that persons with constitutions possessing very feeble vital power, are invariably, depressed after every virtuous attempt to carry out a fancied salutary cold-dip, from an almost total want of reaction on the part of the nervous system, the very almost they can bear being a momentary cold sponging in a warm room. The contact of moderately warm water with the sensitive skin has a soothing influence on the nervous system, producing neither shock nor much stimulation. A hot bath, like a cold one, is stimulating, but not tonic as the cold, it is usually followed by some exhaustion or depression. If, however, a cold shower-bath follows, its tonic action prevents the weakening effect of the heat. The gradually increasing anaesthesia of the skin, which occurs in persons dying from exposure, has clearly a powerful calming influence.
(1) "Pharmacology and Therapeutics."

(2) Spec.
in hastening the production of or deepening the fatal depression, heat-abstraction goes on without any preceeding excitement or nerve-reaction. Somewhat similar phenomena are also witnessed in Opium-poisoning where sensibility or consciousness are alike in abeyance. This seems still further to testify that in the nerve-arrangement of the skin the economy possesses a power of affecting a heat-regulating nervous mechanism.

It was my original intention in this paper also to have considered the Dynamics of the Skin, from the Pathological Therapeutic points of view, which promised a field of study in the highest degree interesting and worth working out. But this paper has already been too much attenuated to allow of this.

43 St. Jue \nDundee, \nApril, 1883.