PRESENT DAY TRACTS.

MAN

PHYSIOLOGICALLY CONSIDERED

BY

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M.D., F.R.S.,

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Professor of Anatomy in the University of Cambridge.*

56, PATERNOSTER ROW; 65, ST. PAUL'S CHURCHYARD;
AND 164, PICCADILLY.

No. 39. SECOND SERIES.

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THE RELIGIOUS TRACT SOCIETY:

56, Paternoster Row; 65, St. Paul's Churchyard; and 164, Piccadilly.

Summary of the Tract.

I. Man a cosmopolite in geographical distribution, although wanting in those qualifications by virtue of which the most widely diffused animals spread themselves. He has the power of using means to extend and supplement his physical powers. Man's mental power is correlated with the development of his nervous system, although we cannot explain the mental results as due to molecular changes.

II. Man's body is a machine formed for doing work. Its framework is the most suitable that could be devised in material, structure, and arrangement. The muscles, or active organs of motion, considered in reference to their structure, adaptation, and dynamical relations. The working power of the human body. Relation of food to work. The human and the artificial machine compared.

III. The heart a muscular mechanism. Amount of work done by it;—its complexity, its susceptibility to emotional influences. The blood; some of its functions.

IV. Speech—produced by correlated muscular mechanisms. Voice and Speech, their respective natures and organs. Vowels and consonants. How dialects arise; correlation and co-ordination required for speech.

V. Law of cycle in human life. Sleep. Changes which take place during its occurrence. Death.

VI. The Body a Temple of God. Its chief lesson, that of perfect adaptation. His body is a monument of design. The fitting of means to ends an evidence of the wisdom of God. Revelation teaches us that a glorious future awaits redeemed humanity.

Man, Physiologically Considered.

I.

THE dry land area of the earth's surface is estimated as exceeding fifty-two millions of square miles in extent. Although the different parts of this area present conditions the most varied, and every conceivable range of climate, from perpetual snow to permanent tropical summer; yet, excepting in a few inhospitable tracts within the Polar circles, and a few desert patches elsewhere, man has attained to a universal distribution. The parts uninhabited by man make up less than one tenth of the whole surface.

Man cosmopolitan in distribution

This is a phenomenon unique in the Animal Kingdom; the bounds of habitation of each animal are determined by the existence of those conditions of food and temperature under which its life is possible; and, generally speaking, the area of distribution of each species is very restricted. A few animals, like the mouse rat, and

All other animals restricted to a limited area.

dog, have been transported by man over wide areas in comparatively recent times, and are now multiplying in regions in which they were unknown before; but man is the only animal that, by his own exertions and capacities, has traversed the natural barriers which have limited the distribution of other forms.

The most widely diffused animals have certain characters, wanting in man.

Those other animals which, like the rat, have now spread over large tracts of the globe, are characterised by an early maturity, a capacity of feeding upon almost any form of food, and a rapid rate of multiplication. Man presents us with characters in all respects the most diverse from these:—he has the longest period of helpless infancy of any animal, and is slow in attaining maturity (one fourth of his life, at least twenty years, having passed before his full growth is perfected); he is also able to use only a limited number of substances in their natural conditions as food. Mankind also multiplies at a slow rate, thus, while within the past fifty years, forty-five persons have descended from a single pair of royal parents in Britain; in the same period of time one pair of rats would, at their ordinary rate of increase, have had a progeny at least as great, numerically, as the whole population of England. Yet, in the face of all these disabilities, man has, by his own exertions, become a cosmopolite.

Those animals which, zoologically, are the most nearly allied to man in structure have exceedingly narrow areas of distribution. The gorilla is confined to a small tract of West Africa about the size of France. The Chimpanzee, although ranging over a larger district of Equatorial Africa, yet does not extend beyond the region limited by the parallels of 12° N. and S. latitudes, and in this belt is only found between the sea-coast on the west and the meridian of Lake Tanganyika on the east. The Orang Utan is limited to the Islands of Sumatra and Borneo. It seems strange that man should have such a universal diffusion, while these are so restricted and so strictly Equatorial.

Man's nearest allies in structure limited in distribution.

Did we only know concerning man as we know of these anthropoid apes, from preserved museum specimens, we could hardly fail to consider him as eminently unfit for a wide distribution, or for maintaining his position in the struggle for life. Bare in surface, while his neighbours are hair-clad, feeble in teeth, while his nearest allies are strong, with thin flat nails in place of claws, and short, weak hands and arms, incapable of grasping with his feet, imperfect as a climber, less fleet of foot than his foes, nature has neither furnished him with weapons for war, nor with implements wherewith to search efficiently for food; yet this bare, weaponless animal has spread over the whole world, has assumed and maintained dominion over

Man apparently unfit for a wide distribution.

the other creatures, has waged successful warfare against animals fiercer, and against forces stronger than himself, and has exterminated many of the foes which were the most hostile to him.

Man's capability of living in all countries due to his power of usingmeans.

The secret of this capacity for adaptation and dominance lies in Man's power of employing means. By the use of clothing he is able to fit himself to live in any climate; by cooking, to use all varieties of food; by the invention of weapons, to engage in all warfare; and by the perfecting of speech he obtains the power of perfect co-operation with his fellows. The most intelligent animal, untaught by man, can do no more than turn to some obvious use the tree-branch or stone which first comes to hand; but the rudest races of savage man, in the most inhospitable districts, have sought out materials wherewith to make clothing, if they need it; have invented weapons; have brought under subjection the powers of nature, using fire to prepare their food, and the winds to waft them across the waters; and the members of every tribe have framed their own articulate speech for the mutual interchange of thought.

The correlation of bodily to mental organization.

While it is thus power of mind, not power of body, which gives to man his supremacy, yet, in all respects, man's bodily organization is fitted to enable him to use to the best advantage his mental endowments. If he conceive in his mind the plan of making a weapon, his prehensile hand with its sensitive skin and its independently moving and opposable thumb can fabricate it. His sinuous backbone and completely extensile lower limbs enable him to stand upright with perfect stability, with an ease and perfection competent to no other animal; and thus his fore-limbs, relieved from all necessity to act as organs of progression, are perfectly disengaged for work and warfare.

The brain, the instrument of the mind.

The material instrument whereby the mind operates in man, and through which it rules over his whole body, is the nervous system, the central parts of which form that continuous series of organs which are called the brain and spinal marrow. The former of these, the brain, fills the entire cavity of the skull, and is proportionally larger in Man than in any other animal; while the brain of the Gorilla, the highest of the apes, averages 24 ounces in weight, or a little less than $\frac{1}{130}$ of the entire weight of his body, that of man averages 46 oz. or a little more than $\frac{1}{50}$ of his total weight.

Its minute structure.

In minute structure this organ consists of aggregations of very minute branched particles of a peculiar and very decomposable material, whic h are called nerve-cells, and which vary from $\frac{1}{400}$ to $\frac{1}{3000}$ of an inch in diameter. From each of these minute pyramidal, spindle-shaped, or irregular nerve-cells, there pass two or more very fine tails or filaments, some of which go to communicate with neighbouring cells, while others, of great length, pass through and out of the brain, and are distributed throughout the body; so widely, indeed, do these filaments wander, and so universally are they dispersed, that one cannot touch any area of skin with the point of a needle without pressing on the termination of a nerve fibre. These fibres of distribution, as we may call the long, tail-like threads from the nerve cells are each enclosed in a delicate sheath, and vary from $\frac{1}{500}$ to $\frac{1}{12000}$ of an inch in diameter. These leave the brain in bundles which are called nerves, and are distributed through the body so generally that there is not a structure in the body which is not connected with some single cell or group of nerve-cells in the brain. We may look upon the brain, therefore, with its five million constituent nerve-cells as the great unifying organ among the constituents of the body.

A great part of the brain connected with movement.

Much of the substance of the brain is directly concerned with the superintendence of the machinery of the bodily movements; when we discount this element, which constitutes nearly one half of the human and about three-fourths of the ape's brain, the disproportion between the remainder of the human and of the animal brain appears much greater. Another large contingent of the brain substance is required for the physical processes connected with the reception of impressions from without. We live in a world of vibrations, our surface is constantly coming in contact with the surrounding material bodies either at rest or in motion; while the waves of sound, and those even more problematical vibrations which we call light-waves, are constantly being brought to bear upon us from without. The conditions under which we live render it necessary for our well-being to take cognizance of these vibrations, as by them we learn of our surroundings, and are taught to avoid danger and to procure food.

A great part of the brain connected with the recognition of sensations.

We have seen that every spot on our surface is connected by fine nerve threads with the nervous centres, and that these threads are themselves fine processes of the minute nerve cells, and of the same impressionable material. These threads are not like simple telegraph wires, carrying impulses to a registering machine, they are outgrowths of the registering machine itself, each capable of receiving and feeling an impulse from without at its termination: hence sensation, that is, the affecting of these extremities by external stimulus is registered at the spot where the impression is made. There are two distinct though associated processes connected with sensation, the reception and registration of the impulse, and our consciousness of it: the former occurs in the part itself, the latter in the brain. I am conscious of an impression by virtue of the connection between the local nerve

The extension of each nervous element.

and the groups of brain cells connected therewith; but I feel the contact at my finger-tip, not at my brain. If I cut the connection between the local nerve and the brain, the consciousness of contact is lost, although the local effects are the same as before. If the nerve coming from the surface of a limb communicate through nerve cells in the spinal marrow with a nerve going to a muscle, and if the brain communication be cut by accident or disease, then irritation of the surface will cause the muscle to move, but without any consciousness.

Purpose discernible in nerve actions.

The element of purpose which is discernible in this instance, pervades the action of the entire nervous system in all animals; here the muscle, by contracting, draws the irritated limb away from the irritant without the operation of a conscious will. If, in a recently killed and decapitated frog, a drop of acid be allowed to fall upon the skin, the leg moves and endeavours to wipe it off; but the purpose in such case is unintelligent, not being under the dominion of consciousness, thus if a snake, killed by beheading, be hung up and touched in several places with a stick, it will coil round it; but if for a stick a hot poker be substituted, it will coil round it with equal readiness.

Disproportion between magnitude of stimulus and effect produced.

In many of these actions of the nervous system we notice a singular disproportion between the magnitude of the stimulus and the effect produced. The contact of a fine hair or of a crumb with the mucous surface of the glottis, or throat-opening of the windpipe, will cause a violent spasmodic fit of coughing, which convulses the whole body; while even a more powerful stimulus to other parts of the mouth, the tongue, or throat, organs in other respects equally sensitive, produces no other effect than a flow of saliva or an impulse to swallow. These again are simple illustrations of the element of purpose in nervous actions, as it is of vital importance to the organism that the glottis be kept clear of all solid matter.

The nature of the changes in nerve-tissue during action.

We can learn much of the local change which occurs in nerve-tissue when exposed to contact or stimulation: it is an impulse propagated in the material of the filament from the peripheral termination to the nerve cell, at a definite rate, a little over 100 feet in the second, and associated therewith are certain recognizable physical molecular changes. But of the real nature of the processes whereby this impulse is translated into consciousness, even in its lowest form, we know almost nothing, and still less do we know of the physical processes which underlie or accompany those mental operations, which originate in and work by the agency of the brain, such as thought, emotion, volition.

Evidence of physical change in the cells of the nervous centres.

That certain physical changes take place in the cells of the nerve-centres in connection with these processes is evidenced in many ways: energy is dissipated as heat, the blood vessels of the head and neck show increased pulsation and fulness, the quantity of blood in the other parts of the body is proportionately diminished during brain work, and in direct ratio of the difficulty of the work, and the blood returning from an acting brain is richer in carbonic acid and other products of waste, thereby indicating the consumption of tissue in the work; but the amount of these actual changes is far too slight, and the actual energy which can be shown to be set free is too small to be adequately measured in terms of other forces, although the consequences dependent on the mental exertion may be of tremendous moment. The physical change in the cell may vary in degree, but we have no evidence whatever that it varies in kind; though the mental state may be intellectual labour, emotion, will, or the merest supervision of bodily menial work, we can in all cases only obtain evidence of the combustion and oxidation of the nerve matter, associated with the dissipation of energy as heat and electric force. When intellectual operations are looked at from the physiological side, the difficulties of regarding them as solely the outcome of physical changes in nerve cells are insurmountable. To refer the *Principia* of Newton, the *Iliad* of Homer, or the *Essays* of Bacon to vibrations due to chemical change in a few ounces of nerve cells seems a *reductio ad absurdum* indeed.

Molecular changes cannot account for the mental results.

But while the physical factors in mental processes seem thus utterly inadequate to account for the nature and magnitude of the results, yet they have certain definite relations thereto. The rate of mental action has been carefully studied and ascertained, more especially in its bearing upon the making of exact observations in astronomy, so that the phrase "quick as thought" has a definite meaning, capable of translation into units of time. The amount of tissue-change in the brain during action, although not determined, has been roughly approximated, and will probably before long be more definitely measured, and the amount of energy set free in the course of the physical changes which accompany mental processes may yet be capable of expression in foot-pound equivalents.

Molecular and mental forces co-operate

Man alone has the singular pre-eminence of being the animal in which the mental part rules or can rule the material: he alone can turn his mind in upon itself for self-study, he alone has the power of making the reception and recognition of impressions from without subservient to his pleasure in a manner quite unknown to other animals. They can recognize the vibrations of sound-waves, and learn therefrom the presence of other animals, or of noise-producing forces. Man perceives these sounds, classifies them, discerns certain relationships, and makes such combinations of them as minister to his pleasure, and thus invents and improves the art of music, and the instruments by

The mental rules the material in man.

which these pleasing combinations of sound are produced. The lowest races of man have their drums, reeds, and pipes for this purpose, and at a very early stage in the history of humanity we read of Jubal "the father of all such as handle the harp and pipe."[1]

Animals can in like manner recognize sensations of form and colour, and thereby learn something of their surroundings. Man, appreciating these in a higher degree, can reproduce them not only mentally in his memory, but pictorially, by the aid of his hands directed by brain and eye; and so can render permanent those combinations of light, shade, and colouring which gave him pleasure; and he can gratify his taste by art, in places and at times when nature fails to minister pleasant scenes to the eye. And man has done so from an early if not from the earliest times of his existence.

Even the earliest men of whom we have traces had the same kind of mental power of Art which we now possess.

The rude savage who hunted the wild ox, mammoth, and reindeer in prehistoric times on the plains of France, has left behind him, scored upon bones, horns, and tusks, life-like graphic outlines of his wild-beast contemporaries.

[1] Genesis iv. 21.

II.

The human body viewed as a machine for doing work.

Among the different aspects in which we may regard the living human body, one of the most suggestive and instructive, although perhaps, from its very attractiveness, one of the most commonplace, is in its character as a machine constructed for doing work. In man himself, as in those mechanisms which he constructs by his art, there is no creation of energy; but as in these, the human apparatus transforms into heat and motion the energy of chemical combination which it finds in the materials taken in as food.

The details of the mechanism of man are so complex that it requires a life-long study to obtain a thorough knowledge of his organization; and the more carefully it is examined, the more forcibly do we recognize how completely every part, even the most minute, bears the stamp of perfect fitness for its place and use. We might illustrate this from any subdivision of the parts of the body, but will only refer to two systems, the bones and the muscles.

Suitability of the framework of the machine.

The adaptation of the skeleton to fulfil its function as the firm basis of the body is shewn, firstly, in the suitability of the material of which it is constructed, bone; secondly, in the appropriateness of the disposition of this material both in its minute and its larger organization. There is not one of the two hundred bones which make up the skeleton whose particles are not so perfectly adjusted as in the most efficient manner to sustain the pressure and bear the strain to which it is exposed.

Conditions which a perfect skeleton should fulfil.

In order to build a skeleton of the most suitable kind, the conditions which require to be fulfilled are, first, the component material must be of adequate hardness, toughness, and elasticity; second, it must present an adequate extent of surface to allow of the attachment to it of muscles; and third, it must have as little weight as possible. All these conditions are fulfilled by bone.

Suitability of bone for the purposes of the skeleton.

In the first of these respects, bone is of all available substances the most suitable. Its power of bearing weight without being crushed is greater than that of any other organized tissue, or even than that of many metals. This can be seen from the following table, in which the numbers represent the number of kilogrammes which are required to crush a rod of the substance measuring one square millimetre in area of section.

Table showing relative capacities of resisting crushing.

Steel ...	145	Lead ...	5
Wrought Iron	22	Granite ...	5·9
Cast Iron ...	73	Bone ...	15
Oak	4·8		

The elasticity of bone is also one of its most characteristic qualities, as can be seen from the following table which gives the values of the modulus of elasticity of different substances.[1]

Table showing the relative elasticities of various bodies.

Steel	21,000.
Wrought Iron	19,000.
Bone	2,400.
Lead	1,800.
Oak, if parallel to the grain ...	1,100.
Oak, across the grain	130.

Lastly, the tensile strain which bone can bear without giving way is also very great; from numerous experiments the following tearing limits have been determined for different substances, the numbers, as before, representing the number of kilogrammes required to tear a rod of the size mentioned above:—

Table showing power of resisting tearing of various bodies.

Steel ...	102	Bone ...	12
Wrought Iron	41	Zinc ...	5
Cast Iron ...	13	Oak ...	$6\frac{1}{2}$

A cube of bone one square inch in surface will bear, without being crushed, a weight of more than four tons; and the weight of the whole human

[1] The method whereby these values are ascertained will be found in any work on elementary Physics. As the co-efficient of elasticity, that is, the proportional amount by which a rod of any substance one square millimetre in cross section is lengthened by the load of one kilogramme, is a very small fraction, the relative elasticities can be more graphically represented by the reciprocal of this fraction, *i.e.*, unity divided by the proportion of elongation, which represents the theoretic weight in kilogrammes which would be required to lengthen a bar to twice its original length, if it were perfectly elastic. This is called the modulus of elasticity.

Lightness and strength of human skeleton.

skeleton is distinctly less than the weight of a similar framework of wrought iron of equal strength. There are few better illustrations of the hardness and strength of the human skeleton than the comparative rarity of broken bones, considering the amount of violence to which the human frame is from time to time subjected.[1]

Extent of bony surface provided for attachment of muscles.

In the second place, the ordinary male human skeleton exposes a surface a little over one thousand square inches in extent, available for muscular attachments; more than double the area which a wrought iron skeleton of the same height and weight, and constructed in proportion so as to be of the greatest possible strength, would present.

Weight of human bones.

The weight of the average male skeleton when fresh and moist is about twenty pounds, when dry and prepared, about ten pounds, and the material of which it is made up is in specific gravity one quarter that of wrought iron.[2] Not only is the substance thus comparatively light in itself, but it is disposed so as to offer the maximum of resistance with the use of the minimum of material.

Those bones which are constructed to support

[1] A comparison of these tables shows that bone is equally strong to resist crushing and tearing, in the former respect being little inferior to wrought iron, in the latter to cast iron.

[2] The following table of the specific gravities of the substances above contrasted will be of interest :

Wrought Iron...	7,788	Marble... ..	2,837
Cast Iron ...	7,207	Bone	1,870
Lead	11,352	Oak	0,845

weight are built as hollow columns; and in these the proportion of the thickness of the solid wall to the whole diameter is the best possible for strength and lightness.[1] These hollow cylinders are still further strengthened by pilaster-like ridges along the lines of greatest pressure, and by struts under the piers of arches. Where the ends of bones come in contact with each other so as to form moveable joints, they are expanded so as to afford large and often interlocking surfaces, combining thus stability with the capability of motion. The shaft of the bone alters in structure as it thus expands;

Architecture of bones, hollow columns.

Cancellated or spongy tissue in ends of long bones.

[1] It has been found by experiment that if the *same amount of material* be used to construct two columns, one solid and the other hollow, that the following numbers will represent their respective powers of bearing vertical weight on the end, and a transverse breaking strain :—

		Crushing Limit.	Snapping Limit.
1. Solid column, diameter	100	1,000	10
2. Hollow column, diameter	125	2,125	17

(Thickness of ring in No. 2=50, therefore solid diameter equal to that of No. 1).

If now we take three columns *of the same diameter*, but constructed of varying amounts of material, and compare these in the same respects :—

	Crushing Limit.	Snapping Limit.
1. Diameter, 100, solid column	1,000	8
2. Diameter, 100, hollow column, with inner diameter 60...	870	7
3. Diameter, 100, hollow column, with inner diameter of 80	590	4·8

This table shows us that, although No. 2 has only three-fifths the amount of bone of No. 1, yet it is seven-eighths as strong; and No. 3 has only one-third the substance and more than one-half the strength of No. 1.

and instead of continuing hollow to its articular or joint-forming end, which would diminish its strength, the hitherto compact bone becomes split up into a large series of closely applied thin plates of bone, which are so disposed that they bear upon their ends the direct pressure of the body. These lamellæ are tied together by numerous intersecting plates placed at right angles to them, and these secondary lamellæ serve as ties to prevent the separation of the primary system. By this arrangement the articular end of the bone becomes expanded and formed of cancellous or spongy bony tissue, the structure of which at first sight seems so confused and irregular, but displays on closer examination an elaborate plan in the disposition of its every plate. As the conditions under which each bone is placed vary, so the plan of the lamellæ varies; but the general principle holds good all through, that the layers are placed to resist respectively pressure and tension. The arrangement is consequently so characteristic in every bone, that an anatomist of experience can at once recognize from what bone and in what plane any given section is taken.

Architecture of spongy bony tissue.

Arrangement of cancelli in each bone peculiar to suit its special conditions.

If, from the statics, we turn to the dynamics of the skeleton, the same fitness is observed: the adaptations of the long bones as levers for so many purposes; the mechanism whereby the sinuously curved spine can be kept erect in

The same fitness in the dynamics of the skeleton.

different positions; the arrangements whereby bipedal progression can take place, and by which standing on two feet can be accomplished with perfect maintenance of stability; the mechanism whereby without the constant action of the straightening muscles of the knee, but simply by the influence of the superincumbent weight causing certain bony surfaces to glide on each other, a perfect ligamentous interlocking occurs in the knee joints, enabling the thighs to continue vertical in standing, without the fatigue of continued muscular work, all these and many more examples could be adduced as interesting studies in the teleology of the skeleton.

The muscles the active organs of bodily work.

But the bones constitute only the passive organs of motion, the muscular system is the real seat of the working power of the body; to it the bones are subordinated, and in this system we are still more strikingly presented with evidences of design.

Number of muscles and amount of muscular tissue in man.

There are about two hundred and sixty pairs of muscles attached to the bones in man, and serving the purpose of moving these as levers in the different ways required for the purposes of life. These constitute upwards of sixty pounds of the weight of the body; but as this includes the weight of the sinews and non-contractile fibrous expansions which ensheath the muscles, not more than forty-eight pounds of this represents truly contractile material.

The contractile substance of muscle.

The substance of which these muscles consist is probably the most remarkable material in the body, and it is worthy of note that although it is a substance easily obtained and presenting no apparent difficulty in preparation and examination; and although anatomists have brought to bear upon it all the improved instruments of modern science, and have used these with all the skill of years of practical experience, yet we have not succeeded in learning the details of its structure. Minute examination has only revealed that the elements which were once regarded as ultimate are compound, and organized with a minuteness which has as yet baffled the highest powers of the microscope to unravel.

Properties of muscular substance.

The most remarkable property of muscle is its contractility. The particles of which it is composed can, upon being bidden, change their place, so as to alter the shape of the whole mass, shortening and thickening it. Most of the muscles of the body are attached to bones at their two extremities; and when this change in shape takes place, the two bony attachments are forcibly approximated. Of these, one attachment is to a fixed bone, the other to one that is moveable; and consequently the force of the contraction is expended in drawing the latter, or insertion of the muscle towards the origin or attachment to the fixed bone. Thus the principal muscle which operates in bending the elbow joint, and which occupies the front of the arm from the shoulder to the elbow, arises by two strong sinewy cords from the shoulder-blade bone; hence it is called *biceps, i.e.*, two-headed, and it is inserted into the outer of the two bones of the fore-arm.

The study of the statics of the muscular system is teeming with interest. There is not an individual muscle which does not show the most perfect adaptation possible for the work it has to do: in its attachments, its proportional size, in the spot wherein it is entered by the blood-vessels which nourish it, and by the nerve which connects it with the brain, or centre of volition.

Every muscle adapted for the work it is required to do.

The force with which a muscle contracts is very great, and has been determined by experiment to be proportional to the area of the cross section of the muscle. The contraction of a muscle whose sectional area is one square inch can support a weight of a little over 100 lbs. The distance through which the muscle, in contraction, draws its insertion is proportional to the length of the muscular fibre-bundles; thus, in the case of the *biceps*, the muscle which bends the elbow, already referred to, in an arm of average size, its area of section is one and three quarter square inches, and its bundles of fibres are six to eight inches in length. It has, therefore, contractile material sufficient to raise a weight of 175 lbs, through a space of four inches. As in the ordinary economy

Force of muscular contraction.

Some muscles arranged so as to increase speed at the expense of power.

of the body the lifting of such a large weight is not required, the insertion is so disposed on the fore-arm bones as to make these work as a lever of the third order, so that the weight-bearing extremity, or hand, moves through a space six times as great as that through which the insertion absolutely moves.

As the area of cross section of all the muscles of an average human body amounts to over 200 square inches, there is thus in the whole muscular system of the human body a potential energy equal to the amount which would be expended in raising at a single effort a weight of nine tons to the height of one foot. All this force can be set in motion by the human will.

Working power of the body.

From observations which have been made on railway navvies, stevedores, and other men engaged in hard manual labour, it has been ascertained that the amount of muscular work which an average labouring man performs in the day is accomplished at the expenditure of a force equal to that which would be required to raise 350 tons to the height of one foot; that is, allowing ten hours in the working day, the rate of work equals the raising of thirty-five foot-tons per hour. It is, however, possible for an able-bodied labourer to work continuously at a greater rate than this. The highest registered rate of work of piledrivers is equal to the raising of 450 foot-tons *per diem*. By working in spurts a much higher rate of work may be attained for a short time. Each man of the crew of an eight-oared boat works, in a boat-race, at a rate equal to that required for raising a little over four foot-tons per minute, expending thus nearly eight times more energy in the time than is done at the rate of work of the ordinary day labourer.

Man's body does not create energy; but as, in a steam engine, the working force is derived from the potential energy of the fuel employed, so in the human body the force of the muscular system is derived from the substances taken in as food. In man, as in the heat-engine, the working force is set free by the occurrence of a process of combustion; and in the body of a healthy man there is consumed daily about half-a-pound of carbon, the equivalent of ten ounces of coal. By the process of combustion, that is, the union of this carbon with the oxygen of the air taken into the lungs in the process of breathing, there is produced an equivalent amount of carbonic acid, which is got rid of by being carried in the venous blood to the lungs and there breathed out. This substance (carbonic acid) is poisonous, and even when a very small percentage of it occurs in the air it produces injurious effects. One man hourly vitiates to the extent of 0.2 per cent. 350 cubic feet of air, and even this small amount of the gaseous products of breathing is unwholesome. Hence the necessity for perfect ventilation, especially in work-rooms,

Energy from the transformation of other forces.

Waste products of combustion set free by respiration.

where persons are assembled for any form of exertion; and as with increased work there is a commensurately increased exhalation of this deleterious gas, the need of ventilation will increase with the severity of the work.

Relation of food and work.

As carbon is the element of human food whose oxidation sets free energy most conveniently, it becomes important in arranging dietaries for labouring men, that carbon-supplying foods should bulk largely therein. Extensive observations on large masses of labouring men have shown that a healthy adult requires daily about the following quantities of food:—

Diet scale for healthy adult.

Of nitrogenous substances, such as meat	6 oz.
Of fats (butter, etc.)	3 „
Of carbo-hydrates (sugar, starch, etc.)	18 „
Of saline matter, chiefly common salt	1 „
Of water	80 „
Total...	108 oz.

Collateral conditions to be taken into account in choosing food.

In choosing the substances of these different classes as foods, their relative facility of undergoing digestion, preparatory to oxidation, must be taken into account, as well as the absolute amount of oxidizable material. This is true of the heat engine as of the man. Carbon, in the form of diamond or of blacklead (graphite), would form extremely bad fuel for a steam-engine, as these are not easily burned ; and similarly, in the food supply of man, we must take into account the facility with which these substances are soluble, and admissible by digestion into the blood, for the purpose of transmission through the body for the nutrition of the tissues, and of undergoing, in the proper place, the oxidation which converts the potential energy of chemical combination into heat and muscular force. The molecules of the contractile stuff in muscle become broken up at each contraction, with the production not only of water and carbonic acid, but also of other substances in smaller quantities. If the blood stream going to and coming from a muscle be cut off, after a very short period of activity, the muscle uses up all its contractile stuff, and becomes unable to continue its contraction, while it becomes loaded with the effete products of the chemical changes. Hence it is necessary for the well-being of the muscle and for its continuance in activity that new material be brought to it to reconstruct its molecules of contractile material ; and so into the blood there must be poured continually from the digestive organs a new supply of material available for reconstituting these contractile molecules.

Chemical decomposition takes place in muscle when in action.

Need for constant blood supply to muscle to reconstruct its contractile substance.

A diet of the description given above contains potential energy equal to 3300 foot-tons in a day, of which we have seen that about one-seventh

Amount of energy expended in internal work, heat, etc.

part is the amount available for useful external work; the rest is expended in maintaining heat, the action of the heart, secretion, nervous action, and other departments of internal work. For the purposes of the life of the body, in order that the necessary processes may take place in the protoplasm of its component cells, it is necessary that the temperature should be maintained between 96° and 100° F.; so we find that the normal heat of the human body is maintained at some point from 97° to 99°, being highest during the most active period of work, shortly after breakfast-time, and lowest when tissue-change is lowest at the small hours of the morning, from 1 to 3 a.m.[1] We are not, therefore, to look upon the six-sevenths of the energy as lost, because it does not show as muscular work. But, comparing the living engine with the artificial heat machine, the advantage is distinctly on the side of the former, for in the most perfect of the latter in actual use there is barely one-ninth of the energy supplied by the fuel utilizable for external work.[2]

Contrast of man and the best heat-engine.

[1] The amount of energy expended in the maintenance of the constant temperature of the human body is equal to the amount required to raise 48½ pounds of water from the freezing to the boiling point. If this energy were converted into motion, it would suffice to raise a man of ten stones weight to the height of nine miles in a day.

[2] By the most perfect construction of gas-engine, Crossley has been able to utilise $\frac{1}{5}$ of the energy of the fuel supplied, and Perkins has by special arrangement got nearly the same amount of work with a steam engine, but the best engines in use give only $\frac{1}{9}$th.

III.

The heart a muscular mechanism.

The heart is perhaps the most wonderful of the special mechanisms of the human body. Its ceaseless activity, its sensitiveness in sympathising with the emotions of the mind, and the intricacy of its mechanism, have from the earliest times attracted notice, and caused it to be regarded as the very centre of life itself. To the older physicians of the classic age, who only regarded the brain as a cold mass placed in the head to temper the undue fervency of the heart, all thought, all emotion, all feelings were supposed to have their seat in the heart; and we in our colloquial language have adopted those Orientalisms of expression regarding the heart which have been familiarised and endeared to us by their Biblical use.

Older views of the nature of the heart.

The physical centre of the circulation of the blood.

The modern physiologist has largely robbed the heart of much of the mystery, and much of the psychic association with mind and desire, with which the fancy of our forefathers had clothed it, and has transferred it from its position as seat of the affections, to the no less interesting place of physical centre of the circulation of the blood; but as the regular uninterrupted flow of blood is absolutely essential to the continuance of vitality, it is therefore physically true that out of the heart are "the issues of life."

Description of the heart: Its four chambers.

The human heart is a muscular organ, about ten ounces in weight, which, in order that its regular changes of expansion and contraction may take place with the least possible friction, is enclosed in a smooth bag, the pericardium, whose surface is rendered still more smooth by being moistened with a small quantity of watery fluid. The organ is hollow, and consists of four distinct cavities, one for receiving the impure or venous blood returning from all parts of the body, a second for taking the blood thus collected, and forcibly propelling it into the lungs. These two cavities are on the right side of the heart, and are called respectively the right auricle and the right ventricle. Into the third cavity or left auricle the blood, which has been purified in the lungs, is returned and collected; and from hence it passes into the fourth and last cavity, the left ventricle, which performs the great work of driving the wave of pure blood through the body for its nourishment.

Work done by the heart.

The wonderful energy of the muscular material of which the walls of these cavities is made up is the first and most prominent characteristic which we notice. The left ventricle by its contraction sends at every beat a wave of blood into the arterial system. At least five ounces of blood is expelled at each stroke, with a force capable of raising the jet to a height of about ten feet. As this is performed about seventy-five times in the minute, the daily work of this part of the heart is easily calculated, and in an average male heart amounts to the lifting of a little over one hundred and eighty foot-tons in the day. If we add to this the work done by the other cavities of the heart, we find that the whole amount of cardiac labour in the day reaches the amazing total of two hundred and forty foot-tons, or two-thirds the ordinary labouring force of the whole voluntary muscular system.

Average day's work of the heart.

We can probably realize in the most graphic manner the amount of work expressed by this figure, if we remember that the muscular work done by a man of one hundred and fifty pounds weight, in ascending Snowdon, comes to about the same total. From many experiments in Alpine ascents, we find that when there are no special difficulties in the way an active man can climb ten thousand feet in ten hours; that is, can raise his own weight one thousand feet per hour; but if the amount of work which the heart performs were expended by it in the task of raising its own weight, it would lift itself to the top of the highest peak of the Himalayas in one hour and a quarter. One of the most rapid ascents known to me was one in which a man of one hundred and forty pounds weight ascended to a height of two thousand five hundred feet in the space of thirty-nine minutes; but within that time the heart has done

Comparison of the work done by the heart with other forms of muscular work.

work equal to the lifting of itself a thousand feet above the top of Mont Blanc.

Ceaselessness of heart's action during life.

A second and equally marvellous aspect of the work of the heart is its ceaselessness. Day and night, whether the body sleeps or wakes, year by year it is ever acting. While voluntary muscular work must intermit for periods of rest greater than the periods of work, the heart's rest-periods are, if anything, shorter than its work periods; and as the vessels which nourish the wall of the heart arise from the great artery immediately above the heart, so it is directly pumping blood for its own nutrition at each stroke, and nourishing itself the better when acting the more strongly.

The heart a complicated machine.

The complexity of the action of the heart is another feature worthy of note: while to the hand the stroke of the heart gives the impression of a single beat, and while even to the ear the sound of the heart's beat seems as a double sound, yet, as we have seen, during each single pulsation there is a dilatation and a subsequent contraction of each of the four separate cavities. As the blood on each side passes from the receptive cavity or auricle into the propelling cavity or ventricle, its return is prevented by the closure of a system of valves which are self-acting. Again when each ventricle has contracted and expelled its contained blood into the large arteries, the return of the fluid is prevented by another series of valves. At each action

The action of the valves of the heart.

of the heart, therefore, four sets of valves, consisting of eleven separate curtains, or membranous folds, are brought into play. It was the study of these valves that, in the first instance, led to the discovery of the course of the circulation of the blood.

Susceptible of influence of emotions.

The ancient view, which attributed to the heart the origin and control of emotion and thought, was based on the observation that the heart is keenly susceptible to the influence of mental conditions, and is, of all organs, that by the alterations in whose action the emotions are most distinctly shown. Many forms of sensations and mental states, especially those which are pleasurable, or those of fear, accelerate its action; feelings of self-consciousness and shame also excite it; sudden shock or sorrow render the action slower and less efficient, or may even temporarily arrest it, causing syncope or fainting. With these emotional states the whole circulation sympathizes.

Mechanism of blushing.

By the action upon the blood-vessels through certain nerves in the neck, mental emotions of self-consciousness or shame cause the muscular walls of the superficial blood vessels of the face and neck to relax, and the face and neck become suffused, producing the phenomenon of blushing. Conversely, with the diminished heart's action of terror, shock or sorrow, unnatural pallor may be produced by the opposite condition of vascular contraction. This close connection of the action of the heart with emotion through the central nervous system, is characteristic especially of man and the higher warm-blooded animals. It is among these alone that stoppage of the heart and cessation of life are simultaneous; for among the lower forms of cold-blooded animals the heart may continue to beat long after the animal is dead. If in a frog or a tortoise which has been killed by beheading, the heart be taken out from the body, it continues to beat even when placed on a plate; and if cut up into pieces some of the portions continue to act for a considerable time after separation.

Heart in cold-blooded animals acts after death or removal.

Heart not under the influence of the will.

The heart is not under the influence of the will, and cannot be stopped by any voluntary natural act. By modifying the breathing and by position we may indirectly affect it, as in the celebrated case of Colonel Townshend,[1] but it is beyond the control of simple volition. So perfect, however, is the involuntary mechanism which regulates the heart and circulation, that they are continually being modified. From moment to moment, changes are occurring in the different organs, so that the quantity of blood required by each needs a continual adjustment. When food is introduced into

[1] Dr. Cheyne, in 1734, describes certain observations made by him upon a certain Colonel Townshend, who professed to have the power of stopping his heart at will; but the case is one of great obscurity and uncertainty, and the evidence that he really possessed the ability so to do is very imperfect and inconclusive.

the stomach the organ immediately requires, and immediately obtains an increased flow of blood: so the brain, so the muscles when they are in action, demand and receive increased nutrition. A practical deduction from this is plain, that as little exertion as possible should be made during the taking place of the earlier stages of digestion, when an increased flow of blood is required by the organs which secrete the fluids used to dissolve the nutritious parts of the food.

The blood itself deserves a special notice. An everflowing stream is a necessary condition for the maintenance of the life of the brain, and through it of the body,—so in this respect "the blood is the life." The human body contains about twelve pounds weight of this fluid, which owes its red colour to the myriads of little bodies, called red corpuscles, which float in it. These are in such enormous numbers, that they make up about five pounds of the weight of the blood. Each one is flattened like a coin, only biconcave, not plane on its surfaces. Their size is exceedingly minute, for if piled up on each other in a column, like so many pennies, it would take twelve thousand to make a pile one inch in height; and if spread out flat on a plate of glass, closely edge to edge, it would take ten millions of them to pave a square inch of the glass with one layer of them; and yet so many of them are there in the blood of an adult man, that if all

The blood.

Its quantity and constituents.

The blood corpuscles.

the corpuscles of the blood were thus spread out, they would pave an area of 3000 square yards.

Respiratory function of the red blood-corpuscles.

These minute bodies have a remarkable function. We have seen that during every vital action in the body, a process of combustion or oxidation takes place in the tissues. The air taken into the lungs in the process of breathing contains oxygen, and these little blood-discs absorb this gas, and in them it combines with one of their constituents. They carry this gas to the tissues, part with it where it is wanted, and thus are the agents whereby the real work of respiration is carried on; the products of combustion being returned to the lungs, dissolved in the fluid parts of the blood.

IV.

Speech a human attribute.

The apparatus of speech is one of the most characteristic parts of the human organization; for although the organs which are used for this purpose are common to man and the lower animals, yet in him they have attained to a degree of specialization far beyond that found in any other animal; to none of whom is real articulate speech physically possible, except in the form of the feeble parody artificially induced in speaking birds, such as parrots and ravens.

In making intelligible communications with his fellows, man makes use of noises of two kinds, voice sounds and speech sounds. The first series of these, or voice sounds, are produced in the gristly box, called the *larynx*, which can be felt in the throat below the chin, and to which the familiar name "Adam's apple" is given, from its greater prominence in males than in females. Through this box the air passes, in breathing, from the mouth into the windpipe, on its way to the lungs and back again; and in the middle of this organ, its cavity is narrowed to a long chink or fissure, bounded on each side by a thin, sharp-edged, elastic, membranous fold, projecting inwards as a shelf from the inner wall of the larynx. To these folds the name *vocal cords* is given, and the chink between them is called the fissure of the glottis. In the process of ordinary breathing this chink is wide, so that the column of air can pass through without influencing the vocal cords; but when, by the actions of certain little muscles, the two vocal cords are made to approximate, then the fissure is narrowed to a long and very straight slit; and in this condition, if the air in the lungs be breathed out forcibly, the two sharp edges of the cords are made to vibrate like the reeds of a harmonium, and the column of air contained in the cavity between this and the mouth is affected, and by its vibration produces the audible voice.

Voice and speech distinguished.

The organ of voice

Method whereby voice is produced.

The nature of the sound produced depends on

Physical conditions which modify the vocal sounds.

certain physical factors. Upon the natural length of the cords the variety of voice is dependent: the shrill high treble of the child is due to the short cords in the undeveloped larynx. The soprano of the female depends on her smaller larynx; while the baritone and bass of the male are associated with the greater length of the vocal cords. In the growing boy a sudden change takes place in the size of the larynx about fourteen years of age; and coincidently with the beginning of this accelerated growth, the lining membrane becomes thickened and vascular: hence the note of the voice is suddenly altered, producing the characteristic cracked voice at this period.

Tone, pitch and timbre.

As these vocal cords can have their degree of tension very much varied, so the note produced, which depends on the tension and length of the cords, is liable to vary. The loudness of a sound is due to the amplitude of the vibration, and depends on the force of the out-breathed blast; while the quality depends on the character of the lining membrane, the shape of the throat and mouth cavity, the arching of the palate, the position of the tongue and lips, and the regularity of the teeth.

Voice not peculiarly human.

Voice is not a peculiar attribute of man; indeed, there are few of the higher, air-breathing vertebrates which are quite dumb; and many, like the finches, mocking-bird, and nightingale, have a great range in their singing voice. But man can voluntarily produce a series of sounds far more extensive than those which can be made by any animal, and can vary them in order and combination, in a way and to a degree unexampled elsewhere; but voice is essentially inarticulate, and requires to be modified or supplemented by sounds produced in the mouth before it becomes genuine language.

Speech differs from voice.

With every fundamental note produced by a musical instrument, or by the vibration of the human vocal cords, there is always associated a harmonic series of higher sounds, which are called *overtones* of the primary note. It can be proved by experiment that, by varying the shape of the cavity through which the sound waves pass from the producing instrument, the relative strength of these can be made to vary, as there is correlated with each of these sets of overtones, a peculiar shape of cavity capable of intensifying it, and of commensurately enfeebling others. If, for example, we elongate as much as possible the cavity which extends from the top of the larynx to the lips, by depressing the former and protruding the latter, and if, at the same time, we narrow the aperture of the protruded mouth, the overtones which become intensified produce the vowel sound which we represent by the letter *u* (*oo*). When the opposite condition is produced, and the cavity

How vowels are sounded.

The influence of the shape of the resonator upon the quality of the sound.

shortened as much as possible, with raised tongue, and narrow, transversely slit-like mouth, the vowel sound produced by the intensified overtones is *ee*, while other altered conditions are correlated to the other vowel sounds.

Relation of each vowel sound to a particular note.

Each vowel shape of the mouth is correlated to a specific note, and singers have learned by practice how much easier it is to sing a given vowel on its appropriate note than on any other. This can be experimentally proved by making the mouth cavity into a series of vowel shapes, and holding before the aperture a series of tuning forks sounding feebly. It will then be found that when the appropriate fork is held before the mouth formed into the correlated shape the sound becomes immediately intensified. With the common Jew's harp we can, in like manner, produce almost any vowel sound, by altering the shape of the resonating cavity of the mouth to which it is applied. These experiments show that the *u* sound is produced when the mouth is in the shape which resonates with the tuning-fork of B flat in the bass clef, and the other vowels correspond to other notes. The vowels are thus laryngeal in their production, but are mouth sounds in development. Other elements are, however, required to produce articulate speech.

Experimental proofs.

How consonants are produced.

When, coincidently with the production of vowel sounds, the current of vibrating air traversing the cavity of the mouth is suddenly interrupted, and then renewed, an explosive sound is superadded to, and modifies the vowel sound; these explosives we call consonants, and they vary according to the part of the mouth or throat where the closure takes place. When the interruption takes place by closure of the lips they are labials, as *b* and *p*, but they may be dentals, palatals, or gutturals when produced by contact of the tongue with the teeth, palate or throat. Sometimes the closure is but partial, then the sound is not interrupted but continuously modified. Sounds of this kind are called aspirates and sibilants.

Units of human speech.

By these varying methods the human speech-organs can produce three hundred and seventy distinct sounds, of which at least sixty are vowels, and three hundred and ten are consonants. Of these we use, in English, not more than seventy-six, of which only fifty are of common occurrence.

Some peculiarities of the production of speech sounds.

When we consider the small space occupied by the organs of speech, the small range of motion permissible to each, and the enormous differences in the produced sounds due to very slight variations, the definition and range of the speech sounds is remarkable; and it becomes more interesting when we note how closely the physical conditions of the parts about the mouth are associated with peculiarities of sound, and even with characteristic differences of dialect. The

Physical basis of difference in language.

narrow high palatine arch of most Indo-germanic races is associated with the capacity of sounding the cerebral *r* and cerebral *t*, sounds which are difficult or impossible to be produced by races with wider, flatter palates. Similarly the absence of sibilation in some languages, as in many of those of the South Sea Islands, the replacement of *l* by *r* or the converse, and the use of a prosthetic nasal, noticeable in so many African languages, are likewise explicable by the existence of small variations in physical conformation of the mouths in different races. In this respect Philology is really but a subdivision of applied Anatomy and Physiology.

Marks of design in speech.

But, in another aspect, the correlated conditions which render articulate speech possible, are worthy of consideration as a prominent evidence of design. The differences between the physical processes which produce the specific sounds are slight, and the conditions under which any of these sounds can be produced are narrowly restricted. To an animal with larger jaws and a longer tongue, speech of the human kind would be physically impossible.

The organs of speech only instruments, subservient through the nervous system, to the intelligent mind.

The co-existence of the even curve of the teeth, the short concave vault of the palate, the broad, mobile-tipped tongue, and the comparatively free thin lips, with laryngeal cords possessing a wide range of vocalizing, is necessary to a speaking animal. But, behind all these physical parts of the apparatus, there must be the co-ordinating nervous centres directing the order of movement of all these parts, and above this there must be the mental power of formulation of words, and the capacity of associating definite mental conceptions with separate sounds, which makes the difference between the speech of the intelligent man and the meaningless babble of the idiot.

V.

Law of cycle in human life.

In the phenomena of human life there is noticeable a certain regular law of periodicity: the actions of the heart, the rhythm of inspiration and expiration, the morning and evening rise and fall of temperature, the recurring need to take in food, and the regularly required period of sleep, are instances of this tidal ebb and flow of activity. Throughout the whole body, work and rest must alternate, for work means transformation of the living tissue, which must be built up again during rest. The state we call sleep is, for the brain, what rest is for the muscle. During sleep, all volitional work is suspended, and the organs influenced thereby have a rest; the automatic work of the brain is stopped, and consciousness is temporarily obliterated. As the transformations of tissue are much diminished, the heart's beat becomes slackened both in frequency and force, and the respiration also diminishes in depth and rapidity. The

Sleep.

Diminished oxidation during sleep. changes in the tissues are slow, and the waste minimised, so, though nutrition is also lowered, yet repair can now take place with little interruption; and those waste products of cellular activity which have been produced in quantity during the working hours of wakefulness, and which, towards evening, have clogged the living tissues, can now be got rid of, and by passing into the venous blood are removed from the body by the appropriate system of purifying glands.

Practical deduction. That rest may be enjoyed to the best advantage, there should be as little visceral work as possible going on during sleep: hence, it is desirable that no food should be taken within at least two hours of the period of rest.

Life cycle of the individual. In the life cycle of the individual, three stages may be distinguished. In the first, nutrition proceeds actively, and repair and growth exceed the waste. Within this period the body increases in size and power; the brain, which at birth is of the capacity of 350 cubic centimetres, grows in two months to the size of 500 cubic centimetres; and by the tenth year is two and a half times larger still; becoming three times this size, or about 1500 cubic centimetres, in the adult.

On attaining to full growth, waste and repair proceed *pari passu* during the middle period of life, and finally in the third stage of the cycle, waste begins to exceed reparation, and the tissues, imperfectly nourished, undergo change, diminution, and degeneration: this is the stage of old age. If there were no disturbing external influences in operation, life would end by a gradual sinking or dissolution; but in the whirl of opposing forces among which we live, some jarring condition is constantly being brought to bear on the organism, whose molecular forces are weakened with advancing waste, and this suddenly interrupts some of the vital processes. If, for example, too little or too impure blood be sent from the heart to the brain, cerebral action is stopped, the nervous centres which superintend circulation and respiration become paralysed, and both these functions become for ever suspended. If, on the other hand, some of the vessels in the brain, with walls degenerated in texture, from want of nutrition, are exposed to an undue strain of increased blood pressure, the coats give way, and effused blood presses on and disorganizes the nervous centres. Some such event interrupts nutrition and causes death, the great change. Before it, the organism was a unity made up of mutually co-operating, integral parts. After death, each organ, each molecule, becomes independent, and undergoes chemical change, which rapidly eventuates in the total disintegration of the whole organism, and the dust returns to the earth as it was, and the spirit returns unto God who gave it.

Death usually not due to simple decay

Death from stoppage of brain's action.

Changes produced in the organism by death.

VI.

The body a temple of God.

"KNOW ye not that your body is a temple of the Holy Ghost;" wrote the Apostle Paul to the Corinthians. He thus indicates what is the highest design of the body of man, and though this temple is, like all things earthly, corruptible, yet it is worthy as a dwelling-place of God. It is a temple excellent in beauty. The sculptor and poet have exerted their highest skill in the representation of it. It is a temple admirable in architecture. Its structure has excited the adoring wonder of the Psalmist. It is choice in material, as we have seen in our foregoing studies. It is a temple whose perfectly organized arrangements for repair can long resist and restore the dilapidations of time and accident; cleansed externally by five million sets of external cleansing glands; ventilated by the most perfect apparatus for the admission and thorough transmission of pure air, and for the removal of the impure; heated by a perfect self-acting system of hot pipes; lit by windows of surpassing complexity; having every part connected with its fellows by an almost instantaneous system of communication, which centres in the shrine of the temple, the seat of the conscious mind; and if those temples which we see round about us are not thus

Its beauty.

Its fitness.

Its organized arrangements.

perfect in all particulars, it is because they have been defiled and neglected, turned to base purposes, and degraded from the high calling to which they should have been consecrated.

Lesson from study of human structure.

The prominent lesson which the examination of the human body impresses on us is that of perfect adaptation of means to ends, of structure to function. The unprejudiced mind cannot fail to read in every organ, nay, we may say in every cell and fibre, the inscription of purpose, and to learn thereby that they are the products of supreme power directed by supreme wisdom.

Purpose inscribed upon it.

The crown of creation

Man thus stands forth as the crown of creation, the chief of the works of God, even when we confine our view to that portion of his organization which allies him to his lower fellow creatures. But when, in addition, we consider him as an intellectual being, bending the forces of nature to his will; or as a moral being, with a conscience and a sense of right and wrong, or as a religious being, with hopes and aspirations raising him to seek communion with God, we are constrained to say with the Psalmist, "Thou hast made him but little lower than God;"[1] nay more, for hath not God Himself, in the person of His Son, in order to our salvation and restoration to His own image, condescended to take upon Himself our nature, so that the perfection of manhood is the "measure of the stature of the fulness

[1] Psalm viii. 5. Revised Version.

His future destiny.

of Christ." The Christian revelation assures us that man will yet be exalted to a position inconceivably more glorious than that which he has hitherto occupied, for as human nature in the person of Christ, is seated at the right hand of God, even so shall those who by faith are united to Christ, be elevated to bear the image of the heavenly. For He "shall fashion anew the body of our humiliation that it may be conformed to the body of His glory according to the working whereby He is able even to subject all things unto Himself."[1]

[1] Philippians iii. 21.

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