The blood, anatomically, physiologically, & pathologically considered, with a view to exemplify or set forth, by instance or example, the wisdom, power, and goodness of God, as revealed and declared in holy writ / by Charles Edward Joseph.

THE BLOOD,

ANATOMICALLY, PHYSIOLOGICALLY, & PATHOLOGICALLY CONSIDERED,

WITH A VIEW TO EXEMPLIFY OR SET FORTH,

BY INSTANCE OR EXAMPLE,

THE WISDOM, POWER, AND GOODNESS OF GOD,

AS REVEALED AND DECLARED

IN HOLY WRIT.

THE WARNEFORD PRIZE ESSAY,

FOR THE YEAR 1845.

BY CHARLES EDWARD JOSEPH, M.R.C.S.

Formerly a Student of Queen's College, Birmingham.

"Εν αὐτῳ γὰρ ζῶμεν, καί κινούμεθα, καί ἐσμεν· ὡς καί τινες τῶν καθ' ὑμας ποιητῶν εἰρήκασι· τοῦ γὰρ καί γένος ἐσμεν."

"For in Him we live, and move, and have our being; as certain also of your own poets have said, For we are also his offspring."

ACTS xvii. 28.

LONDON:
J. CHURCHILL, PRINCES-STREET, SOHO.

BIRMINGHAM:
W. B. MARCHETTI, NEW-STREET.

DEDICATION.

TO ONE,
WHO HAS DEVOTED HIS LIFE, ENERGIES, AND RICHES
TO THE GOOD OF MANKIND,
WHO HAS MORE ESPECIALLY DIRECTED
HIS UNCEASING PHILANTHROPY TOWARDS THE YOUTH OF
A MOST USEFUL AND HONORABLE PROFESSION,
AND BY THE
INSTITUTION OF THE WARNEFORD PRIZE
AT THE QUEEN'S COLLEGE, BIRMINGHAM,
HAS INCITED STUDENTS IN MEDICINE
TO MINGLE AN EARNEST SPIRIT OF RELIGIOUS INQUIRY WITH
THEIR LABORIOUS PHILOSOPHICAL RESEARCHES,
To THE REV. SAMUEL WILSON WARNEFORD, LL.D.;
ALSO TO ONE,
WHO, TO THE LUSTRE OF AN ANCIENT AND FAR-FAMED ANCESTRY,
ADDS THE GREAT EXCELLENCIES OF
UNAFFECTED BENEVOLENCE, AND UNOSTENTATIOUS LEARNING,
AND WHO HAS DEEMED IT NOT UNBEFITTING HIS HIGH BIRTH, AND
SENATORIAL AND TITULAR DIGNITIES,
TO BECOME THE
PRINCIPAL OF THE QUEEN'S COLLEGE
OF MEDICINE AND SURGERY,
To THE RT. HONORABLE LORD LYTTELTON, F.R.S.;
TO THESE TRULY GREAT MEN
THIS ESSAY IS MOST RESPECTFULLY DEDICATED BY THEIR
OBEDIENT SERVANT,

CHARLES EDWARD JOSEPH.

Tipton, March, 1846.

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CHAPTER I.

INTRODUCTION.

MYRIADS of human beings, by the abundant mercy of God, live, flourish, and die peacefully in the fertile valleys and wide-stretching plains of our earth, and it would be thought that all these would lift one united human voice, to praise the beauty and perfection of creation without a dissentient murmur. Such would be the first impression of a grateful mind, but the conclusion is false, the hope is deceptive, the murmurers and the heedless are many and various in their modes of expression. Some there are, who, tinctured by a morbid despondency, look around them with "lack lustre eye," and see no beauty in the bright skies, no mercy in the plenteous herbage, and feel no freshness in the breeze; they receive and employ the gifts of a bountiful Providence sullenly and doggedly, as a prisoner takes his food from the hand of his gaoler, and devours it unthankfully. If, in the depths of their gloomy minds, they acknowledge the existence of a Deity, they do this, solely, in the presumptuous impotence of their folly to blame him, the Maker and Giver of all good, that he has placed them in a condemned world, to labour and groan under the curse which hangs over it. Yes! truly they are cursed, cursed with blindness. There are other men, living immersed in sordid and mere earthly pursuits, degraded by their passions, and looking upon all nature's glories and wonders as matters of course, as actions which will continue because they have always been performed; these feel a meagre animal pleasure in those natural events appealing more especially to the senses, in the same degree as those animals which have lain torpid all the winter, when they crawl forth to bask in the

first sunshine of spring, but here their love of nature (if I may thus prostitute the expression) ends. They think not of the hand which has placed the sun to send down his pleasant beams, gladdening the earth and its dwellers, and which waves the currents of air hither and thither, either sending them down in fertilising showers, or whirling along in the fiercely-moaning and pealing tempest,—for they look not "From nature up to nature's God." Happily and truly has the poet Wordsworth described the effect of natural objects upon one of this character,—

> A cowslip on a river's brim,
> A yellow cowslip was to him,
> And it was nothing more.

But there are others still, and let me hope numerous, who turn above, around, and beneath them, the inquiring gaze of grateful created beings, and to eyes that search thus, the brightness of God's hand is ever visible, shining through the dusky spots with which man's passions and madness have blotted the clear pages of his world-book, and rendered, if possible, more lustrous by the contrast. The curse which God laid upon the earth and disobedient man, is, in their eyes, no longer an anathema, it is the omnipotent fiat which has placed cities and temples of worship, happy homes and joyous faces, where, in former time, the thick forest-tree spread perpetual twilight, and the howling wild beast and yet wilder man held their fitting habitation, fighting in their lairs for brute mastery. They see that man has laboured, and bringing up the treasures of the earth to assist his toil, has made the air he breathes lessen his labour, and the dread element which once almost destroyed man and his works from the face of the earth has become his willing servant, either bearing him gently from shore to shore, or whirling him on, through hill and valley, darkness and sunshine, to his destination. The word which God spake in his wrath was breathed upon by mercy ere it touched the earth and man, and mercy mingling with the curse, labour became a boon to the good man, giving a glad and grateful heart, vigour of mind and

body, happiness and contentment, it proved a curse only to the indolent and worthless This see the true philosophers of the earth, lovers of the wisdom which flows through all nature, they see in the smallest of his works enough to stamp upon it the impress of an almighty maker, and are lost in amazement as they view the stupendous whole towering far above man's puny conceptions, and yet each tiny individual atom of the vast structure harmonizing with its fellow for an all-wise end. The same power is visible to their eyes in the fragile plant which springs out of the black earth, covering its face with greenness and beauty, as in the rushing storm, that devastates the forest, laying the lofty trees low, and sparing not the proud works of man. When the morning sun shines upon them, or the evening dew falls refreshingly, the shadow of his goodness steals over the heart, bringing warmth and purity, and prompting good deeds to their fellow men. In times long past, men died upon the earth untended; when wounded in their wild strifes, the tide of life flowed unceasingly on, until the fountain was dried up, and when sickness came upon them, it was sent from the gods, and they bowed down their heads to die. Good and wise men arose from time to time, enlightened doubtless by a higher power, who discovered new means of healing, and sustaining life, and administered the rude remedies of their brethren with greater skill, and God looked down upon them and saw that the work was good, for it was god-like, and he blessed and prospered their skill. Centuries rolled away, and generations, each one as it fell, adding to the treasure of knowledge, and the glorious science lived triumphantly through the dark period of intolerance, when knowledge was a crime and thought was sin, and spread its fast-increasing light over wider realms. Many gifted men have devoted their lives and energies to add fresh stores of knowledge to the already accumulated treasure; and now in our own times, amid civilization and peace, it flourishes for the service, and with the honor of mankind, strengthening daily by the tributes of every language in which its blessings are known.

When it is thus seen how the great Creator has not only given man whatever is sufficient to sustain the body when in health, but has also with lavish profusion spread over all the earth productions intended to heal the diseases to which his frame is subject, emotions of deep gratitude must arise in every discerning mind. And following this humble acknowledgment which we may make for all his bounties, a feeling of intense wonder must be awakened, when we reflect that the God who, among a multitude of worlds, made this planet, vast as it is to our ideas, teeming with innumerable millions of beings, and governed by numberless intricate and exquisite influences, has yet placed all within the reach of man's weak intellect, so that the wise and good may seek to comprehend the secrets of his power for means of alleviating the pains of their fellows, and stilling, with soothing skill, bosoms heaving high with agony. As we recognize this wondrous adaptation, we must in our hearts acknowledge that nothing but Almighty Wisdom could thus accommodate all his works, alike the grand, elaborate through all their great extent, and the small, vast in their multitudinous minuteness, to the mind of his creature man, that mind so fine and fragile in its constitution, that a comparatively small injury inflicted on the body will sometimes destroy the balance of its powers.

The question naturally here arises, "How shall man best show his gratitude for the favours surrounding him, and the means of enjoying those favours he finds in the faculties of his mind, the far noblest part of himself?" By using them not merely for his own selfish gratification, but for the good of others and the praise of the giver, always recognizing the hand of eternal benevolence. By exercising the noblest faculties he possesses, in seeking to discover the attributes of the Omnipotent even in what to his clouded view appear the meanest of his works, or in describing with all his limited eloquence the plainer traces of the supreme Power which ennoble his fairest creatures. Nor will such an employment be prosecuted without great advantage to himself. As the plant, springing from some dark nook, creeps forth and

turning toward the sun, becomes green and flourishing from the light he gives, the sun still shining brightly as ever, for the plant cannot rob him of his beams; so man, when he elevates himself above the darkness of human affairs, to contemplate the works of the Being above all others, feels the light of Eternal Truth, alone to be found in God, shining into his soul, making him wiser, purer, happier.

The truly benevolent benefactor of the College of which I have the honour to be a Student, had, I presume, such weighty reasons as these in view when he instituted a Prize for an Essay on any subject of Anatomical and Physiological Research, treated so as to shew in the clearest possible light, from the conclusions of science, the Wisdom, Power, and Goodness of God. Probably this great and good man has thought that a Student could not be better occupied, preparatory to his becoming in a great degree responsible for the lives of others, than in possessing himself to the utmost capacity of his mind, of full and just ideas of the glorious nature of that Being to whose merciful decrees he will owe all his success in saving those lives. Many infinite advantages in prosecuting such a labour and duty, his mind may have conceived, which I am incapable of expressing, however the former are, I judge, far more than sufficient to attest the importance and interest of the theme, and I fear also, to confound my temerity in attempting it.

Throughout all nature, animated beings possess the most interest for the observer; their endowment with some degree of life gives them a silent claim for the attention of one who is living and able to feel and appreciate the fulness and value of life. The study of the vegetable kingdom is extremely interesting; and fascinating as it is, from the varied beauty it possesses, it is not surprising, considering their lack of knowledge, that the ancient inhabitants of Greece and Rome gave, in their fanciful mythology, to the lofty spreading tree its attendant and inhabiting nymph, and pictured those who were remembered as the most beautiful of former times, to be changed into the fairest

and most graceful flowers. Beautiful but airy dreams! how much better is our enlightened belief, who can see in these elegant structures the evidence of God's handiwork and the features of his goodness. But the lowest form of animal life, which possesses the least degree of voluntary motion, has an interest in itself, for the man of science, which the most lovely and various-coloured flowers, or trees of the most luxuriant foliage, made to delight and relieve the eye of man, when tired of labour, have not. As we pass from the vegetable kingdom to that of animals, we find some creatures which at first sight resemble the former so much more than the latter, that it is difficult to decide to which they belong; but when it is decided that they are possessed of animal life, at once we view them with an interest far greater than we before experienced. I allude to those singular plant-like animals, the sponges.

We pass then up through the various grades of animal life, from those animals which possess little voluntary motion, and seem to be mere tubes remaining stationary and deriving sustenance from the surrounding and contained substance to creatures which possess the power of motion in a high degree, either those which skim through the yielding air on an untiring wing, or the many tribes which dart with lightning speed down in the quiet depths of the sea, or yet the numerous animals with various degrees of strength and speed, which abound in the forests and pastures of the continent. Our interest in the pursuit increases as the objects of it exhibit more varied powers, and more complex organization, and ample reward is given for the labour. In all these animals we see abundant evidences of an Infinite Maker, their structure admirably adapted for the situations in which they are found, and their powers equally bestowed in relation to their wants. But in man we see the perfection of God's workmanship, his frame, at once beautiful, and complicated in structure, the functions of each part harmonizing with the duties of the rest, so as to secure constant and willing obedience to the dictates of the restless and continually-agitated spirit that inha-

bits it; all these present a study worthy and capable of absorbing the highest faculties he himself possesses. Even if there were no immediate utility in the pursuit of such science, still it would be eminently worthy of attention for its intrinsic beauty and interest; but when it is remembered that upon its prosecution there have depended, and still depends, the lives and happiness of thousands and millions of our fellow beings, capable of bounding to as high notes of joy, or sinking into as dark depths of woe as we ourselves, then is the study invested with the best of human feelings and interests, and the student buoyed up among difficulties with a high and laudable pride. With views like these, uniting the reverential desire to penetrate the mysteries of the creation, to an amiable and philanthropic wish to alleviate the "ills that flesh is heir to," this study will be eagerly prosecuted, and laid aside with regret.

The subject selected for the Essay of this session is one for which extensive research is eminently necessary. The anatomy and physiology of the Blood leads us to consider the formation of the parts of the body; the maintenance of the functions of animal and organic life; in fact, all the operations necessary for the existence of man are in connection with this subject. Besides these, its relations, when the body is in a condition to perform every function, the influence of disease in its varied forms upon it, is to be considered. Such a tableau of the work before him is sufficient to discourage a young and inexperienced student, and render him fully and indeed morbidly alive to his own glaring deficiencies. With such feelings of unfitness do I come to my task, but nevertheless will not shrink from its accomplishment, trusting that *He* who has given to the greatest of men a beam from his own Eternal Mind, to aid them in the search for scientific truth, and can also bring about grand and glorious ends from the most unpromising beginnings, will even aid me in my feeble efforts to see fresh proofs of his great attributes in one of the most perfect of his works.

The judicious adjudicators will well know how to make due

allowance for one over whose head sufficient years have not passed to bring the wisdom that follows in their train, and will kindly bear with the errors that may be caused by the hasty judgment of youth. Should I essentially fail in my endeavour, the subject may bring reflections and lead to conclusions which may give me, in after life, an abundant reward for present labour, and have their secret influence when the cause of their adoption is almost forgotten, and the honored minds from which it arose have long been gathered to the centre of all that is good and generous.

CHAPTER II.

THE BLOOD IN A HEALTHY STATE.

I. One of the grand general distinctions between the animate and inanimate creation is change, a constant or frequent variation either of form or place, which the former exhibits, and which at the same time is a phenomenon not to be effected by the fixed laws which exercise power over the latter. Some inorganic products may change in form from the chemical influence of some other body, as from being suspended in a liquid to a crystalline shape, but beyond this dependent and limited variation, one of these substances cannot go, the power of change resides not within itself.

Thus the mighty mountain stands towering up toward heaven, as if in mockery of the loftiest works of man, bearing forests on its giant sides, and crested with the glittering product of many a vast winter cloud; thus stands this huge inanimate mass, incapable of the slightest movement or emotion, or of adding a particle to itself, and ignorant of the treasures which man, with his busy hand, has for some thousand years pilfered from its bosom; while perchance down one of its ravines, a tiny brook runs and ripples blithely, in each sparkling drop of which are millions upon millions of creatures, each one superior to the great mountain, for it lives, and sports away its brief life, capable at once of feeling and enjoyment. It is true we sometimes see great changes effected in inanimate objects, as when the volcano hurls forth a storm of broken rocks, and pours from its flaming mouth a stream of burning lava, but when these phenomena occur, the substances involved in them are destroyed: destruction of the changing bodies always accompanies this process in inorganic

nature. But not so with structures endowed with life; they vary daily and hourly, and with the revolving seasons, and during all their variations increase in size, and even produce other individuals of the same species, performing this last action without any necessary destruction of the producer, and thus presenting another essential difference to the inanimate substance which cannot add one particle to its own mass.

II. We cannot for a moment suppose that an animal or even vegetable performs these functions of growth and reproduction merely by virtue of the frame possessed at the time of its original production. The same ultimate elements of which its frame is composed, enter into the formation of inorganic substances, and as we have seen how they are destroyed by change, it is reasonable to infer that, unless renewed, inevitable destruction to the animated structure would in process of time ensue. For the maintenance of these functions of growth and reproduction, matter must constantly be supplied, and we must hence inquire from what source animated productions derive this constant supply. The apparently lifeless seed is dropt upon the ground, and if it fall in a moist and kindly spot of earth, and the sun shines warm upon it, it soon springs up, putting forth leaves, at the same time sending through the earth thin fibres, termed roots, which last absorb certain materials from the soil, and these materials ascend in prepared vessels along the slender stem to the leaves, there to be submitted to the influence of the atmosphere; afterwards to be transmitted down the stem, fully fitted in passing to add to the bulk of the plant. By this continual process the plant grows, and spreads on every side its branches and leaves, and in due time bears its seeds and lets them fall, to undergo a similar transformation, and by this continual supply is the plant enabled to put on fresh foliage every succeeding spring, thus especially asserting its distinction from the inanimate world. In like manner an animal, even in the most simple form, admits, or forcibly takes into its interior, where are special organs placed for the purpose, some neighbouring substance, which is then

converted into the form best fitted to traverse the parts with ease, and repair the waste which is caused in different parts of the animal's body by the necessary motions, and thus sustain it for its other duties. The form into which foreign substances are thus changed for the service of beings endowed with any degree of life, is both in the animal and vegetable kingdom that of a fluid.

III. We have thus seen that the general distinctions between animated and inanimated beings are, first, the former possessing powers of change of place, or form, or both, as animals change in form and have power of locomotion, while plants only change in their summer and winter appearance; next, both vegetables and animals increase in size; and last, both kingdoms have the faculty of reproduction. It has also been seen that for the maintenance of these distinctions, without which the creature would cease to exist as an animal or vegetable, it is necessary that foreign bodies should, by the powers of the system, be converted into a fluid, in that form to traverse the different parts of the entire being. In the vegetable kingdom its individuals are enabled, by this arrangement, to carry on what may be properly termed organic life, that is, they increase in size and undergo the customary changes, and produce other individuals of their species, but they are incapable of any degree of voluntary motion or sensation. Animals, on the contrary, possess not only the functions of organic life, but also those of voluntary motion in different degrees, and sensation, termed animal life. I have, in the present Essay, to consider the fluid into which foreign substances are changed under the influence of a process of organic life in animals, and which, by the aid of other structures, enables both modes of life to proceed in the same frame.

IV. Before proceeding to a consideration of the Blood in its natural state, as the present information directs me, it would be advisable to see how the knowledge of this most interesting and intimate component of the body has progressed since the infancy of the science of medicine. There is little doubt that a very

slight degree of experience and thought would teach the first medical practitioners, surrounded as they would be by all the fierceness of barbarian manners, ready to take life at the slightest provocation, that blood was an essential requisite of life, the loss of the greater part of the one causing the speedy departure of the latter; but it is improbable that their knowledge of it extended beyond this simple fact. The earliest mention of the importance of the blood to the animal frame is in one of the books of law given to Moses expressly for the ancient Jews; there it is stated, "For the life of the flesh is in the blood," Leviticus xvii. 11; and while the Jews were forbidden to eat flesh containing it, this short and comprehensive sentence is twice repeated. Amongst the nations not favoured by the direct interposition of Divine Providence in their favour, the Greeks were most advanced in the science of medicine, as they were in all other pursuits of the beautiful and useful that then flourished, and Hippocrates, the first of their physicians whose writings are handed down to us, in whom we find mention of the blood. It has been said by some that Hippocrates had some idea of the circulation, but in this I think they are giving him credit for that which he did not possess, as this is not shown by his writings, the only criterion we can have. It appears to me that this great physician, left without the guidance of facts upon this important subject, believed the doctrine of humours, which I shall now describe, as it appears to us, a strange union of much absurdity with a little truth. The body was believed to be composed of the four elements, as they were then called, earth, air, fire, and water, influenced by as many qualities, as cold and hot, moist and dry, and giving result to four different fluids, thus in the cold and dry state, melancholy or black bile, in the hot and dry state, choler or yellow bile, in the cold and moist state, phlegm, and in the hot and moist state, blood, properly so called; and I believe some afterwards improved upon this system by supposing all these four fluids afterwards to join to form the blood for the nutrition of the body!! A most elaborate composition truly,

and a worthy one for the genius of Hippocrates to purify, if it ever could become needful. We find that this system was very generally received by the ancient physicians, and probably the satisfaction and contentment they felt in thus reposing upon their favourite theory, prevented their making great advances towards the truth. Nevertheless we see, as we proceed, some slight approaches made to an investigation in this, the foundation of all physiology. Some time after Hippocrates, his successor and countryman, Praxagoras, wrote a treatise upon the pulse as a symptom in disease. Succeeding this, and about three hundred years before the Christian era, I remark with pleasure that Erasistratus, of Alexandria, devoted considerable time to the study of anatomy, dissecting the heart and large vessels, and even possessing some idea of the absorbent system, while his friend, Herophilus, was, according to the testimony of cotemporaries, famous for his accurate remarks concerning the pulse. I pass, then, through a long list of physicians without finding any thing upon this subject worthy of my search; the one sect of empirics were too much afraid of trusting themselves beyond the limits of past experience, and present symptoms, to be addicted to anatomical and physiological research; and the other and bolder division of dogmatics were inclined to accommodate every fact, however discrepant, to their favourite preconceived theories, and allowed no idea which might enter the minds of the more sagacious long to oppose itself to the reigning system of philosophy. Celsus, and his great successor Galen, do not appear to have opposed the prevailing doctrine of elements, qualities, and humours, although the latter wrote upon the varieties of the pulse, and believed a limited kind of circulation to be necessary to life. Now was the Romish empire fast passing away, and with it the great opportunity of advantage to science; I allude to the union of so many nations under one sway, and the knowledge of the Greek and Latin languages over so vast an extent of the then known world. And following this came centuries of desolation and decay, when the faint gleamings of neglected science were

scarce seen through the thick cloud of lawless passion and unabashed ignorance, barbarian violence, and monastic superstition that rested upon the earth. From the seventh to the twelfth century, the Arabian physicians were the most famed, and justly so, for their attention to chemistry, a subject of eminent importance in medicine, and more especially useful in the prosecution of physiological study. The fourteenth century brought a great step in the science of medicine. Hitherto anatomists, in the pursuit of their study, had only dissected the animals supposed most similar in structure to man, seldom or never venturing to examine the human body, but then Mondini, professor of anatomy at Bologna, publicly dissected human subjects, and published the result of his researches. This will be at once seen to have great influence upon our present subject. The next age is found to have produced a sect of physicians who believed the entire body, fluids as well as solids, to be subject to the same laws as inanimate matter. Vesalius and others discovered, in the sixteenth century, many of the errors which the ancient doctors taught in their anatomy, thus making another important step. It appears that about this time, physicians generally believed in a limited kind of circulation, namely, that blood passed out from the heart by the veins as well as arteries, the nutritious portion by the former, the spirituous part by the latter, but that none of this same blood returned to the heart, being expended for the repair of the system; a chyle was said to be absorbed by the mesenteric veins, conveyed to the liver, there to acquire the colour of blood, and from thence in that form to the heart. This very imperfect theory was completely put aside in the next century, by the discovery of the complete circulation of the blood, by the illustrious Harvey. It seems that this great man endured much of the opposition which commonly attacks the grandest and most useful discoveries, and their promulgators, for it is said his practice declined in consequence, and his doctrine was disbelieved by the profession. However, the superiority of truth over error is triumphantly shewn by a statement

he makes in one of his works, many years afterwards: "I perceive that the wonderful circulation, first found out by me, is consented to by almost all, and that no man hath hitherto made any objection to it greatly worth the confutation." Attempts have been made since to wrest the honour of this wonderful discovery from his brow. It is certainly true that Michael Servetus, Columbus of Padua, and Cæsalpinus of Pisa, had all of them, in the preceding century, probably incited to the examination by the former researches of Vesalius, asserted that the blood passed from the left ventricle to the lungs, but of the office of this latter organ, and of the real nature of the double circulation, it is plain they possessed no distinct idea. Therefore the attempt, as it merited, has failed. In the same century, organs connected with the formation and aeration of the blood were investigated by anatomists; the absorbent system by Asselli and Bartholini, and the lungs by Malpighi, Hooke, and Mayow. After the circulation of the blood, as taught by Harvey, had become fully established, there were not wanting many to mystify the subject by extravagant theories, as Bellini, who believed it was not any vital power which caused circulation, but explained it entirely upon hydrostatic and hydraulic principles. There were others who adopted a more reasonable theory in connexion with the blood, but not less hurtful when exclusively carried out, namely, that health and disease were to be attributed solely to certain different states of the fluids of the body, more especially the blood; of this opinion were Sydenham and Willis. Van Helmont believed a vital principle to abide in the vessels with the blood, which he called the archæus, but surrounded this opinion with less reasonable suppositions, believing the circulation, and consequently life itself, to be maintained by certain fermentative processes going on in the centre of the circulatory system, and stating the seat of the archœus or vital principle to be the spleen. Boerhaave well combated these fermentative principles, and brought the testimony of Vieussens to his aid. In the eighteenth century, Haller wrote upon the blood, in some

degree distinguishing its component parts. Since that time it has been more fully and philosophically examined in all its composition. In consequence of the advances made in chemistry, the analysis of blood has been performed with more accuracy, and the varieties in its proportions discovered. Through the same medium the essential differences of venous and arterial blood have been better ascertained. The physiology of coagulation, and the means by which it may be accelerated, retarded, or prevented, have been prosecuted. The state of the blood during inflammation, the changes of fibrin, and its exudation on inflamed surfaces, have been studied. These subjects have all been investigated, and proofs drawn from them that vitality exists in the blood as well as in the solids, by Bostock, Berzelius, Hey, Thackrah, Davy, Prêvost and Dumas, Schroeder Van der Kolk, Gendrin, and others. The more particular chemical changes in the blood, and the proximate principles for the formation of animal structures, found in it, have been made subjects for research by Allen and Pepys, Edwards, Collard de Martigny, and others. By this brief summary it will be seen how, from extreme ignorance, we have now arrived at a very considerable degree of knowledge respecting this most important component of the human frame.

V. I have already stated, that a circulating fluid is necessary to all creatures possessing powers of motion, growth, and reproduction, or even the two last of these requisites, and that this necessary of existence is common to all plants is clear. Now as the necessity is greater in animals than in plants, and as moreover this fluid is to be found in all those we can examine well, we may reason, from analogy, that it is not denied to any animal, although, in some few instances, our limited powers of sense do not enable us to recognize it. This we find, on commencing the study of the circulating fluid, among the most minute of the Invertebrata. The class Infusoria, the smallest animals of which we have any knowledge, so small in fact that a great naturalist tells us that 1500,000,000 are capable of exising in one drop of

water, in these creatures it is impossible to discover any circulating fluid, more especially when we consider that in accordance with other classes, somewhat resembling them, the fluid when present would be colourless. Still it is far from improbable, indeed most probable, remembering the vivacity of these little animals, that a fluid in some degree of preparation supplies the waste of their bodies. In the Entozoa, an extremely numerous class of parasitical animals, there is great difference in this point. In some individuals we are unable to discover the circulation of a nutritive fluid, while in others we see a decided vascular system developed. Some of these creatures, then, destined most frequently to live in the very centre of the nutrition and kindly warmth of other animals, would seem to be endowed with the power of absorbing nutritive matter equally at all parts of their bodies. As they possess motion, growth, and reproduction, the last in a high degree, it is most likely they have the same stimulus and mode of supply for these wants as other animals. I pass now to a class of animals no less singular in conformation, and far more independent in habits than the last, the Polypifera. In these, a fluid fulfils all the purposes of nutrition. The animal itself is a mere tube in form, possessing tentaculi at its extremity to retain the matter passed into its cavity. An action immediately commences, by which vessels, opening in the interior cavity, take up matter necessary for the animal's support, and transmit it in the form of fluid to all parts of its frame. Polypi, like the Entozoa, possess the faculty of absorbing nutrient matter by all parts of their body; but this power appears to be at the will of the animal, for we are told if a dexterous manipulator turn one of them inside out, the part of its surface now become the interior will commence the absorption of the required fluid much in the same way as its predecessor in the office. Their singular powers of reproduction are well known. In the Bryozoa, the nutritive fluid is conveyed from the digestive cavity in one long vessel, to be distributed to the rest of the body. In the class Acalepha we find the nutritive fluid passes along a con-

tinuation of the gastric cavity itself to the capillaries, as they may be termed, where it circulates in the same form to which the gastric cavity reduced it. In the class Echinodermata we find three tribes interesting in their relation to the present subject. Of the tribe Stelleridæ, the star or ray fish is a distinguished type; we see here what may be called a true vascular system. From the central stomach and the cœcal appendages which pass to each ray, vessels collect an elaborated fluid, which fluid may be named chyle, they convey it into a circular trunk, from whence it passes through a tube which alternately contracts and dilates, (thus fulfilling the office of a heart), into an arterial circle around the mouth of the animal, and thence is sent to the whole body. Upon all the viscera are placed cilia, which, by their constant motion, excite currents of oxygen for the purification of the blood circulating through them. In the tribe Echinidæ a vascular network surrounds the intestine, which serves for a stomach, and conveys the nutrient fluid into a vessel extending from extremity to extremity, terminating near the œsophagus in a vascular circle which passes round it, from which vessels are given off to different parts. These animals have external as well as internal organs of respiration. The tribe Holothuridæ have a complex circulating system, and only internal organs of respiration. The blood is of a deep yellow colour in this class. We now come to the sub-division Articulata. The class Anellidæ possess a distinct circulatory system, and indeed a complex arrangement of vessels; in some species contractile sinuses are found acting as hearts. The blood of this class generally speaking is red, in some species paler than others, and in some others even of an olive green tint. Some shining, granulated, circular corpuscles may be seen in it of variable dimensions. The frequent divisions, and anastomoses with each other of arteries and veins cause the system to be supplied by a mixture of oxygenated and unoxygenated blood. In the class Epizoa the blood is of a clear colour, and flows in a distinct circulatory system. In the class Insecta there are no absorbent vessels; the chyle,

said to be a greenish fluid, passes into wide irregular sinuses seeming to form a part of the abdominal cavity, but they communicate with ill defined venous receptacles, from which the fluid passes into what may be termed the heart, a long dorsal vessel, in which in the Hexapod insect there are valves; from thence it passes into a tubular aorta, which propels it into every part of the system. The means of aerating the blood in these creatures are remarkable. In the walls of the veins containing blood, in different parts of the body, are interstices through which capillary tubes, passing from the exterior of the body, enter. Down these tubes passes oxygen, thus gaining admittance to the reservoirs of blood, and revivifying it. The blood of this class is generally transparent and almost colourless, and contains globules of a slightly brownish tinge. The Arachnidæ exhibit colourless blood, in which may be seen round colourless globules; in them the fluid, which is formed from their food, is taken up directly by the veins and conveyed to the heart, thence to enter the general circulation. They have internal organs of aeration for the blood. The Crustaceœ have a heart of one ventricle, the office of which it is to propel the fluid to all parts. In one of its species, the Limulus, the aerated and impure blood is mixed in the ventricle. In the sub-division Molluscœ, we first see the class Tunicata. In this class the blood is of a bluish white colour. In some species many individuals are connected, forming a compound animal; in this case, the centre of the sanguineous system is what may be called a hollow *stem* in the centre, from which blood is distributed to the several individual parts of the compound creature. In some of these, the blood may be seen, by watching the globules, to be passing in two different directions at the same time; after a little time the current passing from the heart overpowers the opposing current, and carries it in its own direction. The Lamellibranchiata, to which class belongs the Oyster, possess generally a heart, consisting of one auricle and one ventricle, but in some species we see two auricles. In the next class, Gasteropoda, ranks the

snail, and in this animal we find the blood largely employed in a function we have not hitherto seen so much developed in the animals that have been mentioned. The liver is developed in a high degree, and a large trunk conveys blood to it, there to have formed from it the peculiar secretion of that organ. In the Cephalopoda, as in the other classes of this division, the heart is composed of one ventricle, and the blood, before it enters it, has passed through the branchiæ which fulfil the office of aeration. The walls of the veins are of fibrous texture, and contain small glandular follicles, which are supposed to have the office of secreting from the blood a fluid analogous to urine of higher animals. With this class terminate our investigations among the invertebrate animals.

The vertebrata are seen to be animals possessed of great muscular powers, and consequently habits of motion in a great degree. In Fishes, the heart consists of one ventricle, from whence the blood passes to the gills, and thence the most part flows into an aorto to be distributed to the rest of the body, while a small portion is carried directly from the branchiæ to the head in a state of pure aeration. Reptiles also possess a heart with one ventricle generally, this heart propelling its contents along arterial trunks, some to the system generally, and others to the lungs; the blood returning from the lungs mingles in the single ventricle with that returning by the veins from the system. In some of the higher order of Reptiles, there is an arrangement of those parts more approaching to that of the more perfect animals. Thus in the Crocodile the heart is divided into two ventricles by a complete septum, from each ventricle there is a principal arterial trunk or aorta, but these meet at a little distance from the heart, thus most effectually mingling the blood of the two ventricles. In both Reptiles and Fishes the blood is in some degree red. In most classes we find the red particles much larger than those of warm-blooded animals or birds and mammalia, in frogs more especially they are found to have four times the diameter of those of man. The particles of the blood in these animals

also differ from those of mammalia in their elliptical shape, and in the nucleus being indicated by a central prominence. In the Cetacea and other diving animals we find that the arteries of the trunk have the power of assuming a ramified and convoluted form, so as to contain more blood when the animal is in situations rendering respiration difficult.

It might be thought at first view that I have related many particulars respecting these different classes of animals rather irrelevant to the subject, but I shall be compelled, in treating of the physiology of the blood, to enter much into that of the several organs of nutrition, circulation, and respiration.

VI. We have passed through the various classes of invertebrate animals, as also the lower classes of vertebrata, the cold-blooded animals, or fishes and reptiles, I shall now pause, and endeavour to point out the progression from the lowest to the highest of these in sanguification, in the formation of the component parts of the blood, in its circulation, and in its purification. In none of the forms of Invertebrata do we see lacteals, properly so called. In the lowest forms of Radiata in which we can discern a circulating nutritive fluid, we find it is conveyed sometimes by a continuation of the digestive cavity into the vessels, there to circulate in the same form in which it appeared after the operation of digestion. In the higher forms of the same division the product of digestion is collected by numerous vessels and conveyed towards the centre of the circulation, during which progress, it is probable, its properties are changed, as we find it of a deep yellow colour. The various classes of the division Molluscæ do not present a more elaborate mode of formation of the nutritive fluid; in some classes it is found to have a bluish white colour, which would appear to be a change since its formation. To pass, then, from these to a division of animals more complex in structure than either, the Articulata, in the very numerous class Insecta I find no better system of vessels; the chyle passes into irregular sinuses which communicate immediately with the veins. But in one class in this division, there

is the highest degree of development that is seen in the blood of invertebrate animals, that is to say the nearest approach to the more perfect fluid I shall hereafter describe as circulating in Mammalia. In the Anellidæ there are different degrees of colour, but in the majority the blood is red; and although we cannot, from research, find any more complex organs of sanguification in them, yet from this colour alone I think we are justified by analogy in stating that a more extended process is necessary for the formation of their blood than that of the classes already mentioned. Passing from these to the lower forms of Vertebrata, in Fishes and Reptiles we find provision made for the formation of a nutritive fluid by lacteals and lymphatics, and the blood of a red colour. Such are the progressions in sanguification in the classes hitherto noticed.

Now with regard to the constitution and relative proportions of the component parts of the blood, in these animals we shall find the same ascending scale apparent. Among the lower Radiata, by the wonderful power which the Polypifera have of reproducing a perfect creature from any part which is severed from the original animal, we must suppose, I conceive, that there is in their nutritive fluid a material analogous to the plastic lymph of Mammalia, which possesses the capability of producing the different parts quicker and more entirely just in ratio to the simplicity of structure of the creature, and the small degree of active life it exhibits. The globules are seen to be coloured as the food it has taken. In the higher classes of Radiata, the blood (and consequently the globules, as they impart colour to the blood) is of a hue which we cannot attribute to the food. The corpuscles in the Articulata are circular, in one class the dimensions are different in the same individual, and their colour differing in the various classes. In some classes of the Molluscæ the existence of corpuscles in the blood is not to be perceived, and has been denied; and when present in this division they are more like the lymph globules of more perfect animals, few in number comparatively, and granular, without any definite form.

The colour of the blood derived from these globules is found to differ in each class, and from finding in one class glands on the interior of the veins, most probably for the secretion of urine, it is apparent that the blood contains the components of that fluid, as in another class the biliary organs are highly developed, proving that the circulating fluid has a greater proportion of the components of bile. In these invertebrate animals the globules have only attained a limited development, for it does not appear from research that a central nucleus has been perceived in them. But in the lowest forms of Vertebrata these globules are well developed, red in colour, and regular in form and size; they yet differ much from those of Mammalia. They are elliptical in form, and the spot which indicates the presence of a nucleus is in them caused by a prominence. They also differ in size, for in most of these classes the particles are larger than in Mammalia.

VII. One of the purposes of circulation being to renew the vitality of the blood by exposing it to the influence of oxygen, I shall consider it in its relation to the function of respiration. As was before said, the degrees of activity which the different classes of Invertebrata possess, are extremely varied, and consequently the demand for supply of nutritive fluid to the different structures is varied in proportion. The current of blood runs slower in animals which possess or exert little power of motion, and this slowness is ensured either by the deficiency of a heart, or in consequence of the blood being transmitted through the generally tortuous vessels of the organs of respiration first, and afterwards through the system generally, back again to the heart, so that this latter organ does not receive the stimulus of aerated blood. By this arrangement there will be less blood rendered impure within any given time. It follows, from this, that a less supply of oxygen is needed for its purification, or (which amounts to the same) that supply may be longer in being collected for the use of the animal. Thus, in the lower Radiate classes, we see creatures almost stationary in their habits, the blood, if it may be so called, circulating sluggishly unpropelled by any

active organ, and being purified by oxygen absorbed apparently from every part of the surface. But in the higher classes, as, for instance, the Stelleridæ, endowed with higher power of life, the blood circulates through a system of vessels appearing to possess some power of dilatation and contraction, and in order to secure a constant supply of oxygen, cilia are placed over all the intestinal surface, by their constant motion, to separate the required gas from the fluid admitted into the cavity, and thus ensure a quicker revivification of the circulating fluid to support the more complex life. In the other tribes of the same class, gills are afforded in addition to the internal mode of aeration.

Among the Articulata, the perfection with which the circulating fluid is aerated, differs. In the Anellidæ, slow in motion and torpid in habits, there are contractile vessels serving to propel the blood, and organs of respiration that would lead one to suppose the function of aeration was much needed, and its duties well accomplished; but these arrangements are partly cancelled by the frequent anastomoses between the veins and arteries mixing the impure and purified fluids. In the class Insecta, animals full of activity during their short existence, I find a vessel acting as a heart, already beginning to aid its powers of propulsion by the addition of valves, and in order to keep up a constant and easy process of purification, small tubes opening on the surface of the body, pass into the veins, admitting a supply of oxygen to the blood flowing along them. It is a singular fact in this division of animals, and one I have not seen noticed, that the class of Arachnidæ, some individual species of which, in addition to great activity of body, possess ingenuity of construction, fixedness of purpose, and a subtle artifice far before any creature we have yet noticed, exhibits a more perfect arrangement, on the whole, of circulation and respiration, than most, if not all, of the other classes. In the division Molluscæ, I do not conceive the function of respiration to be so well carried on as in the last division, although the heart is generally more powerful, perhaps to make up this deficiency, which still agrees

with the idea of proportion between the activity of the animal and the perfection of these functions. Among the lower forms of Vertebrata we see the Reptiles, animals the greater part of which are accustomed to a hybernating sleep, and even in the period of their activity move slowly and rest much. Accordingly, in them the heart, consisting of one single ventricle, receives at one and the same time the impure and aerated blood; while, in those individuals which possess the greatest muscular power, the heart is divided into two compartments, each possessing its peculiar faculty of propelling venous, or arterial blood, but we find the fluid mixed at a little distance from the heart by the union of the chief vessels. The majority of Fishes pass their life in a state of ceaseless activity, so that they have a heart acting forcibly and propelling blood to the large externally-placed organs of respiration, thus situated in order to collect from the surrounding fluid a sufficient quantity of oxygen, while, in order to support the nervous system, pure blood is sent off immediately after undergoing the process from the branchiæ to the brain. In some of the animals which have not these external respiratory organs, but have frequently to come up to the surface to inhale the pure atmosphere, there is in the large arteries and veins of the trunk a capability of assuming a ramified form, so as to prevent the column of blood from overpowering the heart, which is unable to transmit it to the lungs, they being in a state of inaction while the animal is under water. From this brief survey, I hope it will appear clear that the perfection in which the blood circulates and is purified, is in exact relation to the degree of active life in the animal. These are the facts I consider it necessary to state here concerning the progression in the development and distribution of the blood in the animals already mentioned. I shall now proceed to describe these different processes and characters, as shewn in the circulating fluid of Mammalia, taking as the most perfect type of these, the blood of the human subject.

VIII. Man is capable of existing under more different cir-

cumstances than any other animal God has created. He can live among the perpetual snows of the Poles, or under the burning heat of the Equator. The same being who has passed his youth amid luxuries and ease, the sun scarcely suffered to shine upon his fair cheek, may in after life tread the dry, pathless desert, subsist on a pittance of food, and a bare sufficiency of water, and still survive the privation.

Daily do I see man placed in the most opposite positions; the artizan pent up in his confined room, reeking with noxious vapours; and the tiller of the soil, braving with brawny limbs almost uncovered, alike the summer's sun and the winter wind, the heavy spring showers and the driving sleet; yet they both live and have a numerous progeny, although perhaps he whose destiny is fashioned by the artificial wants of human society, fares worse and lives shorter than he who gives his frame to the mercy of nature's fiercest strife. Thus not only can man exist *in* the greatest extremes of temperature, but also *upon* substances most numerous in name, varied in appearance, and different in composition. Hence, to reduce these aliments to a state fit for the necessary repair of his body, he must have organs more perfect and complex than most other animals. It is not necessary or fitting here to describe the process of digestion. All matters conveyed into the stomach that are in any degree reducible, are converted by its acid secretions into a homogeneous mass termed chyme. This mass is carried onwards as it is formed, through the pyloric orifice of the stomach, into the duodenum, there to be acted upon by the secretion of the liver, bile, which becomes intimately mixed with it, evidently with the design of separating the nutritious parts from the useless, for the most part of the constituents of the bile pass off with the latter. From the duodenum these now more elaborated matters pass into the remaining intestines, on the surface of which ramify extensively numerous vessels for the purpose of absorbing the nutrient portion, which is now called chyle. This fluid is carried by these lacteals to the mesenteric glands, and thence to the thoracic duct.—

Throughout every tissue of the body are distributed a system of vessels, called lymphatics, the office of which it is to take up those particles of the tissues which have contributed their part toward the maintenance of the whole, and in which decomposition is already begun, as also those parts of the fluid supplied for reparation which are superfluous, and transmit them into the circulation to be revivified. These vessels are most thickly distributed immediately beneath the skin, because there the waste most actively proceeds, not only in the loss and reparation of the tissues, but also by the cutaneous excretion. By these vessels, the lymph, a fluid which may be considered, from its properties, (as of spontaneous coagulation), analogous to a solution of the fibrine of the blood in its serum, is conveyed into the thoracic duct, there mixed with the fluid derived from the process of digestion, and the fluid resulting from this union, is still termed chyle. The thoracic duct empties its contents into the venous system at the junction of the subclavian with the jugular veins of the left side, and on the right, the lymphatics of the upper extremity join to form a small trunk, which conveys the fluid lymph collected by them into the junction of the same veins on that side. This fluid, then, by which the mass of the circulating fluid is maintained, composed of the nutrient matter derived from foreign substances in the digestive cavity and of those parts of every structure of the body which have become no longer fit to remain in it, is milky in colour, and presents difference in its character as it approaches nearer to its entrance into the venous system. It contains in solution, albumen, fibrine, corpuscles resembling those of the blood, and oleaginous particles; these last, more or less plentiful according to the nature of the food taken. Its specific gravity when fresh is about 1,024, its action on test paper, when in the same state, is neutral, but when kept for a time it is slightly acid; nitric acid and heat cause coagulation in it, and acetic acid, when added to it, renders it clearer. Its quantitative analysis, as obtained by Dr. G. O. Rees, is as follows:—

Water	90,48.
Albumen, with traces of fibrinous matter	7,08.
Aqueous extractive matter	0,56.
Alcoholic extractive matter, or osmazome	0,52.
Alkaline chloride, carbonate and sulphate, with traces of alkaline phosphate and oxide of iron	0,44.
Fatty matter	0,92.
Total	100, 0.

It appears likely that in this analysis much of the fibrine was estimated as albuminous matter. The aqueous extractive and alcoholic extractive obtained, resemble those of the blood. Solid matter is found in the chyle under very different forms. There are a great number of minute molecules found in it, evidently composed of albumen. They are so small as not to be susceptible of accurate observation, but are said by some observers to vary in size from 1-16th of the average diameter of the blood corpuscle to a size which can be scarcely seen by very strong microscopic power, and appear to be spherical in form. These are thought to be the cause of the milky colour of chyle. There is another kind of corpuscle seen here, generally much larger than the blood corpuscle, some of them attaining to twice its size. They are irregular and granular upon the surface, and when treated with acetic acid, disclose three or four large central particles. Now the proportion of the different constituents of the blood found in chyle changes as it approaches to the venous system. The change in fibrine is seen in its different degrees of coagulation. In the lacteals leading to the mesenteric glands, the chyle when drawn off coagulates very weakly or scarcely at all; in those passing from these glands to the thoracic duct, it is seen to coagulate better; and in the thoracic duct, more especially toward its upper extremity, a coagulum is formed quickly and firmly. Nor perhaps is this firmness of coagulation entirely owing to the presence of more fibrine; the change in the chyle corpuscles being equally great. In the first set of absorbents they are very scanty in number; in the second they are very numerous, but not yet arrived at their complete size and definite

form; while in the thoracic duct they are large and numerous. Albumen is found in its least proportion in the lacteals before they enter the mesenteric glands, in those passing from these bodies to the duct it is very plentiful, and in the duct itself its proportion is again diminished. The oleaginous globules are in great quantity in the first set of lacteals, in those passing to the duct their number is decreased, and in the duct they are in small quantity. Now it has been supposed that a progressive change takes place in these bodies from one form to another; thus the fatty matter, at first most plentiful, is converted into albumen; the albumen may easily become fibrine, and be converted into the corpuscles; but this is at present only theory, although to me it appears extremely probable. From the great size of the chyle corpuscles, it is evident that they do not individually become blood corpuscles. But it seems that in analogy with a process I shall speak of presently, blood corpuscles are formed from them, the three or four particles seen on the removal of the exterior covering being blood corpuscles in a state of development from the parent body. It has been stated that the chyle becomes red on approaching the venous system; but it appears, in accordance with the views and experiments of Mr. Lane, that the chyle can be obtained, from every part of the duct, clear, and therefore this redness is to be attributed to the introduction of blood to the chyle during the process of obtaining it. A greater proportion of fatty matter is found in chyle than in the blood; therefore it is evident that this disappears from the circulation in some mode afterwards to be referred to. Thus, then, by a fluid, answering to these characters and thus resembling blood, is the circulation maintained in the animal economy.

IX. We are now to observe the blood in the state in which it circulates through the system. The total quantity of blood circulating in the body has been estimated by Valentin as ○xxxivfs in the male, and ○xxvi in the female. The blood is a red homogeneous fluid, of a slightly adhesive consistence,

having strong saline taste, an alkaline reaction on test paper, and a peculiar odour termed halitus. It consists of red corpuscles which impart a colour to it, and a colourless fluid, the liquor sanguinis, being serum holding fibrine in solution. The proportion of solid matters to the fluid has been ascertained to be as follows:—

	In the Male.	In the Female.
Water	805.	848.
Albumen	63.	68.
Globules	186.	167.
Fibrine	4.	3.

The quantitative analysis of the blood, as obtained by Lecanu, is as follows, the results of that of two different persons:—

Water	780,145.	785,590.
Fibrine	2,100.	3,565.
Albumen	65,090.	69,415.
Colouring matter	133,000.	119,626.
Fatty crystaline matter	2,430.	4,300.
Oily matter	1,310.	2,270.
Extractive matters soluble in alcohol and water	1,790.	1,920.
Albumen combined with soda	1,265.	2,010.
Chlorides of potassium and sodium Carbonates, phosphates and sulphates of potash and soda	8,370.	7,304.
Carbonates of magnesia and lime, peroxide of iron Phosphates of lime, magnesia and iron	2,100.	1,414.
Loss	2,400.	2,586.
Total	1000,000.	1000,000.

Having thus premised the general distinctions and composition of the blood as a whole, I shall proceed to describe severally its component parts. The solid part, consisting of the red particles, I shall consider first, and afterwards the fluid part or liquor sanguinis.

X. The red corpuscles (I object to the term globules, as it may lead to a fallacious idea of their shape,) are flattened, circular bodies, rounded at their edges, and having a small central spot or depression; their thickness is about one-fourth of their longest diameter, they are generally alike in size, but some may be a little larger than others, never so much so as to be twice

the average size. They are cells consisting of a capsule containing a peculiar colouring matter, and a central nucleus, the presence of which causes the dark spot observable on the exterior. Two proximate principles enter into the formation of these bodies, globuline and hæmatosine. The globuline is found in the nucleus and the capsule, and in its chemical constitution differs little from protein, a substance formed by exposing albumen or fibrine in a solution of potash to the action of heat. The colouring matter contained immediately within the capsule is composed of some animal matter with peroxide of iron; it is this which gives to the blood its characteristic colour, as it possesses the property of being rendered florid by the influence of oxygen and saline substances, and darkened by carbonic and other acids. This has been named by chemists and physiologists hæmatosine and cruorine. When separated from the rest of the corpuscle it is seen to be of a dark brown hue, is tasteless, insoluble in water, alcohol, or æther, and is said to consist of one grain of peroxide of iron with one grain of the animal compound; its formula is 44 equal parts of carbon, 22 of hydrogen, 3 of nitrogen, and 6 of oxygen. When incinerated and decarbonized, according to Berzelius, an ash is left equal to 1,3 of the entire weight used, and composed thus :—

Carbonate of soda and traces of phosphate	0,3.
Subphosphate of lime	0,1.
Sesquioxide of iron	0,5.
Caustic lime	0,2.
Phosphate of lime	0,1.
Carbonic acid and loss	0,1.
Total	1,3.

When the red particles are separated from the liquor sanguinis, and immersed in any other fluid, as water, the surrounding fluid may pass in or the colouring matter pass out, through the envelope, by the law of endosmosis, thus causing them to assume a spherical instead of a flattened form. Hæmatosine resembles fibrine in being coagulated by heat or nitric acid. The nuclei of the red corpuscles are composed of small granular particles.

These red corpuscles appear to increase in the depth of their colour in proportion to the number in which they are found together. Thus, in vessels, the diameter of which is so small as only to admit a single row of globules, the fluid seems transparent, which has led some to believe in the existence of serous vessels; but let these vessels be dilated, and their caliber increased by any cause, and the red colour is seen to appear in some degree and increase according to the degree of dilatation. This fact is demonstrated in a drop of blood seen under the microscope during coagulation, while the coagulating part, composed of fibrine and most of the red corpuscles, assumes a florid red colour, there are many corpuscles floating here and there in the serum which exudes; some of these are in clusters, and according to their number so is the colour heightened or faint, while others wandering singly have a yellowish white colour. This would appear to be caused by the laws with which the rays of light fall upon circular bodies. The vitality of these bodies is great. We see proofs of it in the difference between the developed corpuscles and imperfectly formed bodies named lymph-corpuscles. These bodies seem to be attracted to the side of the vessel and move tardily on, stopping at those little inequalities and obstructions which the veins, numerously branching, present; but the well developed corpuscles pass swiftly along in the centre of the stream, dividing and passing into different channels without stopping, thus quickly moving even through the tortuous capillaries. The independent vitality of the corpuscles is also strikingly shown in their power of producing other bodies like to themselves. This leads me to consider the origin of the blood corpuscle, and more especially the views and researches of Dr. Martin Barry, upon this interesting point. In the blood, among the usual sized corpuscles, are seen some much smaller, passing along at the side of the vessels and halting at any little impediment which may be presented. These, which were before remarked, are called lymph-corpuscles; but that they are not the globules which are present in the lymph or chyle, is shown

by the difference of size, the chyle globules being so much larger than the blood corpuscles, and it is most likely that these are incipient red corpuscles, not yet possessed of the size and degree of vitality which the blood corpuscles have. In stating that the red corpuscles are thus capable of increasing in the venous system, I do not forget or render void the changes which take place in the chyle-globules before mingling with the blood. The supposition that the red particles are generated, so to speak, within the venous system itself, does not render it impossible that they should be also introduced from without it, from the same sources as the other components of the blood. We have seen that for the formation of the mass of the blood, there are two very different processes instituted, producing two different fluids, chyle and lymph; the former made by the powers of organic life, from foreign substances, the latter composed of the refuse of the tissues, and the remains of the blood itself: then why should not the red corpuscles be formed at the same time from chyle globules which have progressed in the thoracic duct, and from individuals of themselves by a spontaneous act producing several more? It remains now to review the reasons for supposing such productions to take place, and the mode of production. Wagner, in his observations on the (so called) lymph-corpuscles, remarked, that these bodies, always smaller, were in exact relation to the size of the blood-corpuscles of the animal,—that they might be known from blood-corpuscles by their being colourless, spherical, granulated upon the surface, and strongly refracting light,—also that their number was increased in animals well fed, and that in the arterial blood of a young man there were some found only half the size of the blood-corpuscles. This establishes their complete relation to the blood-corpuscle in size and number. Dr. Martin Barry observed on the fimbriated extremity of the fallopian tube post coitum, and two hours and a half after death, fluid containing blood-corpuscles in an altered state.—These corpuscles were observed to be considerably increased in size, and this change was observed in the same situation without

previous coitus. On the ovum, in the fallopian tube, he observed clusters of blood-corpuscles in a more or less altered state; some of them appeared pressed into six-sided figures, or spherical, all strongly refracting light, and some presenting a brilliant object in the centre. In some of these, the diameter was less than in the unchanged, and from the presence of minute globules round such, we must suppose this to be caused by the loss of their exterior covering. However, connecting this capability of increase of size which the blood-corpuscles exhibit, with the intimate relation to them of the smaller bodies, the inference is obvious. Some gradations in change are observable; some corpuscles being elliptical, while others present processes stretching in various directions. In the blood-corpuscles found in the heart after death from bleeding, the division of the corpuscles into minuter ones is most apparent on the left side of the heart. Here corpuscles are sometimes found to have attained to four or five times the original size, very pale in colour, sometimes ruptured and their contents discharged. When this is not the case, they may be seen to be filled with smaller corpuscles, while those which have been discharged have already acquired colouring matter. Then there is a third and smaller corpuscle arising from these last, and others smaller yet, from these, so as to appear mere points. I believe these appearances are only observed in cases of extreme loss of blood, and hence it appears a wonderful effort and provision of nature; but with regard to our present subject, it makes "assurance doubly sure." We must now judge from what part of the particle these new bodies are derived. The nucleus of the blood-corpuscle was considered to be a single object, but Dr. Martin Barry observed it to be composed of two, three, or more distinct granules of a constant and determinate form, that is globular. He also, in the substance immediately surrounding it, observed many cell-like disks, and discovered an orifice in the delicate envelope or capsule. Acetic acid he did not find necessary to effect the separation of these granules composing the nucleus, as they were capable of separating of them-

selves, and moreover must do so in the natural course. Hence he concluded that the nucleus is not merely the originator of one single corpuscle, thus becoming useless, but remains to generate several more bodies. Each of these granular globules becomes gradually developed as a blood-corpuscle, increasing the parent cell much in size as they proceed, and at length having attained to the needful maturity, burst open the envelope, and pass into the current of blood. Thus I imagine it is made clearly comprehensible that the blood-corpuscles may and do, by their own independent vitality, increase their numbers in the circulatory system. The peculiar influence of respiration upon these bodies I shall refer to afterwards. I have before omitted to mention that in Birds alone, of warm-blooded animals, the corpuscles are elliptical in shape, while in all Mammalia they are as I have described them.

Scale of their size in man and other animals, in parts of an inch.

THE LONG DIAMETER.

In Man,	In Cat,	In Fowl,
From $\frac{1}{4029}$th to $\frac{1}{2637}$th	$\frac{1}{7056}$th	From $\frac{1}{2769}$th to $\frac{1}{1680}$th
In Tortoise,	**In Frog,**	**In Proteus,**
From $\frac{1}{1955}$th to $\frac{1}{1219}$th	From $\frac{1}{1292}$nd to $\frac{1}{997}$th	$\frac{1}{337}$th
In Shark,	**In Scorpion,**	**In Asterias,**
From $\frac{1}{1107}$th to $\frac{1}{186}$th	From $\frac{1}{2215}$th to $\frac{1}{1938}$th	From $\frac{1}{5538}$th to $\frac{1}{1661}$th

In Cuttle Fish, $\frac{1}{2769}$th.

XI. I come now to the fluid part, the liquor sanguinis, as it is called. The liquor sanguinis may be obtained by filtering fresh drawn blood, thus making it free from red particles. It consists of serum holding fibrine in solution. Serum may be obtained separate by allowing blood to coagulate, and pouring off the supernatant liquid, freeing it if necessary from red particles by a filter. Serum is a greenish coloured fluid, composed of water holding in solution albumen, saline matters, and oleaginous globules. The albumen exists in the serum in considerable quantity. The saline substances are very important constituents of serum, on account of their influence upon the blood relative to the process of respiration, which I shall speak of pre-

sently. The milkiness of the blood under some circumstances is thought by some writers to be owing to the greater quantity of oleaginous globules held in solution in the serum. These globules of fat and the albumen, I regard as existing in solution in the serum with a view to further organization before they are fit to enter into the composition of living structures. The albumen contained in it may be coagulated at a heat of 167° Fahrenheit, and the supernatant liquid is termed the serosity, and is found to consist of salivin, casein, lactic acid, osmazome, and salts chiefly of soda, held in solution by water. Thus we see that the proximate principles of the several secretions, saliva, milk, and bile, are held in solution in this part of the blood. The quantitative analysis of serum, according to Berzelius, is as follows:—

Water	905,0.
Albumen	80,0.
Substances soluble in alcohol, Namely, chlorides of potassium and sodium, Lactate of soda and animal matter	10,0.
Substances soluble in water, Namely, soda, phosphate of soda, and a little animal matter	4,1.
Loss	0,9.
Total	1000,0.

XII. Fibrine may be obtained separate by stirring fresh drawn blood with a twig; it will adhere to it in fibrous portions. Fibrine, when thus obtained coagulated and separate, is seen to be a buff coloured substance insoluble in water, except by heat. It is extremely like albumen in its composition and chemical properties; indeed it has lately been stated by Liebig, to be identical with it in composition, although before it was supposed to differ in the proportion of nitrogen; still in some respects it differs. All the strong acids, except nitric, render fibrine transparent and gelatinous, when added to it; but when diluted, they cause it to shrink into less volume. It appears more highly organized than albumen. The chief and most remarkable point of difference between albumen and fibrine is the property which the latter possesses of coagulating under certain circumstances.

While the blood is in the vessels, and the circulation unretarded, the fibrine is in a fluid state, but no sooner is the blood drawn from the veins of a healthy person than coagulation commences. At first the coagulum forms loosely, and has within it not only the red particles, but a considerable quantity of serum; but the fibrine gradually contracts, and at length almost all the serum is pressed out. The coagulum consists of the fibrine and almost all the red corpuscles, they being taken into it by reason of their solidity and size, and as we shall presently see, there is reason to believe they have some influence in the process of coagulation. It has been thought by some writers that this process is an action not at all connected with vitality, but on the contrary, is a proof that life exists in the blood; but this supposition cannot be supported. I see in this operation a wonderful degree of vital power: a body which was before fluid, quickly assumes a solid form, and in this form, shows with considerable energy the same faculty and the same principle, by virtue of which our bodies are supported and we perform all active motions. We find that where life is destroyed in an instant, and by modes in which we should expect vitality to be most effectually extinguished, the blood does not coagulate. Whereas in every other mode of death, we find, on examining the circulatory centre, that the blood has flown thither as if to some strong citadel, and has there made its last effort at vitality, evidenced in the fibrinous coagula, named polypi, found in the heart. I believe coagulation to be the last vital effort of which the blood is capable. It may be asked, if the coagulation of the blood is a vital effort, why does it not coagulate in its vessels? That there are influences intended to obviate this tendency to coagulation in the fibrine, there is no doubt. Were these influences not constantly in action, this would be the case, the blood would coagulate in its vessels, and all circulation be stopped. Saline substances, when added to the blood out of the vessels, have been found to hinder its coagulation. Hence it has been thought the salts held in solution in the serum, and in constant apposition with the

fibrine, have some influence in retaining it in a fluid state. But this is seen to be of no avail when the blood is drawn from the vessels, for then a coagulum is formed although the serum holds still the same composition. It follows, therefore, that there must be some influence in the vessels themselves, restraining the fibrine from coagulation. The internal membrane of the vessels has this secret influence; while it surrounds the blood the current flows onward uninterrupted, but should this tissue be deprived of its vitality, its continuity destroyed, or the fluid taken from under its influence, then coagulation ensues. Motion has been said to be the cause of the continued fluidity of the fibrine, that while the heart propelled the blood in an unceasing round, so long would its parts continue mixed as a fluid, and no longer; but this has been proved false. An experiment has been made by placing two ligatures on a vessel with a considerable quantity of blood in the intermediate extent, and no branches present by which fluid in a state of action could intermingle with it; yet the blood confined thus, would remain fluid so long as there remained any degree of vitality in the vein itself. Thus we see that it is by the influence of the interior coat of the vessel in which it circulates, assisted perhaps by the saline substances dissolved in the serum and intimately mixed with the fibrine, that the blood is preserved in a fluid state. In the blood-corpuscles during the process of coagulation, Dr. Martin Barry has observed some singular phenomena. At the top he remarked colourless globules, which were in his opinion parent cells, while those corpuscles which possessed a red colour, began to unwind into a filament, a process which he states would be continued if nutriment were supplied, but in coagulating blood soon terminates. A most important conclusion, with respect to coagulation, he makes from this,—that the corpuscles possess contractile power. If this subject be considered with but a small degree of profundity, this apparently simple act will be seen to be one of great importance. I have traced hitherto the course and changes of the foreign matters which the animal has the power

of taking into its interior, and changing into a form fit for its own service. I have shown how they have been changed into a proximate animal principle (albumen), fitting with slight changes to enter into the formation of all tissues. This principle has been seen to be the basis of the red corpuscles, these bodies possessed of powers of reproduction, it is true, but this is a faculty which is possessed by the vegetable kingdom also. Hitherto we have seen nothing, strictly speaking, indicative of animal life. This is the first glimpse we obtain of powers beyond those of organic life. The act of coagulation in its forcible contraction, shews the first approach from motionless substances, to the active movements of animal life. Under certain circumstances, which I shall speak of in a succeeding chapter, fibrine varies in the degree of quickness and firmness of coagulation. Fibrine appears to form the chief coagulating power in chyle and lymph. I have given but a brief and cursory account of the three component parts of the blood, the more so because I shall enumerate and explain many of their qualities in an after part of this Essay.

XIII. Thus the blood, as it circulates in the veins, is composed of two parts, the solid or red corpuscles, and the fluid or liquor sanguinis. Wherever we see it in the system, it is of the same consistence, and composed of the same parts, but the colour may be different. If we divide an artery by an incision, the blood that leaps forth in an intermitting stream is of a florid red colour; whereas, if we open a vein, the blood flows out dark red or purple in hue. The question hence arises, what is the cause of this difference of colour? We have seen that hæmatosine, in a separated state, is of a dark brown hue; therefore the bright scarlet colour which the blood exhibits in the arteries, is not the natural colour of the corpuscles, but is imparted to them by some other substance. Oxygen appears to possess the power of imparting a florid colour to them; but if a piece of red coagulum be immersed in distilled water, and freed from the serum and salts, it becomes very dark, and is not at all changed

by exposure to oxygen,—proving that this gas is not the agent by which the change is effected when in the body. But if it is placed in a solution of saline substances, its florid colour returns. Therefore it appears that the salts in the serum are the agents by which this first change in the hæmatosine is effected. The venous blood, although it contains as large a quantity of saline matter as the arterial, is yet changed to a dark colour, and this change must be owing to some impurity it acquires in the course of the circulation. Now when venous blood is drawn and exposed to the atmosphere, in a little time it regains its arterial hue; and if collected in a deep vessel, the surface which is exposed directly to the air becomes bright red, while that beneath remains dark. From this we infer that the atmosphere has the effect of freeing the blood from the impurity which causes the second change in the hæmatosine. We must now consider the means by which the blood, when rendered impure, is submitted to the action of the atmosphere. The air, in effecting this change in venous blood drawn from the body, only alters the colour of that which is most immediately in contact with it, the surface, so that in exposing the blood to its agency, it is necessary for it to be placed in very thin strata that it may be acted upon entirely. In the lungs this disposition is found, the air is admitted by means of a large tube resisting the entrance of any other body, to a surface prodigious in extent, yet confined within a very small space, covered by a multitude of vessels with easily permeable walls, so small as to allow the whole of the current of blood within them to be influenced by the peculiar agent found in the atmosphere, while it is rapidly inspired and expired. A constant supply of air is admitted and a constant current of blood flows, and that this process of change in the blood is essentially dependent on the atmosphere, is demonstrated by the fact that when the supply of air is cut off by any means, the blood no longer traverses the pulmonary vessels, the current being stopped by the heart ceasing to contract with sufficient vigour. Seeing that the atmosphere is the medium through which the

blood derives its arterial character, we will first examine the means by which it is exposed to its influence, and afterwards inquire by what component of the atmosphere the change is more immediately caused. As I develope the means by which the blood of the whole body is successively and constantly exposed to the air, it will be seen how intimately connected and how dependent upon each other the functions of circulation and respiration are. As the blood moves swiftly through the system, not only in a downward, or horizontal direction, but also upwards, and through a number of intricate and tortuous vessels, presenting numerous impediments, it cannot be by any laws of gravity merely that it is circulated, but there must be a motive power situate in some central part, adequate in capacity and force to keep the stream in a constant and equable flow, notwithstanding all obstacles. This power we find in a muscular structure, the heart, situated about the centre of the whole system, and aided in its task by the elasticity of the arteries and by the valvular structure of the veins. The action of this organ is distinctly muscular, consisting of alternate contraction and dilatation, the natural stimulus to this contraction being the blood. By virtue of its two cavities, it causes the blood to perform a double circulation, i. e. systemic and pulmonary, which I will briefly describe. The blood, as it returns by the vena cava from its circuit among the various structures of the body, enters the right auricle, by its contraction is forced into the right ventricle at the moment of its dilatation, and by the contraction of this last is again propelled, through the semilunar valves guarding the entrance of the pulmonary artery, along the artery and its divivisions to the capillaries of the lungs, which are distributed immediately beneath the delicate membrane lining the air cells of the lungs. Here it undergoes change of colour, and having become, from its dark, of a bright scarlet hue, passes into the numerous system of pulmonory veins, which converge to four principal, by which it is conveyed to the left auricle, thence propelled into the left ventricle, and from it along the aorta and its

divisions to the system at large. So long as the blood is in the arterial system, so long does it continue of its florid colour; but when it reaches the capillaries, a change takes place, and in the first small veins it is seen to be dark. Thus we see the blood in mammalia, and man in particular, to be in two states in the same body, one fit for nutrition, secretion, and the preservation of the nervous energy, the other impure and needing change before it can perform all these offices; yet these two kinds of blood never mix in the healthy state, but each fluid rapidly passes into the other, the capillaries being the part in which the impurity is acquired, and the organ of purification being the lungs. In the fœtus of all mammalia there are some remarkable differences in the circulation to that of an adult, holding intimate relation to our present subject. The fœtus being confined in a cavity, to the interior of which air is not admitted, and withal, surrounded by fluid, has neither the means or the faculty of respiration. There are vessels, and a circulating fluid in them; how then, it may be said, is the blood retained in a sufficiently vivified state to promote nutrition and sustain the little power of motion it then possesses? By a most beautiful arrangement. In this stage of development the hypogastric arteries ascend to the umbilicus, and passing out there, are named umbilical arteries, and run in relation with the umbilical veins, forming the umbilical chord to the placenta. In it they divide into numerous small vessels. These small vessels project in tufts into the uterine sinuses, through which circulates the blood brought by the spermatic and hypogastric arteries of the mother, and thus the fluid of the fœtus acquires an imperfect sort of purification, being afterwards returned by the umbilical veins. The umbilical veins, after passing the umbilicus, empty their contents into their continuation, the ductus venosus, and this carries the blood to the inferior vena cava, thus mixing the slightly arterialized blood with the totally impure; the vena cava opens into the right auricle, when, by means of the foramen ovale in the septum, some of the blood passes into the left auricle, and after the

remaining part has passed into the right ventricle and thence into the pulmonary artery, this artery is found to be of small calibre, owing to the collapsed state of the lungs, and to allow little blood to pass to its extremity, but the most part goes off by a branch, the ductus arteriosus, communicating with the descending aorta. Thus in the human fœtus shut out from the contact of atmospheric air, by the surrounding huid and parts, possessing little apparent life or motion, we find the blood is purified partly by the contact to its vessels of a fluid containing the necessary of purification, but this imperfectly arterialized fluid is mixed again with the impure blood circulated in the body of the fœtus, so that life is sustained by a fluid almost venous in its character. I before mentioned the same kind of commingling and imperfect circulation to exist in some reptiles, slow in motion, in their habits, either amphibious or spending part of the year in hybernation; and it is remarkable that it should be found in the fœtus of the human race, the most perfect in form and constitution of all animals. Now I have stated the organ by which aeration of the blood is accomplished, and the means by which it is transmitted to that organ, I will consider the change which the blood undergoes and the component of the atmosphere most concerned in the action. The change evident to our senses which takes place during respiration, is the conversion of a dark red colour to a crimson hue, but it exhibits considerable change in its vital properties. The impurity present in venous blood must first be ascertained. It has been proved by experiment that carbonic acid changes the blood from a bright red to a dark colour. We have already seen that the blood is of a bright colour before it reaches the capillaries, but dark after it has passed through them. It is then most reasonable to infer, that when the nutrient matters of the blood are effused from the capillaries, the seat of nutrition, during the formation of the necessary tissues, by the formative parts of the blood, hereafter to be noticed, carbon is disengaged, carbonic acid formed and taken up by the remaining portion of the blood, thus ren-

dering it impure. Then, as the carbonic acid is the impurity, to free it of this is the only necessary action in its purification. This is done in the lungs, and so abundantly, that the estimates of the carbonic acid given off in twenty-four hours, are between 14,930 and 39,600 cubic inches. It has been a question, whether the carbonic acid was formed *in* the *capillaries*, in the *course* of the *blood* from *them* to the *lungs*, or in the *lungs* themselves. The second supposition, that it was formed during the course of the blood from the capillaries to the lungs, has, I believe, been quitted by its supporters as untenable. That the carbonic acid evolved during respiration, is formed in the capillaries, I believe, and the following fact in some degree supports this opinion. When blood taken from a vein is agitated with pure oxygen, very little of the gas is absorbed, and very little carbonic acid disengaged; whereas, according to the second supposition, that this acid is formed in the lungs, *carbon* would be present with this blood in large quantity, and would unite with the oxygen to form carbonic acid, causing great diminution of the former gas, and the presence of the latter in considerable quantity. However this acid gas *is* formed, and it is no less certain that oxygen is an essential necessary for respiration, as we cannot exist without a considerable proportion of it in the air we breathe. Still it appears that this gas is not the sole and chief agent in producing the arterial colour, although it may have some share in it immediately, and certainly aids in a secondary manner by the removal of the carbonic acid. It seems certain that at the same time carbonic acid is given off from the pulmonary capillaries, some proportion of oxygen is absorbed into the blood, and we may suppose that this oxygen continues in the same state and quantity in the blood until it reaches the systemic capillaries. There the carbon, set free during the substitution of fresh animal matter for that which has performed its office, mixes with the blood circulating in these vessels, part of the oxygen may unite with the carbon, forming carbonic acid, the remainder passing in the same state in the blood to the lungs; but the

influence of the carbonic acid upon the hæmatosine has deprived it of its bright scarlet hue, and it is now dark, this change taking place notwithstanding the presence of the salts, and we may suppose some part of the oxygen. When the blood reaches the capillaries of the lungs, by the agency of the oxygen introduced there in the atmospheric air, the carbonic acid is abstracted from the blood, and the salts of the serum again resumes sufficient influence over the hæmatosine to bring forth again the bright tint. It has been proved by experiment, in my opinion, that the carbonic acid is thus formed in the capillaries of the surface of the body. We find that mammalia cannot long exist without the presence of oxygen in the air they inhale; but it is found that many animals, endowed with little activity, can live for many hours without it. On these animals experiments have been performed. Snails confined in hydrogen were found to exhale a considerable quantity of carbonic acid. Frogs have been kept for a long time in hydrogen and nitrogen, and have produced carbonic acid freely. This proves that oxygen must not necessarily combine with the carbon in the air-cells of the lungs, when inspired, and that carbonic acid is formed in some other part of the general system, from elements existing in that system itself, and the part where this process is carried on is the general surface of the body, where the capillaries ramify. Liebig has supposed the manner in which oxygen exists in arterial blood to be in combination with the compound of oxygen and iron present in all blood; but with all due deference to the greatest of modern chemists, I can perceive nothing to substantiate this theory. Most physiologists say, that oxygen does not form a chemical compound with the blood, but exists in it in solution, in the same manner in which it is found in river and sea water.—It is evident, however, that besides the change in the hue, and quantity of the gases which the blood contains, there are other important differences (consequent upon this last) between arterial and venous blood. The blood when thus purified by the contact with air containing oxygen, acts as a vital stimulus. Thus we

see, when an animal of the class mammalia, is placed in such a situation as to be able to inhale one certain gas only, as hydrogen, in itself not destructive to life, unmixed with oxygen, we see the animal die soon, not from any poisonous nature of the gas, but from want of the vital stimulus of blood purified by oxygen. Animals of inferior vital powers, whose functions are consequently less importunate, are able, during the time they live in these gases, to exhale carbonic acid, for this is formed by the union of the carbon with the oxygen contained in the blood then in circulation; but as soon as this supply is exhausted, and the blood in consequence becomes permanently impure, the animal will perish. Not only is the presence of this gas in air we breathe necessary for the right performance of the function of nutrition, but also it is essential for the support of the nervous energy, upon which every action and function is dependent. When I come hereafter to speak of the blood pathologically, we shall see how its perfect or imperfect aeration affects the great centre of the nervous system, the brain. During the act of respiration, a small proportion of nitrogen is absorbed in the blood. Most probably this is to ensure a sufficient supply of this gas to assist in the changes in the elementary composition constantly occurring in the body, forming as it does so essential a constituent of all animal structures. The absorption of gases by the circulating fluid is not confined to the lungs alone; during the circulation of the blood in the capillaries, so near to the exterior of the body, it takes up oxygen and gives off carbonic acid, in man, if any, a very small proportion, but in some animals this forms the most efficacious mode of aeration.

XIV. There is another end to which the act of respiration conduces, and to which I must now refer. In the vegetable kingdom we see few individuals possessing specific heat, if it may be so termed. The generality of these are only able to vegetate within certain degrees of temperature, and the more fragile portions of the individual are destroyed, or renewed, according as the surrounding temperature changes with the seasons.

It has been a question whether, in some plants, heat is not formed during the production and evolution of carbonic acid; but in general we see little necessity for a power of generating heat in them. However with animals the case widely differs. It is true that in some of the lower forms of these even, motiontionless, and almost inert in their habits, we find their degree of heat to be nearly wholly dependent on the surrounding medium, which is generally liquid. But most animals, by virtue of their voluntary motion, change their situations constantly, and thus place themselves in a thousand different positions with relation to surrounding objects, and this also, while being exposed, without any change of structure in themselves, to very great changes in the air which they inhale and are surrounded by. Hence it appears necessary for the perfect health of the animal, that it should have a faculty of producing heat within itself, for its own service, and also that this heat should be proportioned in degree to the surrounding substances in the variation of their temperature. To such a purpose do we find the purification of the circulating fluid subservient in mammalia, and other vertebrata. In man it is found that the temperature of surrounding air, when high, raises the temperature of the surface in a higher ratio than that of deep-seated parts, and when low, the heat of deep-seated parts is increased, while the temperature of the surface is diminished. The temperature of the human body, ascertained by placing a thermometer in the mouth or axilla, is 98° Fahrenheit, while the temperature of the human stomach, ascertained by Dr. Beaumont, is 100° Fahrenheit, in a moderate temperature, thus showing the great necessity there is for the production of heat within the body itself, since the radiation from the surface to colder objects around it is so great. We have already seen how carbon and oxygen unite in the capillaries to form carbonic acid. It is perfectly well known that in inorganic chemistry, when these two elementary bodies are united, a considerable degree of heat is obtained, and there is no doubt but that the process is attended with the same result

when it takes place in the human body. Heat is evolved in greater or less quantity, according to the rapidity of the circulation. Rapidity of circulation, and consequently of respiration, is thus the cause of increased heat. We find, by experiment, that the temperature of a muscle rises a degree or more during its contraction. Thus we always find the heat of the surface increase in ratio to the degree of muscular exertion, with which quickness of respiration is a concomitant. It is found, however, that the quantity of caloric found in the body is greater than the quantity of carbonic acid exhaled will account for, so that there must be some other source from which it is derived besides the union of carbon with oxygen in the process of nutrition. This has been accounted for by supposing that heat is evolved during the process of condensation, which the oxygen undergoes when absorbed in the blood in the capillaries of the lungs. The red corpuscles have some influence in the production of animal heat, probably because, where more numerous, the quantity of carbonic acid disengaged is greater, or, it has been thought that the peculiarity of their structure, in containing a nucleus, promotes the union of oxygen with the blood. Dr. Davy has found that some fishes, having red particles in their blood, possess some degree of specific heat. However, enough has been said upon this subject to show that the blood is the source from whence animal heat is derived.

From the foregoing we observe that the functions of the lungs, all having relation to the blood, are to abstract carbonic acid from the blood, to introduce oxygen into it, and thus to aid in the production of animal heat. Having now taken a brief survey of the means by which the blood is made fit for the uses of the animal frame, and the changes which take place in it connected with the process of respiration, I must approach to the principal of its uses.

XV. The most important end which the blood answers in the animal economy, is the reparation of the losses which the solids of the body sustain. These losses are constant. In the animal

body there are constantly particles in every tissue which are thrown off by the remainder as unfit for longer service. It is the office of the blood to supply fresh matter to take the place of these effete particles at the same time that they are carried off by the absorbents. Although the blood is a perfectly homogeneous fluid, throughout every part to which it is supplied, the same in characters and composition, still it possesses in itself the means of formation of the whole body, and supplies to all structures, varied and distinct as they are in appearance and formation, the materials of their reparation. From the epidermic tissues, strongly resembling the forms of inorganic nature in their appearance, density, and deficiency of sensation, to the finely spreading and interwoven plexus of nerves, scarcely visible singly to unaided sight, yet each one composed of more than one kind of tissue, and many parts, and endowed with that delicate faculty, more resembling mind than any thing else we know, the nervous principle; from the first of these to the last, all are composed from one fluid, that fluid seeming at first, to our limited knowledge, utterly incapable of producing any. It must not be supposed, however, that the power of changing itself into all the different structures of the body, resides within the blood itself; this power is exerted by each of the different tissues needing reparation, and is termed assimilation. It now remains to examine by what part of the blood this process is sustained. I will first state all the principal opinions on this subject, supported until within the last few years. Albumen, as it existed in the serum in great quantity, was believed to enter into the composition of cellular tissue, which contains a great proportion of it. The oleaginous globules which have been seen to float about in the serum, were found again in the human frame composing adipose tissue, with the assistance of cellular tissue, and entering into the formation of nervous matter. But of all parts of the blood, fibrine, as it is that part which first exhibits animal life by it tendency to coagulation, in the process of nutrition, was supposed to enter most largely into the composition of the frame, forming the muscles,

structures exclusively animal in their power and the uses to which they are adapted. In the harder parts of the body which guard the more delicate organs, and enable it to resist the majority of external influences, the phosphates are usefully employed. I may here mention that there is one principle, gelatine, obtained from all animal tissues by long boiling, which is not found in the blood, but this substance only differing from albumen in the proportion of one equivalent of carbon, it seems highly probable that the latter undergoes a change in the process. But these investigators ascribed to the red corpuscles no use in nutrition, and I believe the great John Hunter thought these to be the only component of the blood entirely useless in this process. This opinion had, however, for some time been deemed untenable, but no direct office assigned to these bodies in nutrition until Dr. Martin Barry made them the subject of his research, and by his startling, but no less reasonable, conclusions and discoveries brought very valuable additions, or rather improvements, to this branch of physiological study. Sir Everard Home mentioned his idea that the red corpuscles might be the part of the blood from which muscular fibre was formed. Dr. Martin Barry observed a disposition in the blood-corpuscles to place themselves in a necklace like form. During the state of vital turgescence, he remarked the corpuscles to acquire a singular appearance. He examined a portion of the infundibulum of the fallopian tube of a rabbit, five hours post coitum; the vessels were filled with blood-corpuscles to the exclusion of the serous part; they appeared darker in colour, in this respect, and in their cell-like form and general appearance, approaching to muscular fibre. Some of them having assumed a globular or elliptical form, pressed into the vessels, and were there pressed into many-sided figures. From his observations of the ovum in the fallopian tube, he concluded that the incipient chorion was formed from cells, presenting the same appearance as enlarged blood-corpuscles, in jutting out into processes, joining together. Dr. Barry also remarked a flat filament present in the corpuscle.

He found that the nucleus sometimes was, at its outer part, composed of a flat filament, to see which, it was necessary to place the corpuscles under the influence of some chemical agent, as a solution of corrosive sublimate or nitrate of silver. During the act of coagulation, these filaments were observed to uncoil in the reddest of the corpuscles, and enter into the formation of the clot, while the others were merely entangled in it or remaining in the serum. Filaments like these, were noticed to be present in many tissues, as the cerebrum and cerebellum, spinal chord, optic nerve and retina, olfactory and auditory nerves, voluntary and involuntary muscle, tendon, elastic tissue, cellular and adipose tissues, serous and mucous membranes, the lining membrane of blood vessels, ligament, the kidneys and ureter, the pancreas, the liver, &c. He also observed that the primary muscular fibre was developed from globules or granules, joining in a bead-like thread, these latter joining to compose a tube, on the internal surface of which were seen disks resembling nuclei, and here filaments were formed, constituting, with the surrounding tube, the primitive muscular fasciculus. Lastly, the important fact is to be borne in mind that all structures of the body originate from cells. From these and other investigations, he deduced, first, that muscle is formed from blood-corpuscles thus: The corpuscles enlarging and having a disposition to an arrangement in rows, necklace like, join and form threads, their globular form making them appear like rows of beads. These unite to form a tube, the primitive muscular fibre, on the interior surface of which are placed the nuclei of the original corpuscles. From the nuclei thus situated, he states other tubes or filaments to be produced within the first (the fibrillæ of other writers) and within these last, from disks similarly placed, filaments are uncoiled, forming at first rings in the interior, and then uniting to form spiral filaments interlacing with each other, and in their turn producing smaller spirals. Thus the fibril is a flat and grooved filament, containing spirals running in opposite directions, and of a number of these placed together, and surrounded

by a wall composed of the original cell-membrane, the primitive muscular fasciculus is composed. This spiral formation would appear to have an influence on muscular contraction, but we find it also in other tissues. The blood-corpuscles, before passing into cells for the formation of muscular fibre, are observed to be darker in colour, appearing to have an increase in colouring matter. The capillary tissue he supposes to be formed from the corpuscles, as its elements have the appearance of blood-particles in a state of change. He believes them to unite, forming a necklace of elliptical bodies, coalescing and becoming paler, the membranous partitions of each disappearing to form a vessel, the sides being imperfect at certain points for union with branches. He has observed also many other tissues are originally formed from cells, so like to the changed blood-corpuscles, that it is unreasonable to suppose them formed from any other source, and believes that when necessary new cells are developed from the corpuscle in the same manner by which cells are formed in the germinal vesicle, by the formation of a cavity containing pellucid fluid in the centre of the nucleus. The most remarkable of the tissues he has examined are cellular, vascular, and nervous, muscular fibre, cartilage, the coats of blood-vessels, epithelium, the biliary processes, the pigmentum nigrum, and the crystalline lens. The elements of the spermatozoon and ovum he also found developed in a manner analogous to the changed blood-corpuscles. Thus it appears from his experiments that all the important structures of the body are formed from the red corpuscles. This causes a great change in the consideration of the uses of the other components of the blood. The albumen existing in the serum can be no longer supposed to form cellular tissue, so universally disposed. Fibrine, before said to compose the greatest part in the frame in the muscles, can no longer be considered to serve this important end. We shall see in the next chapter that this last component forms a convenient and necessary vehicle for the action of the red corpuscles, in certain abnormal states of parts, and it may be that

in the process of nutrition, in a state of health, it is employed in this manner. But it is likely that both these substances exist in the blood in readiness to become more highly organized. We see, then, all kinds of animal tissue originate from the blood in a cellular form analogous to the parenchyma of plants. Also every tissue has a power of assimilation, that is, a faculty of producing from the blood (a fluid everywhere alike when supplied for the purposes of nutrition) a structure like in all points to itself. That this process is carried on in the capillaries there is no doubt, both from the convenient conformation of these vessels, and the changes which the blood there undergoes. Thus do we see the admirable manner in which our bodies are formed and supported. We see, however, that the complexity of the process of nutrition is always proportioned to the degree of organization and muscular energy possessed by the animal. In the lowest forms, the nutritive current is taken up by the different parts, and becomes a solid portion of the creature with very little change, for all parts appear to be of the same formation. But as we ascend in the scale, and find the circulating fluid become more elaborate, so we find its changes in the body more numerous, until we come to the highest classes, and find there the variety of changes it undergoes after its elaborate formation. And in these we find the rapidity with which the blood is appropriated by the several structures dependent in a great measure on the degree of muscular action employed.

XVI. In the process of nutrition, the blood, which is a fluid, is formed in every instance into solid tissues, yet differing in degree of solidity. Its fluid state is necessary in order that it may be transmitted quickly and constantly to every part of the body, but it is evident that there are some parts which will become superfluous during its course. Thus, in process of time, matters in themselves not hurtful to the animal economy would, by their accumulation, retard the course of the circulation, and materially alter the functions connected with it. Such a constituent is found in the blood, in water, which, existing in the

serum, is being constantly introduced in large quantity, as it holds an important place in the composition of all aliment, and is necessary to preserve the blood's fluidity; but unless some mode of abstraction from the system were constantly in operation, it would accumulate in too great profusion. Accordingly, it not only enters into the formation of all secretions, but another ample provision is made for its elimination. In the lungs, during the abstraction of carbonic acid and the absorption of oxygen, water is disengaged from the blood in large quantity in the form of vapour. Its exhalation in this state is effected by the extreme thinness of the walls of the capillaries, and consequent easy action of the dryness and heat of the air upon the blood; and it is thus best adapted to pass out during the act of respiration. The quantity of water thus passing off by the lungs is very great, as we find by the experiments of Lavoisier and Leguin, that out of eighteen grains of water passing off from the blood of a man, in one minute, seven disappeared from the lungs, while the remaining eleven were exhaled and excreted from the skin in modes which I must now describe. The external surface has a special function, the disengagement of aqueous vapour. This operation proceeds always when a moist surface is placed in contact with a warm and dry atmosphere. Cold does not appear to have much influence over this evaporation, as in an atmosphere cold and dry, it continues and may increase, while, in one warm and humid, it decreases, or is even checked. The contact of water to the surface completely stops this function. Another mode by which water is carried off from the blood on the surface of the body is in a fluid form. We find this effected by a system of glands, named sebaceous follicles — These minute bodies are embedded in the cutis vera or true skin, and consist of a convoluted tube, on the exterior of which small blood vessels ramify and open on the surface by a spiral vessel, forming an excretory duct, passing through the epidermis. By them a fluid is secreted from the blood, and taken out of the system, consisting of water with a little saline and animal

matter. These glands and their secretion have as yet only been detected in mammalia, so that in this function may be perceived the same progression as in others connected with the blood. It is maintained under opposite external influences to the last mode, or exhalation. Thus it is checked by cold and increased by heat. In moderate temperatures, the elimination of water by exhalation is six times greater than that by excretion, while, if the temperature be elevated, the latter mode will soon exceed the former in the quantity carried off, even if the air be humid; indeed, if it be dry, exhalation may still exceed in some degree. We find, however, the *exhalation* which proceeds in the lungs greater than that which takes place from the general surface, and much less liable to be affected by external influences.

XVII. Hitherto I have spoken of a body being separated from the blood which is not essentially noxious in its properties if retained in it, and which would answer no useful purpose in the economy, after having fulfilled its office in the blood; now I must refer to very different matters in connection with the process of secretion. During the nutrition of parts, a decomposition of particles takes place, and many products, foreign and detrimental to the tissues, are formed. If these were allowed to continue there, in a short time all the functions would be stayed. Accordingly, means are provided for them to be taken up by interstitial absorption, as the tendency to decomposition shews itself, and carried away to be reorganized. During this process, as we have seen, the blood also is rendered impure; the changes which take place during the formation of organized tissues, introduce into it products foreign to its purpose. That the retention of these in the blood would be extremely hurtful to the powers of life, is proved by the phenomena which ensue on the forcible stoppage of respiration and consequent retention of carbonic acid. The stoppage of some of the other secretions will soon produce death to the entire body. Some of these secretions are found not absolutely hurtful to life, if retained, but are necessary in certain organic processes, others are not only essential

to these processes, but are also extremely noxious if retained, while others yet are not useful in any operation of the animal economy, but are fatal to life, if not eliminated. Hence it follows that these products should be constantly, entirely, and certainly abstracted from the circulating fluid, in order that life and health may be maintained.

In animals, the most simple in structure, we find the least development of the organs necessary for the abstraction of these parts; as the complexity of formation increases, so does the development of organs for the abstraction of deleterious principles, and the activity of them is always found to keep pace with the rapidity of nutrition necessary. The peculiar products of the different secreting organs exist in the blood, either ready formed or in a state needing little change. The blood is carried by a special system of vessels to each gland, and there, by its peculiar organization, a fluid is secreted peculiar to itself. Thus the liver secretes bile, the kidney urine, the pancreas the pancreatic juice, the glandular follicles of the stomach gastric juice, the salivary glands saliva, the serous membranes have also their own secretion, the true serous sacs secreting a fluid to lubricate the internal surface, and the synovial membranes synovia. We also find some tissues capable of exerting an independent power of secretion, thus the cellular tissue possesses the faculty of secreting the watery portion from the blood, and placing it in the interstices of its fibres, while an especial form of this tissue has the power of abstracting the oleaginous particles from the blood, and thus forming adipose tissue. I need not say that this last is wrongly placed here, not being a process of *secretion*. The peculiar secretion of the liver is bile. This appears to be for the sake of the diminution of carbon in the blood. In insects, where respiration is very active and proceeding in all parts of the body, there appears to be no developement of this organ, because the further excretion of carbon is unnecessary. In the human fœtus, which in some respects resembles the lower animals, the liver is largely developed, for it is the only organ of decarboni-

zation which can act, and the very imperfect purification of the blood by that of the mother, suffices for the removal of very little of the noxious material. This secretion is formed principally, if not entirely, from venous blood. This blood has circulated over the entire intestinal surface, and is brought back by the mesenteric veins, which vessels are thought to absorb some substances not taken up by the lacteals to form chyle. If it is so, the blood passing to the liver has other impurities than those found in the venous blood in other parts of the circulation. Some have thought also that in the mesenteric glands a change of material is effected between the blood passing about them and the chyle passing along their tubes, if so the liver has some of the latter also to act upon. The use of bile in the animal economy is to change the homogeneous mass to which the aliment is reduced in the stomach, and render it fit to be absorbed by the lacteals, by some mode with which chemistry has not yet made us acquainted. On ultimate analysis it is found to consist chiefly of carbon and oxygen. Two principles are found in it, cholesterine, a crystaline fatty matter, which enters deeply into the formation of biliary concretions, and picromel, a substance which may be obtained in a crystaline form and to which the taste of bile is owing. I mention these, because it has been supposed by Berzelius that the animal matter of the bile is albumen in an altered state, and it seems not unlikely that in the change it may undergo during the decomposition of the tissues, it may become crystaline, a form assumed generally by the products of inorganic nature, and indicating a less fitness for life. The pancreatic juice, secreted from the blood in the pancreas, does not appear to contain any constituents which would be essentially hurtful to the circulating fluid, if retained. In constitution it is much the same as saliva, which I shall presently notice, and it appears to be eliminated on account of its necessity for the process of digestion.

The kidneys secrete a fluid not adapted for any operation in the system, only fit to be immediately excreted. Its separation is

essential for the maintenance of the vital functions, and it seems the principal mean by which the superfluous nitrogen is taken off. It contains saline matter in the same state as it is found in the blood, and some highly azotized principles. The most remarkable of these is urea. When this substance is pure it contains nearly 47 per cent. of nitrogen, a larger proportion than is known to be in any other organic formation. Uric acid, a compound of urea, contains one-third part of nitrogen, is in small proportion in health, but increases in some diseases. Here then we see a provision made for the separation from the blood of substances formed in it during its circulation, with no other purpose than the elimination of them, on account of their highly noxious effect upon life, if retained. If we seek for the source of these peculiar compounds, they will most likely be found in the serosity. This, as I before stated, is the part of the serum remaining liquid after the albumen has been coagulated by heat. When examined, this is found to contain a large quantity of animal matter composed of the effete particles, and it is this, most probably, from which urea is formed. If the secretion be put a stop to by extirpation of the kidneys, or by disease, urea may be detected in this part of the blood, and the retention of it will speedily prove fatal, the effects being most apparent on the centre of the nervous system. The aqueous portion is variable in amount in different classes of animals, in some being nearly deficient, in others very abundant, and in those with which it is plentiful it is vicarious with the aqueous secretion going on through the skin. The compounds abounding in nitrogen are found in greatest profusion in carnivorous animals, while in those living upon vegetables they are more scanty. It does not appear that any constituent of saliva is hurtful if retained in the blood, or its separation necessary for the well-being of the fluid. It seems, in fact, that the sole end of its secretion is to assist in the reduction and digestion of food, as the glands, and consequently their secretion, are developed in proportion to the *solidity* of food of the animal In the saliva itself we find only 1 part of 100 of solid

matter, and this composed partly of animal matter, very likely albumen in an altered state, and partly of saline matter like that of the blood. There are also to be seen in it transparent globules larger than the red corpuscles. The lachrymal and mammary glands are alike important solely for the uses of the economy, and not as a medium of excretion for any decidedly noxious parts, the former serving constantly to lubricate the motion of the eye in its orbit, and the latter, aroused by some mysterious sympathy it possesses, with the reproductive organs, to pour forth its secretion for the support of the new life. It is a singular fact, and a proof of the necessity for these modes of secretion and excretion to proceed, that when one of them is stopped, another gland, or even another kind of tissue, not formerly possessed of the power of secretion, will take on its peculiar action, and secrete its fluid from the blood, as uric acid may be deposited around the joints, and urine secreted by the skin, stomach, or other parts. I have now briefly described the processes of formation, the characters and uses of the blood, as it is seen circulating in the body in its natural state. All these run into each other, and are so interwoven in their action and effects, that it is difficult to describe them separately and distinctly, without appearance of inaccuracy, and without losing sight of the connexion that exists between every part and every change. If I have failed in accuracy, or wandered too frequently into matter at first view appearing irrelevant, let the vastness of the subject be my excuse, and the important connections it has with the study of every structure, afford sufficient reason for my bringing to my aid in its research all concerning other parts of the economy holding a close relation to it. If, after all I have stated concerning the blood in its formation, circulation, and in its office of nutrition, any thing need yet to be said demonstrating that vitality exists in it, *I* know not from what source to bring arguments. That life exists in the blood as in the solids of the body, appears evident from its tendency to spontaneous coagulation, and the changes which occur in its component parts, more especially the red particles.

CHAPTER III.

THE BLOOD UNDER THE INFLUENCE OF DISEASE AND INJURIES.

In times of darkness and superstition, when men constrained an infant and almost unnurtured science to bend to their own wild views, and mingle with their own dwarfish interests, it was thought by some that man might live for ever. There was a certain mistaken nobility of soul in these men which led them on beyond the little knowledge they possessed into enticing regions of speculation and uncertainty, and there whispered to their willing belief that they might become as gods. So, while others eagerly sought, through all the fast awaking lore of Arabian chemistry, for the means of obtaining riches,—of transmuting base substances into precious metals, an equally fallacious hope; enthusiasm kept constantly kindled the lamp of another votary, and ever and anon his fire shone with a bright flame, and his crucible sent forth a red glow, in the hope that soon he should hail with joy the wonderful elixir, the sparkling draught that should make him eternal, ever to live, ever learning the thousands of mysteries that preside over every grain of earth and every star of heaven. The "son of the morning" fell by pride, and the brightest intellects of the middle ages were thus often led by pride of mind into mazes of visionary expectations, which detained them in worse than ignorance, until death fell upon them amid the glare of their unceasing fires, not the less terrible because fancy pictured the cup of immortality almost within reach of their lips. If they had expended the same intellect and indomitable perseverance in exploring true science, in carefully gathering facts from nature, and thence drawing correct conclu-

sions, they would have seen that the symptoms of dissolution and decay exist in all the animated creation, even in its strongest life, and that death is decreed to all. To the first fathers of our race, whose sturdy frames seemed almost insensible to the lapse of ages, down to their degenerate descendants of modern times and luxurious habits, death has been alike certain. Sometimes imperceptibly stealing upon its victim in gradual decay; at others, crushing all existence and feeling at one fell blow; and again, sending before it numberless pangs, as changeful in their character as the pleasures of existence, and following these dread precursors as a welcome guest, however different its appearance, still, sure as sunrise and sunset, still it comes. The aid of man cannot *for ever* avert this end of the body,—but, like the insect that struggles into life only to sport in the sunlight and then die, man loves to enjoy his little hour of existence; and here his fellow-being may assist him, with the power and knowledge entrusted to him by the Almighty, causing the pulse once again to throb with the consciousness of life and joy, until the cord that binds the mysterious principle to the grosser organization is finally severed, or worn away by time. Long might I expatiate here on the nobleness of this office, God-like in its ends, and yet appealing to all tender human sympathies, and shewing to its possessor in the most forcible light the fragileness of man, and the weakness of his greatest efforts, but space forbids.—Happy and honoured should they feel to whom God has delegated a work which he, when on earth, deigned to consider as one most important, and fulfilled with a gentle kindness we should endeavour humbly to imitate.

I. A disease is but imperfectly understood if we do not know its cause. Remedies may be administered empirically, and a chance stroke of the physician may, it is equally probable, speed the cure of the patient's body, or waft his soul to the shores of eternity,—but all is uncertainty; one man groping and fumbling, as it were, after the precious life of his fellow. Happily there are few diseases, and few professional physicians, to whom this

can apply in the present day. We are accustomed to decide in our own minds upon the cause of a disease, before we feel competent to prescribe a remedy. And not only do we seek for causes in the external influences to which the body is exposed, but endeavour to ascertain what change has taken place in the components of the frame itself, causing the symptoms visible even to the unlearned. Since these changes were first observed, controversy has been rife among the most learned physicians of former times, whether the solids or fluids of the body were the parts solely the subject of them; and the advocates of both opinions wandered into error, as all will who adopt dogmas in medical science instead of arguing on wide premises. The solid structures of the body are most certainly and greatly changed in many, or even in most, diseases; but it is folly, from this, to deny that the fluids are as soon altered, especially as we have yet to inquire through what medium these changes are effected in the solids. We know also that in many diseases in which the changes of structure are nearly imperceptible, there are great alterations in the fluids, and those alterations sufficient in importance apparently to account for the other morbid appearances. It would appear, however, that disease originates in changes in the fluid as well as solid parts of the body, which are not confined to either, but are perhaps more constantly visible in some diseases in the fluid parts. Hence in the blood, as the chief part of the fluids in the system, we look for changes in disease. Nor are these confined to disease strictly so called; in those persons who die naturally, i. e. of old age, the blood is found altered in its constituents, and that alteration is most probably the cause of the other changes in the body. Thus, while the phosphates of lime and magnesia exist superabundantly in the circulating fluid, in the bones these phosphates are deposited in greater proportion, making them brittle and easy to break, and in the inner coats of the arteries ossific matter is placed. It is likely also that the colouring matter in the blood is in less quantity, as we find the hair gradually blanch, and at length appear

totally devoid of the colour peculiar to the individual. These changes in the circulating fluid are slow and gradual in their effects, agreeing with the gradual progress of decay from organ to organ, until the whole frame is unfitted for life. But in disease, which attacks the frame in a career of health and vigour, the alterations in the blood are sometimes more sudden and powerful in effect, although at others they are gradual and almost imperceptible. The proportions of its three principal components, the serum, fibrine, or red particles may be altered, or the matters held in solution in the serum may be too abundant or deficient; and these changes are shown to the observer by difference of colour or consistence while in the vessels or when first drawn, and difference in its manner and degree of coagulation afterwards. Also the blood may be greatly changed by imperfect aeration, which is exhibited by the dark colour. The alteration in the blood forms an important symptom in almost all diseases; by it we are frequently able to discover the amount of injury the system has sustained, the power of resistance and recovery it still possesses, and consequently choose medicaments most fitted for it. In speaking of the blood in different diseases, I shall not observe any nosological order, but pass from one to the other, as I am led by the similarity of changes occurring in the fluid. The blood is altered in specific gravity in some diseases, that of health being about 1,044, and it is found to become greater as the proportion of water is less, or of fibrine and red particles more. But this character is dependent greatly upon another which is much influenced by disease; the temperature of the blood is in many diseases much higher than the natural standard. It is so very frequently in the disease to which I shall first refer, in fever.

II. In the different varieties of fever, different changes occur in the blood. I shall first review those which are seen in contagious fevers, and those arising from marsh miasmata. It appears evident to me that, in these diseases, a depraved state of the circulating fluid is the proximate cause. It has been fatally

shown by the effects produced by the blood of animals diseased, or in a state of unnatural excitement, that the fluid then acts in a manner as malignant, if not as sudden, as the most deadly of cheminal poisons. Hence, as the blood of these same animals has been found innoxious when drawn from them in a healthy state, and injected into the veins of another,—it follows there must be some influence by which the blood while in its vessels is made not only unfit for nutrition, but hurtful also, and destructive to the life of the animal. Then it is not at all wonderful that the blood, dependent as it is in formation upon the digestive function, being the fluid of nutrition for every part of the body, whether devoted to animal or organic functions; and thus forming a most important part of what may be termed the circle of life, should be the primary seat of fever, a morbid influence which affects alike every function of the body. This supposition appears to me to be converted into fact by experiment. The blood taken from the veins of a patient with putrid fever, and injected into those of an animal, has been found to produce symptoms much analogous to the original disease, not explicable by any other reason, and ultimately terminating in death. Add to these facts the observations upon the changes in the blood, which I shall enumerate, and I think few will doubt that a diseased state of the blood is the proximate cause of fever. First, in the contagious fevers of the West Indies, which have been observed so minutely by a distinguished physician and physiologist, on opening a vein before the appearance of the disease itself, the blood is even then found to be dark and diseased. During the first or cold stage, it grows darker and emits a peculiar odour; while upon the crassamentum formed in the withdrawn blood, which exhibits no buffy coat and is very soft, there are occasionally dark spots. In the hot stage the blood is of a redder colour, and in the most severe forms the albumen is seen to coagulate in flakes above the surface of the crassamentum, and the surrounding liquid is brownish in colour, sometimes containing more oily particles. In the climate fever of the same

country, not contagious but eminently fatal to Europeans, the alterations of the blood are somewhat different. In the first stage of this fever the blood is of an extremely florid colour, and when drawn coagulates firmly, so as to express the serum from the crassamentum, but is still without any signs of the buffy coat. In the next stage it is less florid, and in the last becomes dark; in severe cases being so thin as to pass through the walls of its vessels, in consequence of losing almost all its fibrine and albumen. We may now pass from these to the contagious fevers of our own country. In the first stage of simple continued fever, the blood is dark; it coagulates quickly, forming a large clot; in the next or hot stage, the blood becomes thinner, more florid, and coagulates slower. In the last stage, the blood is still thin, but is again darker, dissolved, and barely coagulating, hence it is most probably deficient in fibrine and red corpuscles. In typhus fever the blood is found to be thin at the very commencement of disease, and as it advances becomes more so, until at last it appears almost entirely destitute of fibrine. I may here also mention that a puriform liquid injected into the veins of a healthy animal, has been found to produce a disease much resembling typhus. Now, in all these diseases, both foreign and appearing in our own country, which have been thus classed together, the blood becomes preternaturally *dark* in some part of their course. In some also it is at one time preternaturally florid. This difference of colour is said to arise from variation in the quantity of saline matter contained in the serum, and this has been stated to be the most important change of the blood in these fevers. How the saline matter disappears after having existed in too great abundance, is a matter of inquiry, which might be prosecuted with great advantage. Still, it has been shown by the experimenter, that blood thus darkened in fever does not recover its red colour on being exposed to the atmosphere, as is usual, but immediately becomes florid on saline matters being added to it while thus exposed, and as might be supposed from this, on analysis, the blood has been found almost

deficient of salts. The extreme thinness of the blood, in some of these forms, may be accounted for by supposing that its solid material is exhausted in supplying the various structures, the lavish waste and expenditure of which, during the progress of such a disease, is more than the stores of the circulating system can replenish, without injury and destruction of themselves. The great injury which ensues to the whole frame, where we can perceive little change in the blood but the diminution or absence of saline matter, exhibits the importance of the office these salts fulfil in the economy.

III. The next disease I must review, is inflammatory fever. In this disease, the principal change is not in the colour of the blood, but the crassamentum is large when drawn, and the chief character is the peculiar mode of coagulation. Healthy blood, when taken from a vein, begins to coagulate quickly, almost immediately that it has passed from the vessel, and the fibrine encloses the red corpuscles (these last indeed being thought to have some share in the act), expressing the serum, and binding up in a moderately firm homogeneous mass. This property of healthy blood is universal, although in some individuals it is found to coagulate very slightly. Andral has supposed that the variation in the power of coagulation seen in the fibrine is caused by some change in the proportion of its different elements. We know, however, how much fibrine resembles albumen, and albumen some other products, and knowing this, cannot easily suppose how fibrine may be changed in its property of coagulation, its chief distinction from albumen, and yet not merge into any of the forms it so much resembles. There are several different modifications of the coagulation of the blood from the healthy crassamentum in the fevers I have before mentioned; in some cases the blood remaining thick and equal in colour in its whole extent, not forming a clot; in others, a large crassamentum being formed, containing, in the interstices of its fibrous texture, much serum; in others still, a large, loose, and soft clot is formed, not containing serum; and in a still more different

variety, the buffy coat is seen, which must now be noticed as always present in inflammatory fever. I will premise, however, that I do not think we should refer these different degrees of coagulation to a change in the chemical constitution of the fibrine. Why should not this singular change of action be referred to the operations of that mysterious agent, which all physiologists agree to assign a place in the body? but some grudgingly refuse to allow an influence over as many functions as they can with conscience claim, ascribing them to any chemical change, however absurd, to electricity even, rather than to the principle of life, the finest, because the most mysterious, part of the animal. But with regard to the buffy coat of the blood. When blood drawn from a person suffering under inflammatory fever, or even local inflammation which affects the system generally, is set aside to coagulate, a considerable time elapses before this process is performed. On looking then into the vessel, we see a moderately sized clot floating in a greenish liquid. But the clot is not here coloured alike through its whole extent; the lower part is red, and shows that the fibrine is there mingled with the red corpuscles, while the upper part is of a yellow buff colour, evidently consisting solely of fibrine. Sometimes this upper part, on examination, exhibits two layers, the upper of the two being soft and easily broken, while the lower is more solid and coherent. Accompanying this appearance also, when the blood is collected in a deep vessel, the upper surface of the crassamentum will be concave, for the fibrine is able to contract into less compass when separate, than when mixed with the red corpuscles, consequently the upper edges of the coagulum are inverted, and the surface concave. This appearance is termed buffed and cupped. This peculiar action appears dependent upon the relative quantity and specific gravity of the component parts of the blood. Thus, if the specific gravity of the liquor sanguinis be less, or the red particles greater, than natural, it will ensue. The way in which this appearance is generally accounted for, is the following: the red particles form the hea-

viest part of the blood, but in a state of health the fibrine coagulates so soon as to prevent them from subsiding to the bottom of the liquid, and thus the crassamentum is formed of fibrine and red particles. But when the blood is under the influence of inflammation, the fibrine coagulates generally very slowly, and in the meantime the red particles fall down to the lower part of the vessel, when they meet *with* and are enclosed *in* the fibrine there coagulating, while the fibrine in the upper part coagulates free from their admixture. Another cause of this difference in the upper and lower parts of the coagulum, is said to exist in the greater abundance of fibrine in the blood of inflammation than in the healthy fluid, the average quantity of fibrine in 1000 grains of crassamentum being 3,53 grains in a healthy state, while in blood buffed and cupped, there have been found nearly 14 grains. In consequence of this greater proportion of solid matter, this peculiar phenomenon is exhibited more frequently in blood above the natural standard of specific gravity, although it may be found also in that below it. On dividing the crassamentum, cavities are sometimes found in the interior, containing a fluid, which is the liquor sanguinis. This fact is singular, namely, that one part of the fibrine should still remain in solution, uncoagulated, while the rest, surrounding it, is already coagulated, and it appears that as animal heat is in some degree dependent upon the number of the red particles, so coagulation, which is greatly influenced by temperature, is in some way aided by their being mixed with the fibrine. Addison has stated his belief that blood-corpuscles, in a process of development into parent cells, coalesce to form the buffy coat. Wherever this state is exhibited in the blood, there is increased action in the circulating system, and this is proportioned to the supply of nervous energy transmitted to it from the centre of the nervous system. It is most frequently found in diseases when capillary action is increased; and wherever it is present, polypi are found more abundantly in the heart and large vessels after death, consisting essentially of fibrine. In the state of inflammation there

is also considerable variation in the formation of the serum. It has been demonstrated that it contains much more albumen than in its natural state. These are the changes to be noticed in inflammatory fever, or states in which the general system is greatly affected by local inflammation.

IV. Sea scurvy, the disease so frequent among sailors, kept long upon the use of salt provisions, presents many peculiar changes in the blood, and appears to originate in a morbid condition of the circulating fluid. The blood, when drawn at the commencement, is seen to flow in different shades of light and dark, and as it advances, the light shade vanishes, leaving it uniform in colour, black, and of thin consistence when flowing, but after standing some time, thick, disturbed and muddy in its appearance, and here and there upon its surface patches of a greenish hue. In the next and last period of the disease, the blood is very dark, and after lapse of time the fibrine assumes a very loose and flaky texture throughout its whole extent. During the progress of the disease, the blood shows little tendency to coagulation, and is found fluid after death in most cases. The circulating fluid has lost here some of its affinity for its vessels, as it is known to pass through their walls and form petechiæ in many parts. Here also is well shown the influence which the blood possesses over the other functions, for we see many tissues become diseased and ulcerations formed without any external cause, puriform fluid discharged again from all openings which have formerly performed that action and left it for a healthy state; in fact, all the secretions disturbed, changed in their nature and quantity.

In the purpura, or land scurvy, the proximate cause also appears to be a diseased state of the blood, as a chief symptom is its tendency to escape from its vessels, being effused into many structures, and it is said in severe cases to present all the appearances of sea scurvy.

V. I now pass to an epidemic which has proved the most fearful scourge of our own times, and to say the honest truth,

has generally, through its terrific rapidity, baffled the skill and efforts of physicians. The pathology of malignant cholera is but imperfectly understood; but I think enough is known to show us changes in the blood sufficient to account for its most energetic symptoms. The alterations are remarkable, causing an utter unfitness in the blood for the purposes of nutrition. In the commencement of the disease, the blood exhibits a greater proportion of solid matter, more albumen in the serum, and probably also a greater number of red corpuscles. Accordingly, the serum is found to possess a high specific gravity, and contains less water, the salts also being in small quantity. These latter have been said by observers to be quite wanting in microscopic structure, a fact which would lead us to infer the presence of an abnormal substance. The blood, even in the first onset of the disease, is dark coloured and tarry in consistence, which may be supposed owing to the deficiency of salts. Coagulation is variable, in some instances taking place rapidly, in others slowly, and in some rare cases a buffy coat has been observed. However, in the course of the disease, a deficiency of serum and fibrine is observed, and the blood becomes darker. The serous secretions, so copious during its progress, have been examined, and in them serum and fibrine discovered. The lividity of the general surface and the collapsed state is what we may expect from the imperfect respiration and consequent dark colour of the blood. It is worthy of remark, that these changes in the blood are the most important to be seen throughout the system in the disease.

VI. In chlorosis, we can discover no other efficient cause but the defective formation of the blood in consequence of digestive disorder, and the subsequent injury to the assimilative functions. When blood is drawn from a vein, it coagulates, and presents a crassamentum of pale red colour, and small in proportion to the serum. It is also soft and weak in its texture, and on examination the blood is found to be deficient in fibrine and red particles. To this deficiency the loss of temperature

and the pallor which the subjects of it evince, may be attributed. The œdema also shows the relaxed and unhealthy state of the blood.

In the diseases I have thus briefly noticed, the blood is not changed by the introduction of a principle foreign to it and differing in its composition and purpose from its natural constituents, but it is generally from the loss of some part or proportion of its components, that the general system is injured. But in those which must now be remarked, the blood appears altered by the retention within it, or introduction to it, of some part of the secretions. In this state in some instances it becomes decidedly noxious to the structures it should nourish, while in others only a part of it is contaminated, and thrown off afterwards.

VII. Among diseases answering to the first description, one most important is a peculiar disease of the kidneys, termed "Bright's disease," from the celebrated man who first obtained for it a distinct place in nosology. In this disease, albumen, a chief constituent of the blood, is found in the urine, and that even in so great a proportion as one-eighth of the whole quantity existing in the circulating fluid. It is certain, therefore, that the office of the kidney has been deranged, and that with the watery portion of the blood and the urea which should be secreted by it, it separates albumen also from the blood. This opinion is strengthened when we examine the blood taken from a patient of this description. It generally exhibits a firm crassamentum with a thick buffy coat, the serum appears somewhat turbid, and on trial is found of less specific gravity that usual. Its proportion of albumen is agreed by observers to be less than natural. But it seems also that, while albumen is separated from the blood by the kidneys, the proportion of urea which they should secrete is lessened. The serosity contains a peculiar animal matter, nearly analogous to urea. It has been found by experiment that when both kidneys are extirpated, urea exists in the circulating fluid. There is little reason for stating here the

probable cause of this alteration of function in these excretory organs, but it appears to me to result from an undue proportion of blood being transmitted to them, by the irritation of which the affinity of the secreting organ for certain principles of the blood is changed. The quantity of urea retained in the blood, is here, I apprehend, so small as not to cause any great mischief, but the albumen of the circulating fluid very gradually drained off by the offending organ is the cause of the evils which ensue. As in all diseases where the solid constituents of the blood are at all lessened, so here its serous portion exhibits a tendency to escape from its vessels and infiltrate the surrounding tissues. And in other diseases, which evince their presence by the effusion of serum into different parts of the body, albumen is found in the urine. In most diseases of the kidney there is manifested a tendency to pass off the red particles of the blood in the urine; and in aggravated cases, the blood itself passes off with this secretion.

VIII. In the next disease to be noticed we find a product of whose existence in the natural state of the body we are not aware, poured forth in its secretion of urine. In diabetes mellitus, sugar is found in the urine in considerable proportion, and the question arises from what organ or process of the system is this morbid product formed. In this enquiry we have been greatly assisted by the examination of the blood. The blood is thin in consistence, the coagulum is soft and weak, free from a buffy coat generally, but in some cases, is firm and exhibits a buffy coat. The serum of diabetic blood is in the same proportion as in health, also the albumen and salts are found in it not altered in proportion. It has been found to resist putrefaction for a very much longer time than healthy blood, and after many attempts sugar has been at length detected in it. From this it would appear most probable that the process of digestion is altered, and in consequence sugar taken up by the lacteals, with their natural fluid, and thus introduced into the blood, thence to be eliminated by the kidneys. It is noticed of the urine in this dis-

ease, that it is defective in the proportion of urea to the other ingredients.

IX. In icterus, the bile is stopped from passing by its natural passage, and is therefore either absorbed by the small vessels ramifying on the duct itself, or retrograding into the liver, is there taken up into the portal circulation. However this may be, it passes by the circulating system into every part of the body, and tinges the cutis with a greenish yellow hue. Both the arterial and venous blood, on examination, is seen to be coloured by bile. After coagulation has taken place in blood withdrawn, both the portions, the serum and the crassamentum, exhibit this peculiar tint, and when the coagulum is dried, it still preserves it. It has been supposed that it does not exist in the blood in a free state, but forms a compound with the albumen. However, by chemical analysis, the cholesterine and the colouring matter have been found in the blood. Its presence in blood is shown by the addition of dilute sulphuric acid to the suspected fluid, which changes the yellow to a decided green colour. Here the blood shows the presence of a noxious matter by a tendency, as in some of the foregoing diseases, to form petechiæ, and the fluids secreted from it are unhealthy.

X. I shall next refer to that species of melanosis in which the character of the blood is changed by chemical action. The seat of this alteration may be the stomach or intestines, more frequently the former; and in order that it may be effected, the blood must be in a motionless state. When the blood is motionless, it may be effected, either in or out of the vessels. It likewise depends upon circumstance, whether the stomach or intestine during the time of its hindrance contain any of the chemical agent. Generally this appearance results after incurable disease of the organ has proceeded some time, and caused permanent impediments to the circulation. When the blood is impeded *in* its vessels, the acids of the stomach, if present and in contact with it, immediately begin to produce a peculiar effect upon it, changing it from red to orange, and afterwards through the vari-

ous shades of brown, to a nearly black hue. Under the chemical action necessary to produce this colour through their medium, the coats of the vessels soon become affected, and at length entirely dissolved, leaving the blood open to mixture with the secretions of the stomach. Another mode in which the blood is thus changed in the stomach is by the rupture of some vessel, from which blood is poured out among the acids, and by their contact soon becomes blackened. This dark blood rejected from the stomach, may be known from blood,—dark merely from the presence of *carbonic* acid,—by its acidity, and power of rendering litmus paper red. In consistence it varies from watery to thick. The discoloration of blood while in the vessels may be effected also in the intestines, by the abnormal pesence of an acid, either fluid or gaseous. It may be produced in the peritonum likewise, by its contact with the intestines containing these agents, though, as I before said, it is necessary that some prior disease should exist, to impede the circulation, and thus expose the blood to their influence. This change in a part of the circulating fluid is accordingly of importance only as a symptom, but a fearful one.

XI. There are some states of the system which can scarcely be called disease, but rather the forerunners and proximate causes of *it*, or of some great natural change, as parturition, but are frequently extremely important in their effects, and cause great changes in the circulating fluid. The one most common of these (probably from our luxurious habits in modern times) is plethora. It appears singular that corpulent individuals, although they have in reality less blood than those with less adipose tissue (cœteris paribus), are yet more frequently plethoric than these latter. It is likely that this is caused by the greater resistance which these too well supplied structures present to the current of blood. However, it is shown from this that plethora does not consist in forming above a certain quantity of blood in relation to the size of the individual solely. Plethora may be produced likewise by the increase of certain components of the

blood in a greater proportion than the others. The fibrine generally, and, I conceive, the red particles also, are the part of the blood increased in plethora. The blood, when drawn from a vein, commonly shows a buffy coat. The skin assumes a purple hue in consequence of engorgement of the capillaries, and unless the general fulness be relieved by hæmorrhage from the mouth or nose, accumulation of blood, either near the surface, causing local inflammation, or in some internal organ, causing congestion, extravasation, or inflammation and effusion of serum, will take place. Even, when not amounting to this degree, it affects the nervous, and consequently the assimilative functions of the body in a remarkable manner; the circulation is frequent and strong in the extremities, pain in the head ensues, because the accession of blood to the brain is quicker than its return, and it consequently contains a larger proportion than usual of arterial blood; inability for mental exertion is shown, and dyspnœa in consequence of the amount of blood requiring to be arterialized being more than the air introduced to the lungs suffices for; muscular debility also, through the deficient supply of nervous influence. Such are a few of the symptoms caused by an over abundant supply of blood, or an undue proportion of its components. The state of plethora is well exhibited in the female sex before parturition, appearing to be a necessary preparation for the coming event.

XII. The next state of the body I here notice, as deviating from the general health in the condition of the blood, is anœmia. This state is decidedly the contrary of the last mentioned, it being generally caused by a diminution of the mass of blood contained in the system, while that which remains is healthy, although sometimes it is accompanied by great morbid changes of the fluid itself. In the former case its causes are great loss of blood, the continuance of any excessive secretion, &c. Its effects on the general system are evinced by pallor, coldness, weakness, dyspnœa from a reason exactly contrary to that mentioned for the last disorder, frequency of circulation, and disturbance of the

cerebral functions. The secretions also suffer and become scanty. In excessive cases we have some singular trains of symptoms which I must here only mention. Syncope is the most common of these. Exhaustion sometimes follows this, in which all the powers appear to have departed, such a semblance to death does this state occasionally wear. On the recovery from this, the powers of circulation seem to have received an impression from the nervous centre, of the want of circulating fluid, as this function (of circulation) in the state of reaction proceeds at an extremely rapid rate, as if to make up for the smaller quantity of blood by the increased rapidity of circulation. The last state is that of sinking where the powers, both mental and corporeal, gradually pass away into a state of death. The latter form of anœmia, when the blood suffers morbid alteration, has been seen most frequently among those confined from the light of day and living upon scanty diet. The changes are great; in some cases the red particles have been found almost entirely deficient, as also the fibrine, so that only a thin serous fluid circulated in the vessels, and the change of colour of the general surface was proportionately striking. The evil effects upon the system are the same as in the above described form, with the exception of the last remarkable symptoms. The effect which the want of solar light has in causing this deficiency of the most important part of the blood, is worthy of notice. Here the proportion of blood circulating may not be altered; it may remain the same, while in its components the change takes place. There is yet another important condition of the circulating fluid, which does not imply its loss, but rather its depravation. Cachexia may be caused by impure air, miasmata, bad diet, slow poisons, or it may be congenital. From whichever of these causes it may arise, it generally results that the element of some disease is lurking in the circulating fluid. It is shown by the unhealthy hue of the skin, frequent pulse, alteration of the secretions, and emaciation. The cachexia preceding the formation of tubercles in the lungs is called tubercular.

XIII. In some of the diseases I have mentioned, it would be seen that the coagulating property is much lessened. It is usual after death, by most means, to find little or no blood in the smaller vessels, while it is collected in the heart and large arteries leading to and from it, and here separates into two portions; a great part of the fibrine sinks to the lowest part and coagulates without the red particles, while these latter mingle with the serum and form the fluid part in the vessels. But in certain deaths, where a sudden and violent shock has been given to the nervous system, so powerful as at once to deprive every part of the animal of life, the blood has entirely lost its power of coagulation; in every and all parts of the venous system it is found fluid. Such is the case with animals poisoned by hydrocyanic acid, or asphyxiated by the inhalation of carbonic acid gas, with those exhausted by great exertions in speed just previous to death, and, according to some, in persons killed by the stroke of lightning. I believe that as the coagulation of the blood, when drawn from the body, is the last effort at vitality, so in these cases the power which causes death is so overwhelming as to quench at once every spark of life in the system, and thus deprive the blood of this mode of showing its loss of vitality. I must next consider the relations of the blood to the state of inflammation, and this by connection with other diseases will lead us through the remainder of this chapter.

XIV. Inflammation may be defined to be *that* state of local plethora and over action which is induced in any part of the body by the continued contact and influence of a stimulus. A stimulus of whatever degree it may be, if it have been applied long enough to become irritant, *increases* at first the sensibility of the part, and by reason of this augmented sensibility, the capillaries alternately dilate and contract (we may suppose) with more force and frequency, and a larger quantity of blood will thus be propelled through them in a given time, although the quantity in the part itself is *as yet* no greater than natural Its second action is very different. In all the actions performed by

any part of the body, dependent as each is upon the nervous system, there must be an alternation of excitement and rest. It is a peculiar character of the nervous function to need an interval of rest after a period of excitement; the mental powers even show this, if excited beyond the time fitting for the individual, a reaction follows, placing them without the power of exertion until sufficient time has passed to renew their energy. Thus it is found in the progress of inflammation. In the first stage, the capillaries are incited by the stream of nervous energy they receive to perform their office with undue activity, but in a little time this ceases, their sensibility is diminished, they do not contract so frequently as before; the minute arteries near them, as they entered in the first stage into their degree of local action, so now they agree in their loss of contractility, and the blood distends them, thus the current is retarded. But this variation in the sensibility and contractility of the arteries, although it is the greatest influence in inflammation, is still not the sole one, there are evidently other causes which have some share in producing this state and the effect following it. The first of these results from the sudden change in the vessels from a state of greater activity than ordinary, to one of inability for contraction. By this means, the calibre of the capillary vessels, into which the minutest arteries pour their contents, is enlarged, and we can easily imagine the effect of this upon the blood would be the same as that shown in the progress of fluid passing from a small tube, which it fills, into a larger one. I apprehend that by this means some influence is obtained to retard the current of the blood. We may also conclude, with considerable reason, that there is an increase of vital affinity between the blood and capillaries (or rather a disproportionate degree of vitality in the former), which causes an increased quickness of circulation, and afterwards slowness and retardation, for we know that such a process is constantly performed in a state of *health* in the erectile tissues.

And it is equally certain, from the phenomena I shall presently

notice, that there are prior preparatory changes in the constitution and vital principle of the blood, and that these changes, when being further developed, still more impede the circulation. I shall now enumerate these alterations in the properties of the blood itself in the order in which they occur.

XV. During the first stage, or that of excited sensibility, the fibrine of the blood increases in quantity, and if the local derangement be extensive, the blood of the whole system will be found to exhibit a peculiar appearance in coagulation, the buffy coat. The fibrine also appears to change in its qualities, it retains a state of fluidity longer, and when it coagulates, does so more firmly and increases its plastic property. The circulation of the whole system is invigorated, and the temperature heightened, more especially that of the affected part, which may be perhaps accounted for by the influence of a greater number of red particles passing through it. To avoid some part of the effects of this vital agency, the function of secretion is excited to a greater activity than natural. When glandular structures are the subject of inflammation, the secretion of them is increased at the commencement, while in serous tissues the secretion is increased to a greater degree and for a longer time. Absorption also is very active. In the second stage, as the state of the vessels is the reverse of the preceding, so the condition of the blood is different. The blood gradually becomes slower in its circulation, at length coagulates, and becomes darker in colour. The temperature of the part sinks, and the processes of nutrition, absorption, and secretion are interrupted. In the first stage, redness of the part was caused by quicker circulation, and in this it is first rendered deeper by the increased quantity of blood in the part, and afterwards darker still by the coagulation of this blood. If the part remain in this condition, either new products are formed, fit for the uses of the part, or other diseased conditions follow, in which a product is formed to be evacuated from it. It has already been seen that during the first stage the fibrine is increased in quantity, as also in its plastic properties,

and it is here the place to consider the use for which it was thus altered.

XVI. In this I must first remark, the first effect of inflammation, adhesion. When the second stage of inflammation has continued for a longer or a shorter period, the fibrine, which, in the first stage, was seen to retain its fluidity longer, exudes through the walls of the relaxed and dilated vessels, (accompanied, I suspect, by another component I must hereafter mention), and immediately that it is effused begins to coagulate. This plastic lymph, as it is termed, is seen in the greatest profusion in inflammation of serous membranes. Changes are seen in the diseased surface prior to this effusion, it becomes more vascular and its substance softened, in order that channels of communication may be more readily formed with the exuded lymph, when in a process of organization, and possessed of vessels. The lymph is exuded in successive layers over the whole surface, but is not all equally organized, some of its solid part adhering but loosely or not at all to the original structure, and falling down to the lowest part of the cavity, mixes with the serum which has been exuded at the same time, and separated from the fibrine. At the first appearance of this product it is creamy in consistence, but as it coagulates it becomes gradually firmer until it has gained the solidity of fibrine coagulated in its pure state; but, from the phenomena to be mentioned, it appears evident to me that it contains some of the corpuscles of the blood. Now, when the lymph is disposed in this manner, it apparently holds no more relation to the structures surrounding it, than a foreign body which might be introduced. If it is necessary to supply some deficiency, and form any part of the body, it must first be intimately connected with it, and, for this, requires a vascular apparatus, supplying it with the nutritive fluid. It possesses this singular mark of life, that, although we do not know it could be developed any further without the aid of the blood of the general system, it appears that it can generate blood vessels within itself. The first sign of these is a

small vascular spot in the lymph, which contains globules, it is supposed, possessing some power of motion; slowly this spot becomes elongated, some say that the fibrine contracts in a curved manner, so as to form the sides of a vessel, but, according to the changes Dr. Barry has observed in the corpuscles, it is most probable these are the source of its formation. However, a vascular curve is soon manifest, the ends of which oppose the extremities of some vessels in the original structure; they meet; a circulation is established, and carried on so as to completely organize the new product and assimilate it sufficiently for the part to resume its natural functions. Physiologists are agreed that in all cases the circulation in the new tissue is established by one of two modes; either by that just described, or by the blood circulating in the surrounding inflamed part working through the softened diseased structure, and by the force of the circulating power forming for itself channels in the yielding plastic lymph. To me, the former explanation appears more probable in all cases, as it appears more analogous with the office of the blood corpuscles in nutrition, to suppose them thus commencing a new formation in the plastic lymph. From the plastic lymph effused from the blood under this inflammatory state, most of the tissues composing the whole body may be formed. Vascular, cellular, nervous, adipose, serous, mucous, cutaneous, cartilaginous, and osseous tissues are all formed, as they are required, from this product of the blood. Occasionally one of these tissues is formed from effused lymph in a situation which is not natural to it, and in which it would appear to be useless, but this is sometimes effected for the prevention of serious consequences from disease. Thus, to take a most frequent illustration, the lung is sometimes found bound to the walls of the thorax by strong cellular tissue uniting the pulmonary and costal pleuræ; and this, to prevent a tubercle seen under the pulmonary attachment from bursting into the cavity of the thorax, and thus causing serious mischief. If a foreign irritating substance be introduced into the solids of the body, or inflammation has

been so violent as to produce morbid matter unfit for contact with living structures, then this product of the blood takes on a peculiar action. It is effused from the vessels immediately around the irritating body, and in such quantity as to consolidate the tissues, forming a wall around the unhealthy deposit, and thus preventing it from contaminating the still healthy part by its influence. In relation to the solutions of continuity, which are constantly liable to be caused in our bodies by external influences, this effusion is the mode of reparation for all these injuries. When the bleeding of these wounds has ceased, a slight degree of inflammation shows itself in the severed vessels, the cut and contracted extremities of which pour out the plastic lymph plentifully and quickly, and if the parts are brought together in this state, speedy reunion, through the medium of the organized lymph, ensues. When fracture of a bone takes place, the blood circulating near it effuses a large quantity of this lymph, for the purpose of supporting the parts until they are reunited by matter of their own density and constitution. In these various conditions we have seen for what admirably wise and beneficent purposes the plastic lymph, a peculiar product somewhat differing from fibrine in its properties, but resembling it in its power of coagulation, is effused from the blood; and we are next led to remark certain changes, similar to these, which occur in the fibrine of the blood while in its simple unaltered state. I specify them here because, although themselves not the result of inflammation, they are yet frequently connected and cotemporary with it. These may be divided into those which take place in the blood contained in its vessels, and others when it is effused among the solid structures; I shall speak first of the former.

XVII. The fibrine of the blood always retains its fluid state while in *motion* in the vessels, but if the circulation be stayed in any vessel by a vital, physical, or mechanical agent, the property of coagulation is evinced. As the retarding force continues, the coagulum acquires greater density, the red particles appear to be removed from it, thus then it will consist entirely

of fibrine. It now exhibits a pale straw colour, is arranged in rows of fibres, and shows a tendency to contract towards the exterior of the coagulum, where it may be in contact with living tissues. Before the fibrine has long been in this state, blood vessels are seen to ramify through it, and these may be introduced to it in two different ways. It appears that, unlike plastic lymph, this does not possess the faculty of generating vessels in its own substance, sometimes the cause which impedes the circulation, at the same time produces inflammation in one of the coats of the vessels; lymph is effused and vessels pass from it to the less organized fibrine. Or when no inflammatory action accompanies the impeded circulation, it would seem that the fibrine, acting as a foreign body to vessels only used to the presence of a fluid, induces a modification in the circulation and nutrition of the walls of the vessel, and perhaps fulness of the small vessels. These parts are then fit to be prolonged through the fibrine, and thus give it the material for further organization. This organization sometimes proceeds through the whole of the fibrine, rendering it impervious and forming a fibrous cord of the vessel. In other cases it is only organized to near its centre, and through the opening left, serum coloured by the colouring matter, or a milky looking fluid may be slowly passed by its contraction, thus keeping a communication. The organized fibrine is ultimately converted into cellulo-fibrous tissue. The phenomena which follow the division or ligature of an artery, partake of the character of inflammation as well as that of simple coagulation of the fibrine from retardation. The circulation is continued by the nearest branch above where the artery is tied, and from thence down to the point, a coagulum is formed.—Death of the coats takes place at the point where a ligature is applied, and the inflamed capillaries throw out lymph, joining the sides of the vessel. Lymph is also effused on the external coats, they become thickened, and in process of time the coagulum is organized. The formation of, and phenomena attendant upon, aneurism have relation to this part of our subject. In

advanced life, or after the occurrence of arteritis, a degeneration takes place in the formation of the vessels, and calcareous matter is deposited between their coats, in consequence of which ulceration, or rupture without its precedence, follows; or from loss of elasticity in that part the vessel may be dilated, forming an aneurism. If the entrance to the aneurismal sac be wide, the blood will coagulate very little, but if it be narrow, the following are its changes. The fibrine at first coagulates with the red corpuscles, but is afterwards divested of them, being of a pale colour, and gradually increasing, attaining considerable thickness. Sometimes this coagulation has increased so as to fill the aneurismal sac, also filling up the calibre of the vessel above and below the diseased part, acting as a ligature, and thus producing a cure. But this is seldom the case. In general the fibrine is found denser as it is nearer to the exterior of the sac, and in some instances the most external layers have been found changed into osseous or cartilaginous tissues.

The polypi formed during life, and found in the cavities of the heart, are composed chiefly of fibrine, and their cause is doubtless an inflamed state of the blood, and the slow passage of it through the heart. They are found more frequently in the auricles than ventricles, and are interwoven with the musculi pectinati and the smaller of the columnæ carneæ. The red corpuscles are absent from them, and they are formed primarily of fibrine, if more organized, of cellulo-fibrous tissue. There are some other very singular substances found in the blood, formed from its fibrine. A clot of blood is first formed by some slight impediment to the circulation; it is carried forward with it, and soon parts with the colouring particles, being composed of fibrine in several concentric layers; from this gradually acquiring greater density, until at length it exhibits the hardness of mineral substances. These bodies are named phlebolites, and are contained in an envelope of serous membrane, of the size of a hemp seed to that of a pea, being found generally in the veins contained in the broad ligament of the uterus.

XVIII. I have next to note the changes which the blood exhibits when effused in some of the principal organs, and the effects upon the system which are then presented. The influence for evil which the blood obtains when effused in any of the vital organs, is not from any essentially noxious principle it contains, for its constituents, when rightly disposed, are the source of nutrition and life to those very organs, but on account of the interruption to the functions, which by its mechanical qualities of weight, consistence, and volume, it causes, and the irritation which these parts, unused to the presence of a foreign body, experience. The parts most exposed to this danger are the lungs and the brain. The blood generally becomes firmer in consistence the longer it has been effused and the darker it becomes, and varies in quantity from the modicum which causes a dark spot beneath the cuticle, to several pints poured out with fearful suddeness in some internal organ, quickly causing death. There are two ways in which this effused fluid may be disposed when not of such quantity, as soon to cause death; it may be absorbed, or it may be organized and become a part of the solid system. Different structures vary in their mode of disposal of it. When effused beneath the skin it is soon absorbed, but when effused in much larger quantity in some internal organ, it is frequently seen to become organized. I shall here briefly notice the phenomena resulting from effusion into the organ of respiration or the centre of the nervous system. The blood may be effused into the lungs in two distinct modes. In the first of these it is contained in the air-cells of the lungs where it coagulates. After this mode of pulmonary hæmorrhage, the blood is sometimes absorbed. The other mode of effusion is one in which it occurs with so much violence as to break the slender partitions of the air-cells, and diffuse through the cellular tissue, and this form may be rendered still more destructive by the laceration of the pleura and effusion into the cavity external to the lungs. Here it is frequently found in a liquid state, or only partially coagulated, and effusion to such an extent of course cannot long

be compatible with life. In the brain changes are seen in the effused blood most worthy of notice, which I shall therefore relate with more minuteness. The blood, when effused in the substance of the brain, is generally collected in a round or oval form, in size up to that of an orange. It is frequently so darkly red that it may with justice be called black, often coagulated entirely, but at other times partly fluid and partly solid, rarely, I believe, altogether fluid. This is its appearance soon after effusion, but in a little time it begins gradually to lose its colour, going through various gradations, until it has reached a pale yellow colour, that of fibrine. It is then only the fibrinous portion which remains it appears, the colouring matter and the fluid portion having been absorbed doubtless, and it is firm in consistence. When this is thus separated, blood commences to traverse it, we may suppose, from the extremities of the vessels of the surrounding structure. After this there are two modes in which the process of organization may be finished. The fibrine may become a firm, contractile fibrous tissue, and this will gradually lessen in size until at length nothing is left but a cicatrix, which points out the seat of the original injury. Again this mass of fibrine may be transformed into some loose cellular tissue, having vessels crossing about it and containing in its interstices serous fluid; the latter increases in quantity, while the cellular tissue with its nutrient vessels diminishes, until at length it is placed in contact with the cerebral substance, forming the lining membrane of a cavity filled with fluid resembling serosity, and appearing to be transformed into a serous membrane. Gradually this fluid is absorbed and removed, the cavity growing less in proportion to the loss of its contents, until at length the sides touch and unite, forming a cicatrix. Finally, the cicatrix also is removed in both these cases. Such is the process by which nature repairs the effusion of blood upon the brain, the most frequent and fatal of all effusions.

XIX. Having now remarked the changes which occur in the fibrine of the blood, both when it is slightly modified by inflam-

mation and with another component of the blood acts an important part, and also when it still retains its natural qualities but is hindered from circulation, I must pass on to notice a morbid alteration of the blood which generally occurs during inflammation, subsequent to the action we have noticed. When inflammation has reached a certain duration and violence of action, the blood contained in the part, either coagulated in the vessels or effused from them, is changed into a peculiar fluid termed pus. To form this fluid, two of its component parts are necessary, the serum and the red particles, and this action frequently proceeds at the same time as the effusion of coagulable lymph. Thus, while pus is being secreted, the plastic lymph, also a product of the blood, becomes partially organized, and forms the wall of a cavity in which the morbid formation is contained. The formation of this fluid has been accurately observed and the following phenomena noticed. The increased redness which the vessels so obviously exhibit in the first stage of inflammation, begins to abate, and this continues gradually until at length the capillaries are seen to contain a fluid rendered yellow by the yellowish grey globules. These bodies increase in number and become larger, and, when they have attained their full size, commence a slow motion towards the surface. The softened capillaries oppose no resistance to their progress, and thus, if the integument be whole, they collect immediately beneath it, mingled with the serum of the disorganized blood, or if there be a solution of continuity pass out at the wound. This fluid thus collected or evacuated is pus. It is certain that the globules thus seen in pus are no other than altered blood-corpuscles. Gendrin has stated that he saw the blood-corpuscles, of blood stayed and coagulated during inflammation, first lose their colouring matter and become opaque, then acquire a yellowish colour near that of pus, increase in their size, and alter in shape, acquire a small degree of motion, and arrive at the surface, there exhibiting the characters of pus. It appears, therefore, from these experiments, as well as the researches of others,

that pus is essentially formed from blood in a state of coagulation from inflammatory influence, that the distinguishing feature in this process is the alteration in the colour, size, and form of the red corpuscles, and that it most frequently occurs in the capillary vessels themselves. But it is equally certain that this change is not confined in situation to the inflamed capillaries; this fact is abundantly proved by the observation of most local inflammations; while the blood in the capillaries is disposed of in the way described, that which has been effused and coagulated, causing the swelling of the part, is in like manner changed into globules approaching to those of pus, and these are carried to the surface in channels formed for the especial purpose, there to mingle with the secretion from the capillaries, and be evacuated. Hence it is evident that the influence of the capillaries upon the blood is not essential to the process of suppuration. And this last situation of the formation of pus, which is generally proceeding at the same time as the former, is also independent of it, so that it can be carried on without any capillary excitement. As the capillaries are the seat of nutrition whereby the blood is converted into many tissues, and no other structure in the body possesses this faculty, it has been thought that these vessels alone had in a diseased state the power of changing the blood into so singular a product as pus. But it appears that in other vessels, provided the blood has ceased to circulate, it will coagulate, and its solid part be changed into pus. I do not suppose for a moment that this product is the result of any other action but inflammation, but if no other cause exist, the presence of the coagulated blood, as a foreign body, will produce a sufficient degree of inflammation in the vessel containing it to convert it into this fluid. The progress of phlebitis shows this. After a vein has become inflamed, from whatever cause, perhaps from the absorption of irritating matter, the blood in it coagulates, and it is easily felt hard and impervious. But in process of time the hardness disappears, the vein regains its former softness, and the reason is, the coagulated blood has by the influence of

inflammation been converted into pus. On examination of the parts, the progress of inflammation is well exemplified in the gradual alteration of the blood circulating in the veins connected with it. At a distance from the diseased vein, in consequence of the inflammatory state pervading the whole system, the venous blood is seen to be more arterial in its colour than ordinary; as it approaches nearer, it gradually assumes the yellow hue and consistence of fibrine; when nearer, again it changes, becoming cream-like, and at lengh is lost in the collection of pus at the primary seat of disease. In order to discover whether inflammation of a vein, induced by other means, would have this effect, Gendrin stopped the circulation in a vessel for a little time, and then brought in contact with its internal surface a solution of nitrate of silver. Withdrawing this, he then allowed the circulation again to proceed to a certain extent, and tied the vessel above and below the irritated surface; the blood retained in it first coagulated, then lost its red colour, gradually approximating to that of pus, and at length became perfect pus. Inflammation in some part of the vascular system always precedes the formation of pus, but it is *not* to be inferred from this that, wherever pus is found in the blood, *there* inflammation in the surrounding structure must be present,—it is only certain that suppuration, the consequence of inflammation, is going on in some part. Pus is sometimes found in the blood in vessels in which no inflammation can be detected; it is likewise frequently collected from the blood and deposited in some organs, of which the lungs or the liver are the most frequent situations. After death it is sometimes found in the interior of the coagula found in the heart, when there is no inflammation of the lining membrane. In all these cases, suppuration must be proceeding in some part of the body, perhaps a distant one. The affections in which it is likely to have this effect would be the following: external ulcers, wounds, operations, as amputation, lithotomy, &c. fractures, or phlebitis from its various causes. In these states of the system pus may be carried into the general circulation, and there

it is almost constantly found in the veins, the smallest as well as the largest; in some cases it has been found in lymphatics, but from these *causes*, arteries never contain it. It is true that the pus may, by a disposition of coagulated fibrine at the extremity of a diseased portion of vein, be prevented from passing into the healthy blood, but this is rarely performed. The communication is generally remarkably free, and hence arise the collections of pus found in otherwise healthy organs. But it is not improbable that the quantity of pus contained in the healthy blood may be so great as to be the source of irritation, and even inflammation in a vessel it may pass through. The constitutional symptoms, when the depravation of the circulating fluid is excessive, would seem to denote the presence of *pus* in the blood, as they are analogous to those seen in animals when puriform fluid is injected into the veins. Pus, then, is formed solely from the blood, and that only under the influence of inflammation, inflammation not confined to the capillaries, but producing the same results in other parts of the circulatory system; and its presence in the blood does not imply inflammation in the part in which it is found, but affords good proof that it is proceeding in some organ of the body. As it is formed from the blood, it bears a most important relation to this subject, and must be described in its pure state. Pus is a homogeneous fluid, having the consistence of cream, possessed of a higher specific gravity than water, and of a yellowish white colour. When more accurately examined, it is seen to consist of globules contained in a fluid much resembling serum, and only differing from it in being coagulated by the muriate of ammonia. The globules impart colour to the pus, they are yellow, spherical in form, and larger than the red corpuscles; yet they are known to be formed from them. The blood-corpuscles then must undergo change of formation. Dr. Martin Barry says that they are formed, not from the whole corpuscle, but from the nucleus, and this appears the more probable, as we have seen that during their change the blood-corpuscles appear to be divested of their

colouring matter. He supposes also that the process by which these globules are formed is the same which takes place in the germinal vesicle, and by which we have already seen cells to be developed from the blood-corpuscle for the formation of different tissues. That the pus globules are formed in a manner analogous to this from the blood-corpuscles, appears more likely, from their appearance under the microscope. They show at first an uneven surface covered with small granules, and on the addition of acetic acid these are dissolved, and there appear two, three, or four oval or round granules concave, with projecting margins.

In its chemical constitution pus much resembles serum, containing albumen, differing only from that of serum by being concreted, a substance resembling adipocire, extractive matter, and various salts. It manifests a great power of resisting putrefaction. There are some differences in the salts which it contains, regulated by the tissue from which it is derived. Although the pus of variola and other diseases conveys the infection to another system, if introduced to it, there is no difference to be perceived in it from the pus of ordinary inflammation.

XX. There is another termination of inflammation which exercises through the medium of the blood a great influence on the general system. This condition is seen most frequently in parts of the body possessed of a high degree of vascularity, and so placed as to be much affected by external agency. When the inflammatory action attains to a certain height, the flow of blood to the part is much greater than natural, and the vessels more distended. In consequence of this loss of the balance between demand and supply, the part speedily loses its innervation, the function of nutrition being dependent on nervous influence, soon ceases, and in process of time, death of the part, or mortification ensues. The physical signs of the first part of this change are, the redness consequent upon inflammation becoming darker, gradual and increasing insensibility to external impressions, decrease of temperature, and, in some cases, hardness of the part because of the fluids it contains. The changes in the blood itself

are most worthy of observation. After the circulation ceases, it passes through its accustomed process of coagulation, and gradually deepens in colour, until it reaches an almost black hue. After this, the globules show a tendency to collect around the internal surface of the vessels, thus causing an appearance of increased solidity. Sometimes the serous portion of the blood is effused, and collects beneath the cuticle, even accompanied by the colouring particles. With the continuance of this state of the circulating fluid, absorption will cease, and no nutrition be carried on in the part. However, up to this point it is possible that the evil may be remedied, and these functions re-established. For this end the circulation around the diseased organ, which has become feebler, as the original excitement passed away, is again rendered more vigorous, the corpuscles are separated from the coagulated blood and carried into the nearest vascular channels, and thus at length the current through the obstructed vessels is again established, with the accession of circulation, nervous power is again transmitted to it, and the functions of absorption and nutrition recommence. But if this reaction do not take place, death of the part must necessarily follow. When this last state is induced, separation of the dead part from the living is necessary for the preservation of the latter, and this action nature accomplishes by a modification of the same influence which causes the destruction. If the vessels separated at the point of division between the healthy and diseased structures without previous preparation, the consequence would be loss of life by hæmorrhage. To prevent this, as well as to ensure the entire separation of the useless and noxious part from the healthy, inflammation is set up to a moderate extent in the neighbouring structures. The blood effuses plastic lymph in considerable quantity, closing the small vessels, and forming the termination of the healthy part. But in the largest vessels, where the mere effusion of coagulable lymph around would be insufficient to stay the current of fluid, the blood is coagulated for a certain distance within them, and afterwards organized, thus forming an effectual bar-

rier. It is seen that the commencement of mortification is caused by a powerful degree of inflammation, producing certain changes in the vital properties and relations of the blood,—that its progress may be stayed at a certain point by an increased vigour of circulation, an healthy action, though approaching in character to inflammation,—and if it proceed to its last effect, an extension of the evil is guarded against by a change in the qualities of the blood working with curative power.

XXI. In concluding this notice of the morbid conditions of the blood, I must refer to its appearance when the important function of respiration is deficient or altered in its action. In certain structural malformations of the heart, we find that the venous and arterial blood mingle before being distributed to the general system. The surface acquires a blue colour from the dark coloured blood circulating, temperature becomes less, nutrition is less active, and the various parts manifest a tendency to disease. Life, when carried on under such circumstances, is less valuable, the brain is deprived of its natural stimulus, and nutritive fluid, the mental faculties are less active and powerful; in some cases confirmed idiocy is exhibited. In disease of the lungs, when extensive in its depredations, the blood has not a surface upon which to circulate for the purpose of aeration, large enough to supply the wants of the system. The blood circulates imperfectly oxygenized, the feeling of necessity for oxygenation causes increased quickness of respiration, as if to make up by the frequency with which the remaining portion of lung is filled with air, for the diminished capacity it possesses. Death ensues, at length, in consequence of the impossibility of aeration of the blood. With this I shall conclude this part of our subject, which has already been protracted to great length, it may be too great in comparison with the remainder of the subject; but I apprehend all that has been advanced is intimately connected with the knowledge of the blood, and conducive to the great end here in view in its investigation. The mysterious sympathies, powers, and actions exhibited in disease, are as wonderful

as the influences by which the body is maintained in perfect health, and it is only by a persevering study of the former, that we can truly estimate the latter, and preserve the frame in the possession of it. Thus the pathology of the blood forms a most important part of its study, and it would be vain to consider the relation of the circulating fluid to the body without its aid.

CHAPTER IV.

THE EVIDENCES OF THE WISDOM, POWER, & GOODNESS OF THE CREATOR, SHEWN IN THE BLOOD UNDER ITS DIFFERENT CONDITIONS OF HEALTH & DISEASE.

GRATITUDE is one of the most ennobling, self-devoting of human feelings. It has no mixture of earth's selfishness in it, it hopes for no future reward, it claims no acknowledgment, satisfied with pouring out its exhaustless store of thanks.—Constant as the sunshine, the kindly sense of well remembered benefits follows the benefactor through evil and good report, alike through the calms and tempests of life. It is sad that the cold and stern reality of human life and interests shows how seldom this noble emotion puts forth its genial influence. And the men who would establish themselves as gods upon the earth, owning allegiance to no higher power, divest them of all this feeling which should fill their hearts towards the author of all life. Some men have spent the powers of mind bestowed upon them in endeavouring to prove to their own satisfaction that there is no God. This doctrine is, in addition to its baseness, so contrary to all human reason and observation, that few now embrace it. But there are other opinions, equally blasphemous in their tendency, and far more dangerous than the last with respect to proselytism, as they are more easily reconcileable with the limited human capacity. Some men of powerful, but wild, undisciplined minds, others of comparatively weak intellect, affect to disbelieve that God exists as he has revealed himself to us in Holy Writ, and shape to themselves out of the rocks, woods, plains, and skies of universal nature (as they term

it) a deity of their own, which only differs from the god of untutored, half-clad savages, carved from a tree branch, in the material and rude representation of the latter. These men manufacture for themselves a god, and blindly worship it, while they exclaim against the worship of the Father of all, the Maker of the heavens and the earth, as an act of superstitious devotion. Thus does it become a duty of all those who sincerely believe God's written word, to make sure and stedfast that belief, being aware that the love of novelty, so inherent in the human mind, may make any opinions palatable, however foolish and dangerous. In no manner can we better confirm this truth in the mind than in tracing the attributes which His word declares Him to possess through all the beauties and wonders of nature. Proofs of this wisdom, goodness, and power, shine far above us in the stars of heaven, beam upon us in the rays of the sun, and fall heavily upon the ear in the booming of his thunder voice. But although these are constant and striking evidences of the ever-living God, we need them not to tell us of his existence and character.

I. Within the frame of man himself, every structure and every part attests it to be the handiwork of an all-wise and all-good Architect. Mark how, through many years of toil and hardship, this delicate fabric still retains its size and fulness, with undiminished strength of muscle and unfailing energy of mind. See how from the bed of pain and weakness, where, with sharpened features, and attenuated limbs, it lay so long, almost unrecognizable, it has again arisen, with the glow and contour of health upon those features and limbs that have regained their former size and activity. Behold how, from some quick and strong emotion, the unwilling cheek flushes and burns, or how, from fear, despair, or hope deferred, the strong current falls back upon the centre, with a sickening sensation of weight and chilliness. And this subtle agent, the blood of life; the supporter of corporeal strength and mental energy; the restorer of parts injured by disease to their former state; so intimately connected with the

passions that agitate men, as to become to the eye observant of human nature, a key for the knowledge of secret emotions; does not this present numerous and sufficient proofs of its origin from God's own hand? Yes truly the same God who is so terrible in the storm, so wise in the disposition of so many and great worlds throughout the vast expanse of the universe, and so good in all things, exhibits most clearly his wisdom, power, and goodness in this seeming simple component of the human frame. Most wonderful and mysterious is that power which all living creatures possess of taking up from inanimate matter a part which, under the influence of their peculiar organs, becomes fit to sustain life, and be made part and parcel of themselves. All plants derive certain matter from substances differing in appearance, and appropriate it to their preservation and increase. Substances differing as widely from each other in composition as they do from the animals for whose service they are collected, are, by special means and organs, amalgamated, and become a homogeneous mass more resembling in the principal features of its composition the animal structures which perform this operation upon them. It is in animals that we see the most constant, active, and indiscriminating faculty of appropriating foreign substances of different compositions to their own use; and in man, of all animals, it is perhaps most extended. Nor is it *alone* the wonderful power and wisdom displayed in this adaptation that we must admire and fear; we must also adore and praise the goodness of God who has allotted sustenance to all those vegetable products that arise from the earth and clothe it with luxuriant beauty, from the proud forest tree to the green moss springing from the arid rock, who has given food and digestive organs to all animals, from the smallest of insects to the most gigantic of beasts, and has afforded to man, who is frequently placed in the most opposite situations with regard to nutriment, a power of accommodation to more varieties of food than other animals. Here we see exemplified the abundant goodness and great wisdom of God; viewing with like mercy and care all the creatures

of his providence, forming all, providing for all, sustaining all, the same Almighty Being, "Which by his strength setteth fast the mountains; being girded with power: which stilleth the noise of the seas, the noise of their waves, and the tumult of the people."* Also in his benevolence "Causeth the grass to grow for the cattle, and herb for the service of man; that he may bring forth food out of the earth; and wine that maketh glad the heart of man, and oil to make his face to shine, and bread which strengtheneth man's heart."† Such are the thoughts which will crowd upon a grateful heart, as we are every day recipients of this bounty, and His Hand is constantly working in the unseen depths of nature, to secure sustenance for our frames, and has placed in that frame itself organs so well adapted to reduce the food to a state fitting for its support, without which it would soon droop, waste, and die.

II. A most beautiful arrangement is perceivable in the form in which the products of these foreign matters, by which the life of the being is to be maintained, is found in the body. It is not seen in a solid state; in such a form it would be highly detrimental, and opposed to all those characters and actions which distinguish living and changing beings from the inanimate creation. In all creatures possessed of any degree of life, even in plants, it is found to be a fluid. For this form there are many reasons, all indicative of the presence of almighty power, accomodating the frail and perishable materials with which his wisdom worked, to his own beneficent ends. The office of this product being to repair and sustain the solids of the body, for this purpose a fluid form is necessary, as the laws which regulate the motion of fluid bodies allow it thus to be distributed to every part of the body for the purpose of reparation, which in a solid form would be absolutely impossible. As also this agent of nutrition must inevitably become impure in its progress through the frame, its fluidity enables it more readily to be submitted to purification, and the deteriorating substances sooner to be disen-

* Psalm lxv. 6, 7. † Psalm civ. 14, 15.

gaged from it. By assuming this form, the circulating agent is safer from external injury. Were the nutritive product a solid, it would be liable to all those accidents and injuries which the other solids of the body suffer, but in its fluid state, so long as the solid textures immediately around, and containing it, are whole and uninjured, it circulates in a pure and unmodified state, while neighbouring structures may be greatly injured. In consequence of the yielding nature of the circulating product, the muscular fibres are able to contract, the limbs to be thrown into different and various positions, and indeed all those voluntary and complicated actions to be performed, which are so strikingly indicative of animal life, and which could not take place were the nutritive agent in any other than a fluid form. Thus then the fluidity of the blood is necessary for the performance of nutrition, as it is needed in all parts of the body, for its purification when adulterated, for its safety while performing its office, and for the due performance of muscular action. How profound must be the wisdom, infinite the goodness, and all-prevailing the power of that Being who, when he first formed animals, and man to have dominion over them, could, amidst the manifold productions and interests of a new world, thus accommodate each part of his creatures to the rest, and simply by adding the character of fluidity to the blood intended for their nutrition, *qualified* it for so many important services and guarded against so many evils. How puny appear the loftiest efforts of human genius, when compared with the slightest touch of the creating mind. When man wishes to accomplish an object, he brings to his aid all that his imagination may deem useful, and gathers around him so many instruments, so many assistants, and so much of human learning, that at length the workman and his imperfect work are almost hidden in the crowd of means he has collected; but when the hand of God works, the means are simple, the instruments single, and the artist stands alone, to be seen of all men, visible in his perfect work.

III. We may now remark how wonderfully these attributes

are exhibited in the progressive developement of the blood, and its manner of circulation and aeration among animals from the lowest in the scale to those possessing the same circulatory system as ourselves. By this review it will be seen that, in the lowest animals, remarkably simple in form and structure as compared with the higher classes, the circulating fluid is also simple and undergoes little change before being admitted to enter into the formation of the structures; and as we ascend in the scale, through animals gradually becoming more complex in structure and enjoying more perfect functions, so the blood becomes more fully developed, has more organs set aside for its formation, and passes through a longer process before it is fit to become a part of the body. But in no function connected with the blood is the universal adaptation by eternal wisdom of the powers and organs of animals to their situations and wants shown more than in the mode of purification. On referring to Chapter II. Section VII., it will be seen related that in some of the lower animals there appears no special organ for this action, but it seems to be performed by all parts of the surface; in higher classes than these, there is a mode of ensuring a constant supply of oxygen around the veins of the intestinal surface by the action of cilia. Passing up higher, we meet with external organs of respiration or gills. The mode of aeration in insects, by tubes passing down from the surface of the body, is exceedingly singular. And as we arrive at the higher classes, we find internal organs of respiration established, even in those animals whose sluggish habits do not require purely oxygenated blood for their support, but this superfluity of arterialization in the blood is obviated by the mixture of arterial and venous blood in their systemic course.— Throughout all these, I imagine it will be seen clearly that in ratio to the degree of activity and variety of function which the animal possesses, so the circulation of the blood will be perfect or imperfect. This tender attention to the wants and habits of the meanest of his creatures, this skill in providing them with organs and faculties adapted to their places of habitation, and

the mode of life assigned to them, is it not an exhibition of the goodness, wisdom, and power of the God of the Bible? The Being who watches over the lives of the creatures inhabiting the silent depths of the ocean, and has given them special means whereby they may purify the fluid that renews the employed and decomposed parts of their bodies, is the same God who created the first inhabitants of the waters, and blessed them, saying, "Be fruitful and multiply, and fill the waters in the seas."* The same almighty power which retains the ocean, swelling and bounding in sullen majesty, within the limits he has stationed; and has placed the lofty mountains standing immoveable in their terrific grandeur, is equally well seen in the mode of purifying the blood of the small ignoble animals that live in the bed of the sea, or in the respiration and circulating fluid of the insect that flits around the mountain top. And will the atheist still stolidly insist that there is no God, or the deist impudently assert that he worships nature? It may well be so, but I envy them not their belief and blindness.

IV. However we must proceed to view in the blood of man yet stronger proofs of the sovereignty of God, and the tender mode in which he exercises it. A merciful provision is made by the formation of the blood from chyle and lymph, the two fluids which unite in the thoracic duct. If the circulating fluid were dependent for the maintenance of its mass solely upon the lacteals, i. e. the chyle which they convey to the thoracic duct, the consequences in relation to life would be very injurious. By every slight disorder which interrupted for a time the digestive functions,—functions almost certain to suffer from any disease,—the supply of chyle would be stopped, the circulating fluid would soon be lessened, and the strength much impaired, so that death would inevitably ensue. All those privations of food which man, from his habits of wandering, is likely to suffer, and which, by the present wise disposition, he is able to bear for some time, would under these circumstances very much sooner prove fatal.

* Genesis i. 22.

But the lymphatics carry a considerable supply of effete material from various parts of the body, and in the event of any interruption occurring to the function of the stomach, either from privations or disease, they act with increased activity, and take up any superfluous matter, as adipose tissue, thus for a time sustaining a sufficient quantity of blood to supply the wants of the system. There is much also to admire in the preparation of the chyle (i. e. the mixed fluid) to become blood; the fibrine acquires greater power of coagulation, the corpuscles are gradually developed, probably to become the parent cells of blood-corpuscles, and it appears to me extremely likely the fat-globules and the albumen likewise progress in organization, the former being developed into the latter and the latter into fibrine.

The perfection of God's work is eminently shewn by its continuing to exist, only as a whole, as he created it; no one part is superfluous, no organ or structure is useless, and the life of the body is endangered or destroyed by the interruption of any one function, or the destruction of any organ destined for its nourishment. Hence we need not marvel that accidents and ills are incidental to human nature. Short as the life of man is, it is a constant scene of change and vicissitude, wisely ordered no doubt for our trial and ordeal in this world, but from events over which he has no control, these changes are full of dangers seen or unheeded. In every situation of life, whether the lightning of God's arm flashes around in the storm, or he sleeps calmly in his quiet dwelling, in either case dangers hover thick around him, in the shape of a thousand accidents, one of which might terminate his existence. Instead of repining, therefore, that death is so rife amongst men, and the hour of life so short and transitory, we should rather wonder and admire that this frail body, this painting of such fine and fleeting colours, this inimitable but fragile piece of workmanship, producing most complicated ends from simple materials, should so long retain all its parts uninjured by the rude shocks of time and accidents. We may truly congratulate ourselves on the possession of health and

strength, but remember to tremble while we rejoice. Happy are they who can join with the fullest feeling of adoration and gratitude in the words of the pious Psalmist, "I will praise thee; for I am fearfully and wonderfully made: marvellous are thy works; and that my soul knoweth right well."* Yes! it is fearful to behold the fineness of the thread of life, which retains us from an eternity; it is fearful to feel the earth yield as we tread on the brink of the tomb; but it is wondrous to see how the Father of all endows the slender thread with miraculous strength, and with his powerful arm retains one that is sinking into the grave, so long as his mercy shall direct.

V. In the blood, as it is seen circulating in the vessels, numerous are the proofs of almighty power and forethought, so intense and all-seeing, that it exceeds the comprehension of our finite minds. The substances entering into its composition all influence each other for the benefit of the whole. The salts have a peculiar influence over the colouring matter of the red particles, and probably some effect in retaining the blood in a fluid state. But in the composition of the red corpuscles, is a great example of God's wisdom and power. These bodies are extremely minute, and yet alike, perfect, and composed of several parts. The capsule, infinitely fine and delicate, is never ruptured or injured in the rapid flow of blood, only when an action for this purpose proceeds in the interior. Its contents are preserved safe as in the strongest vessel man's art could make, and these contents, how beautifully singular in their character and formation! The colouring matter imparts a colour so faint in its appearance in single bodies, so gradually heightened by the addition of numbers, so constant and true in its formation, so easily changed by slight impurity; the arterial hue of the blood is at once so rich, so soft, and so delicate, that the almost inspired touches and the brightest tints of earthly painters sink into insignificance by contrast. And the manner in which this fine colour is immediately produced, is as secret as its effect is beautiful, for at pre-

* Psalm cxxxix. 14.

sent it passes the knowledge of human chemistry. As the hæmatosine is wondrously beautiful in its colour, so is the nucleus remarkable in its power of producing other bodies. It is only visible in the strong microscopic power in which the corpuscle is seen, by the small spot on the exterior, yet this most minute centre of a minute body grows, divides, and is developed into several bodies larger than itself, each of them afterwards acquiring the splendid colour, and becoming corpuscles with nuclei fit to perform another evolution. Such is the admirable and continuous process by which the supply of corpuscles is at least partly maintained. And who is he that has formed these multitudinous bodies in such profusion? Will one of his creatures answer "The God of nature?" Away with such a miserable subterfuge from belief! Tell me not of the God of nature in *contradistinction* to the God of revelation! The Being who forms these marvellously small corpuscles, enables them to traverse the system without laceration, without injury, who adorns them with their brilliant colour, who endows them with a power of producing others, is not a God formed from nature, whose actions are subject to be modified by its laws, but a presiding Deity who forms and rules all, who can change the laws of nature when he pleases, or compose a million natures, not one of which we are capable of comprehending. In this action, in which so much power is devoted to the production and perfection of such extremely minute objects, I view the attributes of that God who, in the words of inspiration, "Hath measured the waters in the hollow of his hand, and meted out heaven with the span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance? Behold, the nations are as a drop of a bucket, and are counted as the small dust of the balance: behold, he taketh up the isles as a very little thing."* God, in his immeasurable and incomprehensible superiority to his creatures, looks down upon the large and the small with the same beneficent eye of providence, and

* Isaiah xl. 12, 15.

scatters his blessings with a lavish hand, giving brightness to the stars of heaven, and beauty as well as useful perfection to the smallest molecules which compose the animal frame. The faculty of coagulation present in the fibrine is no doubt eminently useful in the process of reparation, and admirable in its action, but must be again reverted to in its relation to abnormal states of the system. We may here remark the skilful arrangement by which the blood is prevented from coagulating while in the vessels, an accident which would at once put a period to the vital functions. The influence which the vessels exert for the prevention of this, both in its constancy of action and unity of purpose, in all parts, and in vessels so exceedingly different as the arteries and veins, merits our closest attention, and is a striking proof of the power and care bestowed in the establishment and support of our bodies.

VI. Great should be our gratitude when we survey the marvellous mode of circulation, by which the blood is carried to all parts for purposes of nutrition, and submitted to the influence of the purifying organs. The powerful heart, faithful to its office, and constantly propelling blood from one of its cavities, the elastic arteries aiding it by receiving the current of blood without injury to themselves, and gently forwarding its onward motion, the capillaries, the beautiful arrangement of valves in the veins to facilitate the return of the ascending fluid; all these I must merely name here as many wonderful means subservient to the great end of insuring a constant and equal flow of nutritive fluid throughout the system. The structure of these parts, so perfect and well adapted to their office, the splendid and varied mechanism which they present as a whole, their universal distribution, vessels being found in every part of the body; all attest the importance of the fluid they convey, and the essential dependence of life upon it. Seasons and years roll away, cold and heat alternately affect the system, accidents and disease threaten it constantly, but while the system of vessels is preserved, the tide of life still rolls on, impetuous, continuous, and

sure. The power which thus causes blood to flow through the veins of animals, is from that Eternal Spirit which "moved upon the face of the waters, when the earth was without form and void, and darkness was upon the face of the deep," and by the word of his power fixed the boundaries of the seas, and caused the rivers to flow from the lofty hills. In the security of the position which the principal of these organs occupy, and the consequent comparative immunity which they have from the accidents common to external parts, the goodness and love of that all-powerful Being who watches over man as "the apple of his eye," shines forth prominently.

VII. In all parts of the system we see an exceedingly great number of small vessels, interlacing with each other, and running in all directions; into these the arterial blood flows for an especial purpose of the utmost importance. In viewing the extensive capillary system, we must remember that in it alone, of all organs of the body, the means for the preservation of life are directly applied. In them, matter derived from inanimate or less-organized bodies, having passed through many processes and grades, at length arrives at the last link in the chain of organization, and is incorporated in the substance of a living, breathing, and sensitive animal. In these little vessels life is supported, and that by such gradual and imperceptible additions of material, at once in all parts of the frame, that although our bodies change materially with the hours and minutes, yet when the frame is vigorous and matured, no alteration is visible to us from year to year. And wisely ordered this is in unison with all the plan of creation; our feeble minds would be appalled and filled with dread, were we able to note and appreciate with our senses the mode in which our frames are renewed and disappear, constantly changing, never the same. But it is well as an antidote for human pride and vain boasting, to consider how fleeting, uncertain, and dependent is that body, which in its most vigorous moments is fast hasting to the dust from whence it came, and how this consumption is supplied by means so small and

trivial in appearance. Surrounded with intense interest therefore must this process in the capillaries appear, proceeding so universally, yet so mysteriously, its existence in the living animal not to be discovered by our senses, yet constant and certain, forming all the essentials of life. Nor does what we are able to comprehend of it in the least disappoint our expectation of the marvellous nature of this proceeding. The blood flows into the capillaries, bright red in colour and homogeneous in form, containing only small molecules of solidity; and from this apparently fluid body are formed vascular tissue endowed with its necessary influence over the formative element, muscular fibre with its power of contraction, thus enabling the animal to exercise voluntary motion, nervous tissue having the faculty of conveying to our minds the finest impressions of sensation, thus warning us to direct muscular action so as to produce pleasure and avoid pain, these and many others aiding them in their objects, have their origin in this process and from this fluid. I confess that when I view the multiplicity of objects, each of them calculated for an equal multiciplicity of action, thus attained in one process and from one substance, wonder and astonishment fill my mind. High-sounding words and finely-chosen phrases seem like a mockery when applied to the description of works so astounding in number, having such claim for fervent gratitude, forming, as they do, the basis of our existence and happiness. The constancy, the beauty, the many ends of nutrition, evince its establishment by him of whom his servant said, with the beauty of inspiration, "He telleth the number of the stars; he calleth them all by their names;"* and who, when living in indignity upon the earth, said, in kindly condescension to his fearful disciples, "The very hairs of your head are all numbered."†

VIII. There is great cause for our admiration in the observation, to the best of our ability, of that part of the blood which thus forms tissues so exceedingly different in their purpose, and apparently in their formation. By the beautiful simplicity and

* Psalm cxlvii. 4. † Matthew x. 30.

the similarity of their primitive structure, a great end is gained. All animal, as well as vegetable products, as before said, originate in cells, and thus they may all be formed from a similar substance, grow, and be repaired by gradual and imperceptible additions, as we behold the process performed in the animal economy. Thus the animal structures are all of one origin, which may be supplied by such a fluid as blood. Furthermore, in the blood itself, we find dispersed a multitude of small cells, showing considerable power of developement, and of producing others. The mode in which these cells become a part of all structures, and are constantly produced and supplied for that purpose, is, in my view, a striking illustration of the power and wisdom of God. Their disposition, when arrived at a certain degree of growth, to coalesce in determinate forms, the distinct parts of each changing or disappearing in different manners for the formation of various structures, and from influences that have hitherto resided in them unseen and unmanifested,—is an evidence most palpable of supreme power of creation, directed by unlimited wisdom of design. Much as we may admire these perfect and beautifully-formed bodies, when we remark their colour so singularly caused,—their minute but secure structure,—and the changes they undergo to produce others of a like character, they appear to us still more interesting and wonderful when they are seen to be the immediate source of nutrition to all parts of the body.

IX. There is another view in which the office of the blood is clearly shewn to have been assigned by the foresight of an Omniscient and Omnipotent Being. As animals are, by the force of a law which is equally binding upon all forms of matter, retained upon the surface of a world of inorganic substance; they are constantly,—both from the motions they themselves perform, and from the limited movements which, under fixed laws, bodies without life involuntarily exhibit,—coming into contact with these last. Hence it is necessary that some part of the frame should possess sufficient firmness and density (i. e. force of adhesion) to

act as a centre from which all the actions of animal life are performed, to sustain it in its progress upon inorganic matter, and to resist the shocks which may be caused by the laws of gravity influencing all bodies. This needful frame-work is found in the osseous system, but to produce it, recourse must be had to inorganic matter; its union with an organized substance is necessary for its formation. This inorganic matter is found to be contained in the blood, and supplied to these structures by means of it. The earthy matter, or phosphate of lime, forming so essential a constituent of bone, is found in appreciable quantity in the blood. It is shewn, therefore, that the circulating fluid contains all that is needful for the formation and reparation of every individual part, and all the divers structures composing the frame. After contemplating its beautiful adaptation for this end, we may no longer hear and read of the goodness of the Lord with indifference and apathy, but feel in the inmost heart that it constantly exists, a glorious and merciful reality, joining with power and wisdom to sustain all his creatures.

X. Again, this process of nutrition is not only the mean by which the mass of the body is maintained, and the expenditure which ensues in muscular action replaced, but is also the action by which the important influence of animal heat is produced. If a perpetual summer reigned upon the earth, the sun shining ever with the same brilliance, the genial temperature never changing in the least degree, and the same kindly warmth pervading every object around, then man and animals might have been constituted without animal heat. But in the world as we see it, constantly changing its temperature and heat, constantly radiating from our bodies to the objects of inorganic nature; without this disposition, in vain would be the elaborate formation of the blood, in vain the vigorous circulatory system, the powers of life would soon be depressed and depart. Hence we see this admirable provision made for its maintenance, that in every part as a necessary consequence of nutrition, the oxygen of the blood may unite with the carbon of the system, and thus an abundant

supply of heat for the service of the animal be produced. The great Creator, while he bestowed upon his creatures powers of sensation, by which they perceive the slightest deviation from the customary degree of heat, has afforded them also ample means of providing against the insupportable effect of extreme cold.

XI. If the mode in which the blood is made to repair the losses of the solid parts, and sustain them in an equable temperature, is marvellous to our conception, no less wonderful in execution is the mode by which the blood is purified. The most direct mode by which this is effected, the introduction of air into the lungs, is also that most decidedly necessary for life. If respiration be entirely prevented for a very few minutes, the blood ceases to exert a vivifying influence in any part of the body, although equally needed in all, and the consequence is fatal. A few of the evils which result from an imperfect respiration have been noticed in the last chapter. Such being its importance in relation to the circulating fluid, which never ceases its constant round while life continues, this act is made accordingly easy, grateful, and constant in performance. In proportion to the poisonous influence of carbonic acid, the agent which renders the blood unfit for its office, so is its mode of elimination certain and ample. A pure atmosphere is spread around man far as his feet can journey, or his most adventurous hands may climb ; in the larynx and trachea a communication is established for it with the interior of the body, and at the extremity of this last, an immense surface is spread out, with countless vessels ramifying over it, having walls of exquisitely fine texture, so that the impure fluid may be freely exposed to the purifying air. Admirable also is the manner in which the carbonic acid is disengaged from the blood when it is exposed to this agent, and strikingly beautiful the change in colour it exhibits. What in art can equal this instantaneous operation, evinced by the sudden appearance of so bright a hue producing a most efficient and vital change in the fluid itself, proceeding constantly with fresh

portions submitted to it, and all effected by an agent we should deem simple and inadequate to the task. This process also serves for the abstraction of water from the blood, a part which by its increase would doubtless cause serious injury to the system at large. By exhalation, the water is eliminated from the system in a state of vapour, in the same easy and effectual manner by which the former positively noxious agent is disposed of. What deep emotions of gratitude should arise in the mind of man at the view of these mingled vast and minute arrangements, each equally grand and beautiful, made for his benefit and well-being. This boundless expanse of air, spread around and above him, which sometimes exhibits its terrific power in the tempest, is made an important minister to the most imperious want of his frame, and by abstracting a noxious agent, acts upon the numberless minute and perfect bodies in the blood, shewing its duty well performed by the rich colour imparted to it. Humbly grateful should he be, that the air surrounds the earth for his good. Assuredly for his good chiefly, for although God is inexpressibly kind to all his creatures, man is his most especial care; him he "created in his own image;"* and of him alone it is written, "The Lord God breathed into his nostrils the breath of life."† One duty man, in his insignificance, may perform; standing, as he must ever do, at an infinite distance from the ineffable purity and goodness, and the awful majesty of God, he may recognize the traces of his perfection in these his "perfect works," admire and fear in silence.

XII. Fresh evidences of his watchful providence are revealed to us as we proceed farther in this subject. The blood, although relieved from the carbonic acid by the lungs, has yet matter within it, some superfluous, other also injurious, if allowed to remain in it. The elimination of these matters is necessary to life, if not as immediately needful as that of carbonic acid. For this purpose, therefore, special organs are provided, to which the impure blood flows, and there has these superfluous and

* Genesis i. 27. † Genesis ii. 7.

hurtful materials abstracted from it. The same wisdom which planned their elimination from the blood, has also designed some of them afterwards to fulfil important offices in the animal system; as bile secreted by the liver from the blood is the agent by which chyme is converted into chyle, thus forming one most important link in the process of general assimilation. Thus, in the economy of the creation, nothing is useless or waste; all move on in a ceaseless circle, even the destruction of a part serving eventually for its reproduction and the maintenance of the whole. The fluid secretion of another organ exhibits some highly nitrogenized products, and in the constant and certain manner in which they are secreted from blood brought to them by arteries coming off immediately from the aorta, and excreted, is clearly shown the great care with which all that is destructive to the system, is abstracted from it. In the secretions we more especially see how, with a watchful eye and guardian hand, God has deigned to ward off evil from the frame of man by many devices of excelling skill and admirable wisdom. "The Lord is good to all; and his tender mercies are over all his works."* These most cogent and forcible illustrations of the wisdom, power, and goodness which formed the blood as it is found in health, must here suffice, as there is not space for a more minute reference, and I must advert to the blood in a state of disease.

XIII. When the sentence fell upon man from an offended God, death was laid on him as a certain and final doom, but it was not said that disease, gnawing with envenomed tooth at his frame, should embitter his days, and make him wish for death, as a welcome evil, a terrible friend. There is no doubt that a body which bore within it the seeds of decay even at the beginning of life, would be in some degree obnoxious to disturbance of its functions, and thence disease. Nevertheless, we may suppose that the diseases which first affected man were much fewer than the astounding tribe of "ills that flesh is heir to" at the present time, and that then more frequently than now, man died

* Psalm cxlv. 9.

naturally, from the decay of the functions, one succeeding another; as the forest oak dies gradually, yielding one by one its sturdy limbs and huge trunk, until at length the scanty green branches, still flourishing on its naked side, have also vanished, and it remains, a specimen of gigantic death, a superb ruin. So life departed slowly from man when he was fresh from the hand of his Maker. Vice and crime rioted and flourished in the world, and in their train came disease, a dread attendant, for the Almighty, with all his mercy, was also just, and allowed the sins of men to bring after them an adequate punishment. This view is confirmed by the experience and origin of some diseases which have appeared in comparatively modern times, and have been seen to have arisen from excesses, and to have ravaged with most fearful intensity where these were most frequent. But the same Being, whose "judgments are terrible," and who can send such a number of dread ministers upon the earth, striking at the heart of man upon his pinnacle of vaunted civilization and wealth, and bringing his proud head low beneath the sod,—this same Being tempers his justice with mercy. He might have constituted diseases innumerable, variable in character, the disease which strikes down one of the human family entirely distinct from that which prostrates his neighbour, a disease to every man who died, each one utterly unknown, because never before seen. Thus human aid could never have been administered, and the first symptom of disease would have been the signal for death. Man may say, that from the nature of the system, this dread variety would be impossible, but "with God all things are possible."* Instead of this fearful means, diseases have come into the world with marked characters, by which they may be known, appearing in the same form in successive generations, the same system of remedies being applicable, thus He has graciously ordained that the experience and mental power of men may be of eminent service to their fellow-creatures. These provisions exhibit the providence of God in a strong light. Surely

* Matthew xix. 26.

man should be grateful to that Being who, while he has in justice visited him with affliction, has given him a strong hope and means by the use of which he may regain the field of life, from which he was fast gliding. Among the many symptoms which characterize diseases, through this great mercy which has given them so decided and constant a character by which to be known and combated, the state of the blood is one of importance. Its rapidity of circulation, its tendency to coagulation being less or more than natural, the buffy coat, &c. are symptoms which those who have seen and studied disease know how to fully value and observe.

XIV. We cannot sufficiently admire the beautiful arrangement by which the blood has within itself a power for the prevention of hæmorrhage. The vascular tissue being necessarily disposed over every part of the body, is destined to suffer frequent lesions, either from external and foreign bodies, or from some disease of the structures it supplies; and if the blood remained fluid under all circumstances, it would escape from the smallest opening, even one so minute as not to be discovered by unassisted sight, until the support of the body were drained away and life extinguished. Thus the slightest puncture from a thorn or needle, the most insignificant of instruments, would be the sentence of death; and truly, there are few who would live long under such circumstances. But this is wisely obviated by the quality the blood exhibits of coagulating when removed from the influence of the lining membrane of the vessels. By this mean, hæmorrhage from a small vessel is speedily stopped. If, by the division of a large vessel, hæmorrhage has proceeded to a considerable extent, the temperature of the surface becomes lower, the vessels contract from this and retreat in their sheaths, the blood coagulates at the extremity of the vessel, thus by its mechanical impediment, and the contraction of the vessel restraining the already enfeebled circulation; in process of time a coagulum is also formed in the vessel itself to the nearest branch, and the circulation proceeds by another course. Thus,

then, the property of coagulation, which, if suffered to act in the circulatory system, would impede its purpose, and arrest the progress of life, is the principal mean by which the danger of wounds and ruptures of vessels is materially lessened, and their cure effected. Without it, surgical operations would be inadmissible, the gush of blood following an incision would be so fearful, complete, and irrepressible. Without it (or some provision for the same end) action would be impossible, for man must, in its performance, traverse the world, like some curious exotic, swathed in the softest substances, and beholding with fear and dread the penetrating stones and the rough trees.

XV. In fevers, and other diseases attended with altered colour and consistence of the blood, the presence of petechiæ and other effusions exhibits the consequences which ensue from the slightest deviation from its normal constitution in proportion of its constituents; while in diabetes mellitus, and Bright's disease, some of the evils consequent on depraved secretion and retention within the blood of its constituents are manifested. From plethora and anæmia, we see also the effects of undue proportion between the circulating fluid, and the system to be supplied by it, and the importance of a due proportion of that part of the blood which more especially enters into the formation of organs. The former, as well as the latter, by their powerful effects upon every function, more especially that of the nervous system, prove the fineness of the distinctions which, in the constitution of his creatures, an All-wise Being has established, with regard to the quantity as well as composition of the circulating fluid and its component parts. The peculiar product of melanosis shows us by what slender boundaries and easily overthrown the blood is separated in the course of its circulation from agents which would deteriorate it so much as to make it noxious to the system.

XVI. The curative influence exhibited in the course of many abnormal states of the system, bids us to remember that it is God "who healeth all diseases."

In none is this restorative power better shewn than in the

phenomena occurring in the blood, and the products formed from it during inflammation. Its termination in resolution, by the re-establishment of the circulation through the obstructed vessels,—the absorption of the effused fluid, and the disappearance of the red colour and heightened temperature, are all interesting actions, exhibiting the admirable means by which Almighty Wisdom and Power checks the progress of a painful and destructive disorder. If the disease continues longer, the exudation of plastic lymph, its further organization and assimilation are alike wonderful and useful. One remarkable instance in which this product of the blood is adapted not merely to the structure but also to the necessity of the part, I have already narrated in the formation of adhesions during the presence of pulmonary tubercle. We also find this product provided as the agent of union for divided parts. Its singular disposition when an offending substance is present, so as to shield the hitherto uninjured parts from its influence, is equally worthy of our notice and admiration. The formation of pus shews much that is interesting, and here we may notice the disposition of this product of the blood under inflammation to approach to the surface of the body. By this law, however deeply seated originally, it gradually traverses all tissues and arrives finally at the surface to be evacuated: were it not thus wisely planned, it might remain in parts where its presence could not be detected, causing great general disturbance of the system. The process by which it is formed proves indubitably that the same Wisdom and Power is employed in regulating diseased action, as in the perfect and complicated processes of healthy formation.

XVII. In mortification, the consequence of inflammation, the same Almighty Power is present, exerting a curative influence for the preservation of the part or at least of the rest of the body. While the blood is as yet in a state of coagulation, and the part not yet materially altered in structure, the circulation may be re-established and the affected portion regain its natural state. This is well and skilfully effected by the incitement of

the circulation immediately around the part to greater vigour, and thus all obstacles to the flow of blood removed. Again, if this morbid process proceed to its extremity, and the part dies, as it is useless its separation is necessary, and the admirable mode in which this is effected, although once before described, I must here again allude to. If it were accomplished without previous preparation, the vessels would bleed freely, and this, in the state of the system consequent upon the morbid action, would in all probability prove fatal. But these vessels, prior to this necessary act, effuse plastic lymph from the blood contained in them in the same manner as when under the influence of inflammation; the fibrine of the blood also coagulating within the vessel; and thus the fearful evil of hæmorrhage is prevented, and a line of separation formed between the dead and living structures, by a product of the blood. Thus of the two products of inflammation, it is wisely and mercifully ordained that one should be made of use in the reparation of injuries, and that the other not calculated to serve in any vital process, should possess a tendency to approach the surface and be evacuated from it speedily.

In aneurism, a disease of fearful and insidious nature, through the medium of the blood, a marvellous mode of spontaneous cure is sometimes effected, and this, as before related, by the deposition of fibrine, undergoing organization, filling the sac and the vessel above and below it, thus changing the course of circulation as effectually as by the operation of ligature. In this operation also, the property of coagulation in the fibrine, when the flow of blood is arrested, is the mean of success, although it is assisted by the incited action of the vasa vasorum at the point of ligature, and the effusion of lymph there from the blood.

XVIII. We also see an arrangement which merits great gratitude and admiration in the disposal of the blood, when effused into important organs. In the brain even, the centre of sensation, and most readily affected by the slightest pressure from without, a provision is made for the gradual absorption, or still

more gradual organization of the effused blood, until in process of time not a vestige of it remains.

XIX. In the diseases I have thus enumerated, as those in which the blood is most essentially changed, it will be seen that the Creator has also endowed the blood with a power of altering the diseased action into one of reparation for the evils it has caused. We may not, therefore, even in the most secret thought, accuse the Creator of visiting unnecessary evils upon his creatures. The Being who vitiates the circulating fluid in its vessels when he so wills, rendering the very fount of life impure, does also, with the care and tenderness of a father, alleviate and soothe the pains this has caused, purify all by his healing power, and breathe the flickering flame of life once more into the radiant happiness of health. Sickness also, while it exhibits bad effects upon the body, exerts a wholesome and salutary influence upon the mind, purifying it from the contact of the gross passions which beset the best of men, shewing the vanity of earthly possessions and pursuits, and elevating the soul to a nearer view of that eternal rest and happiness to which it should be its brightest and warmest hope to attain. He who is restored from sickness thus employed, will return to his duty here a purer and better man; the dross of the world's influence and the passion's strife will be lessened; and some portion of heaven's gentleness and purity shine forth through the veil of human imperfections, with its natural lustre. Let us not, then, suppose that God doeth any thing amiss, but rather be astonished at the marvellous goodness and power which sustains so many myriads of offending men upon the earth, by the wonderful laws with which he has surrounded us, and the exquisite manner in which he has built our frame,—so weak in itself, yet so vigorous in the powers of life he has established in it,—so fragile and fleeting that it is constantly changing in the matter composing it—yet retaining its shape and size for "threescore years and ten"—finally, so essentially material and mortal in its own constitution, yet containing a soul which must live for ever, and which, when

purified by his grace, God has deemed worthy to abide with himself through the countless ages of eternity.

XX. No tongue, however eloquent, can tell the boundless greatness of the Eternal, whose majestic power, infinite wisdom, and ineffable goodness are so plainly displayed in the subject we have thus far pursued. Feeble and vain therefore in the extreme would be my efforts, were I to attempt the noblest task which the lips of a mortal can utter: but we may obtain some conceptions of his character by the vastness of the works which He has formed and rules. Traverse the wide world wherever the foot of man has marked a path; see the grain whiten, and the fruit mature, in the fertile countries of Europe; view the perpetual snows and icy mountains of the north; feel the scorching sun in the sandy desert, or behold it struggling through the thick foliage of primeval forests; observe the numerous animals that swarm upon the earth or fill the air and the ocean, and hear all these formations bear testimony, "The hand that made us is divine." Then gaze upon the star-lit heaven above, and imagine there myriads of myriads of worlds, each one equalling or surpassing this in immensity of structure, diversity of life, and wondrous influences.

Thus some idea may be formed of the great God, even this glimpse dazzling in brilliancy and overpowering in magnitude, the Author of all! the Supporter of all! the Giver of every good gift! The might of his power, the excellency of his wisdom, and the universality of his love, is feebly shadowed forth in the multitude of worlds, and the infinite variety of beings that environ us on every hand. Above all, the provident care by which his love toward his creatures is shewn, excites the warmest gratitude and admiration, so that we may conclude this survey of the means by which we and all his earthly creatures enjoy existence, with the words of his servant of old.

Psalm CIV. 24. "O Lord! how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches.

25. "So is this great and wide sea, wherein are things creeping innumerable, both small and great beasts.

26. "There go the ships: there is that leviathan whom thou hast made to play therein.

27. "These all wait upon thee; that thou mayest give them their meat in due season.

28. "That thou givest them they gather: thou openest thine hand, they are filled with good.

29. "Thou hidest thy face, they are troubled: thou takest away their breath, they die, and return to their dust.

30. "Thou sendest forth thy spirit, they are created; and thou renewest the face of the earth.

31. "The glory of the Lord shall endure for ever: the Lord shall rejoice in his works."

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