TABLETS

OF

ANATOMY AND PHYSIOLOGY

BY

THOMAS COOKE, F.R.C.S.

ASSISTANT SURGEON TO, AND DEMONSTRATOR OF ANATOMY AT, THE WESTMINSTER HOSPITAL.

LONGMANS, GREEN, & CO., PATERNOSTER ROW, LONDON;

AND

WILLIAM WOOD & CO., GREAT JONES STREET, NEW YORK.

1873.

PHYSIOLOGY.

PART I.

CIRCULATION, RESPIRATION, ANIMAL HEAT.

To

WILLIAM SCOVELL SAVORY, Esq., F.R.S.,

SURGEON AND LECTURER ON SURGERY AT ST. BARTHOLOMEW'S HOSPITAL;

LATE PROFESSOR OF COMPARATIVE ANATOMY AND PHYSIOLOGY

AT THE ROYAL COLLEGE OF SURGEONS; MEMBER OF

THE COURT OF EXAMINERS OF THE

SAID COLLEGE.

Sir,

As an expression of my respect for your efforts in promoting the study of Physiology among Students, and as a token of my gratitude for past kindness, I beg to dedicate to you these unpretending little Tablets on Physiology.

I am,

Sir,

Yours very Respectfully,

THOMAS COOKE.

Woburn Place, April, 1873.

OPINIONS OF THE PRESS ON THE LITHOGRAPHED EDITION.

"They present a mass of condensed information on Anatomy and Physiology, which will, we believe, be found very useful to students."—*British Medical Journal.*

"We can heartily recommend the Tablets to medical students for refreshing the memory on dry points of Anatomy and Physiology without the necessity of wading through descriptive text-books and wasting more than half the time expended on them in picking out the salient points."—*The London Students' Gazette.*

"The 'Tablets' place the essentials before the learner in the clearest and most concise manner, and we should advise all students who are preparing for the Primary at the College to obtain them."—*The Students' Journal and Hospital Gazette.*

"We do not hesitate for a moment to recommend the Tablets."—*Guy's Hospital Gazette.*

PREFACE.

The demand which has been made for these Tablets, even in the rough lithographed form in which they were first scribbled out for Private Pupils, has induced the Author to print and publish without further delay, the Tablets on the Eye, the Ear, the Brain, the Cranial Nerves, the Perinæum, and the Surgical Anatomy of Inguinal and Crural Herniæ, which Tablets Students have more particularly asked for, and also those on Circulation, Respiration, and Animal Heat. The publication of the other Tablets in the printed form will have to be delayed for a while, as the Author cannot at present find time to revise them.

In a Learner's point of view Scientific facts may, the Author thinks, be divided into those which are daily met with by the Student, and which soon become familiar to him, and those which are learned with considerable pains, and afterwards easily forgotten.

The Author has endeavoured to deal with the latter class of facts only. *What every one knows, who has at all studied Medicine, he has purposely left out.* Greater condensation is thus obtained. To the non-medical reader these Tablets may appear disconnected, and the descriptions they contain (if descriptions they may be called) may seem dry and naked. The Author believes that the Student will easily supply the links, and give life and shape to the skeleton sketches.

Order and method have been carefully studied in the topographical arrangements of the headings, sub-heads, and main and minor facts. Words unnecessary to the sense have been suppressed.—The words printed in *italics* call attention to the salient points.

The Author is of opinion that Science can be studied to full advantage only in those larger and more comprehensive works, in which not only known facts are exposed, but also personal investigations and private opinions are brought forward and discussed. He sincerely hopes that these Tablets will be found not only to assist Students in passing their Examinations, but also to encourage them to study substantial standard works.

GOWER STREET, *May*, 1872.

The teaching power of the Tablets has now been tested for more than a twelvemonth with the most favourable results by numerous Students preparing for the primary M. & F.R.C.S., and for the first M.B. examinations. The Author has therefore ventured to aim higher in his later tablets than he did in his former ones; the Tablets on Circulation and Digestion are in some respects still incomplete; those on Respiration, Animal Heat, the Secretions, the Nervous System and Development are more exhaustive, and the Author believes that they fully reflect the actual state of Science.

The Author begs to thank Mr. T. Cattell Jones, who was instrumental in making the lithographed Tablets known at Guy's Hospital, and who has kindly assisted him in correcting the proofs of the printed edition.

WOBURN PLACE, *April*, 1873.

ADVICE TO LEARNERS.

THERE is an art of learning as well as an art of teaching.

The grand secrets of this art are to classify and to condense the facts that are to be retained, and to proportion, according to their relative importance, the attention to be given to them.

Classify.—" Similia similibus" is a favourite tutorial motto with the author.—Group things that are alike: by learning one you will then learn a dozen. Mix not up those that are not alike, if you do not want to labour in vain.

Condense.—The more concise your wording is, the more facts you can learn in a given time, and the better you can learn them. Large books are not necessarily good books for study; they are intended principally for reference. A firm grasp of the facts of your science is what you want first; court erudition afterwards.

Proportion according to their relative importance the attention to be given to the facts that are to be retained. Master the headings & sub-heads first; then, in succession, the divisions, the sub-divisions, the principal points, the minor points, the noteworthy details, ... the minutiæ. Begin, not at the periphery, but in the centre; then radiate as far as your strength will allow you.

This method is pre-eminently suited to the preparation for examinations:

Examiners are men of high scientific standing; men whose time is valuable, and who make the best use of it. Their questions, especially in the viva voce examinations, are short & to the point; answers they want also short & to the point.—Ex.:

Q.—What bone is this? *A.*—The right cuneiform.

Four words to the question, three to the answer. The test is, however, a searching one; it shows whether the candidate recognises the cuneiform bone, and whether he is sufficiently acquainted with its surfaces, angles, borders, etc., to be able to discriminate between a right bone & a left one.

What are the branches of the femoral artery? Of the internal maxillary?
What are the ligaments of the knee-joint?
What is the composition of bile, blood, urine?
What are the ordinary inspiratory muscles? What the extraordinary?

Now, if the studies have been conducted according to the rules above laid down, it is precisely such questions that the candidate is best prepared to answer.

These "Tablets" are destined to assist students in carrying out these rules.

The grouping of things that are alike, and the condensing, are done by the Author.

For the Student, there only remains to proportion according to their relative importance, the attention to be given to the facts that are to be retained. This, it is hoped, he will naturally be induced to do by the very topography of the Tablets; the Tablets, especially those on anatomy, show at a glance the general outline of the subject they treat of.* Let the Student look first at all the headings & subheads of the Tablet he is studying, and learn them well before going further. It is highly important, in the Author's opinion, to consider a subject as a whole, and to pass in review all its parts at one and the same time. It is, in fact, to inculcate this principle on the mind of the learner that the Tablets are built up, so to speak, each one on *one* page.

WOBURN PLACE, *April*, 1873.

---

* The lithographed Tablets strike the eye more forcibly than the printed ones; they are, therefore, in that respect preferable.

Physical Properties of the Blood.

The blood is a *thick & heavy* fluid of a *bright scarlet* colour, when flowing from an artery, and of a *deep purple*, or nearly black colour, when flowing from a vein.

Its average *temperature* is *about* 100° *or* 102°, but is not the same all over the body, for the blood is cooled when passing through the capillaries of the skin and is slightly warmed when passing through large & active glands such as the liver.

Its *specific gravity* varies *from* 1050 *to* 1059, the average being 1055, the gravity of water being reckoned at 1000.

The blood is slightly *alkaline* in all animals and under all circumstances. The supposed exception in the case of menstrual blood is due to the admixture of acid mucus from the uterus and vagina.

The blood emits an *odour* similar to, but fainter than, that emitted by the animal itself. This odour is principally *due to a volatile fatty acid*, and it may be set free, even when the blood is dried up, by adding to it small quantities of a mixture of equal parts of sulphuric acid & water.

Quantity of Blood in the Body.

The whole of the blood weighs normally in man *about* 1-8*th or* 1-10*th of the weight of the body*. The quantity of the blood varies, however, considerably according to the amount of food & drink recently taken, and to the quantity of water given off; it may be reduced to nearly half by long fasting.

The quantity of blood in the body *cannot be ascertained* with any degree of precision *by simply bleeding an animal to death and measuring the blood that escapes*, for on the one hand a large amount of blood would then remain in the vessels, and, on the other hand, if death ensue but slowly, large quantities of fluid would be absorbed from the tissues to refill the emptying vessels, and would add considerably to the apparent amount of the blood that would be drawn.

Leaving aside the lengthy calculations of Vierordt, based upon uncertain estimates of the amount of blood expelled from the left ventricle at each beat of the heart, & of the number of beats necessary to complete the round of the circulation, there remain *two principal methods of ascertaining the quantity of the blood* in the body:—

1. Welker *bleeds an animal rapidly to death*, and measures the blood which escapes. He then *washes out the vessels* by abundant injections of water, and calculates the additional quantity of blood which then flows out, mixed with water, by comparing the colour of the mixture with that of other mixtures made in known proportions;

2. Valentin *injects a known quantity of water;* Blake, *a certain quantity of some saline substance*, such as sulphate of aluminium, which is not found in the blood, and which is of easy detection. The *calculation* is then founded upon the *diminution of the specific gravity* of the blood, or upon the *proportion of the saline substance diffused* in a measured quantity of the fluid. This latter method may, however, be objected to, on the ground of the probably unequal dilution of the blood, or of the probably unequal diffusion of the saline substance through its mass, unless a considerable time be allowed to elapse, between the injection and the collecting of the samples of blood, upon the modified condition of which blood the calculation is to be based; but then the result would likewise be vitiated even to a greater extent, by the passage into the tissues, of an unascertainable amount of the water or of the salt used in the experiment.

For the *most accurate estimate* we have of the total quantity of the blood in the human body we are indebted to Weber & Lehman. They had the opportunity of *weighing, before & after decapitation, two criminals* who had been condemned to death. The difference in the weight represented the weight of the blood that had escaped. The quantity of blood remaining in the head & trunk was calculated by Welker's method.

Structural Characters of the Blood.

Structurally the blood consists of a colourless fluid, *liquor sanguinis, or plasma,* o *blood and lymph corpuscles,* of more or less numerous *albuminous granules & fatty particles,* similar to those found in the lymph and chyle; also, during the height o digestion, of a few *exceedingly minute oil globules,* like those which constitute the molecular base of the chyle.

Red Blood Corpuscles or Blood Cells.

Human red blood corpuscles as they circulate in the vessels are *minute flattened or slightly concave discs;* but they swell out through endosmosis, & *become convex when the blood is diluted* with water, and *shrink* & assume various irregular forms *when salt, syrup,* or any other substance *is added* which increases the density of the blood. They are elastic, and admit of compression & elongation, in adaptation to the small diameter of the lesser capillaries. Their *diameter* varies *from* 1-3000*th to* 1-4000*th of an inch.*

They are now *believed, however, to be homogeneous in structure,* the only difference between their several parts being, that their external layers are dense & firm, while their internal substance more or less approaches the fluid state. They have *no nuclei;* while they remain concave, however, the *appearance of a central spot,* due to unequal refraction, is perceived *in their thinner central portion,* and is either brighter or darker than the border, according as it is viewed in or out of focus.

A peculiar property manifested by the red blood corpuscles, is their *tendency, when the blood is at rest, to adhere in the shape of rolls, columns, or rouleaux,* like piles of coins, which latter soon join together & form a kind of network. This tendency to adhere is increased in inflammatory diseases; it partly explains the formation of the buffy coat, for the more the blood corpuscles are clustered together, the more rapidly they sink to the bottom.

Chemically the red globules consist of a delicate colourless stroma very abundantly infiltrated with a red colouring matter. The stroma consists of a nitrogenous proximate principle, protagon, combined with a modification of globulin termed paraglobulin or fibrino plastin (Hoppe-Seyler, C. Smidt). The colouring matter is a nitrogenous crystalisable substance, hæmoglobin (Hoppe-Seyler) or cruorin (Stokes), capable of absorbing oxygen in the lungs and of readily giving it up in the capillaries. The red globules also contain fatty matters, among which cholesterin, and salts, chiefly phosphates of potash, soda, & lime—(Vide Tablets on Animal Chemistry).

White Corpuscles

Are spheroidal nucleated cells, *about* 1-2500*th of an inch* in diameter, and of a greyish pearly colour. They present a finely *granulated surface, granular contents,* and a simple or compound *nucleus,* which is clearly brought into view by the action of dilute acetic acid, the remainder of the cell then becoming transparent. It is *doubtful whether* they are surrounded by *any true cell-wall.*

They are very similar in appearance to the corpuscles of the lymph or chyle; but they differ from them chemically, for the latter are but very slightly acted upon by acetic acid.

A most remarkable property which the white corpuscles have recently been shown to possess in common with the amœba (Von Ruklinghausen, Waller, Cohnheim), is their capability of *assuming,* spontaneously, *different forms,* and of *enclosing milk-globules,* or *particles of colouring matter* or of carbon; of *sending out processes in different directions* and subsequently *withdrawing them;* of *adhering to the walls of the blood-vessels, pushing processes through them,* and then *following these processes into the surrounding tissues,* in which they accumulate in great numbers, in any part of the body that has been irritated.

The average proportion of the white corpuscles to the red ones is *about* 1 *in* 400 *or* 500; but the relative number of the white corpuscles is very variable, being much increased after a meal and greatly diminished by fasting.

Coagulation of the Blood.

When drawn from the body, and left at rest, the blood *coagulates in about* 10 *minutes.* The *clot* gradually *contracts* and becomes firmer, while a transparent yellowish fluid, the *serum, oozes from its surface,* and is soon abundant enough for the clot to float therein.

When examined with the microscope the clot is seen to *consist of solidified fibrin,* in the shape of minute fibrillæ, between the meshes of which the *red globules* are joined together in piles, columns, or "rouleaux;" the *white globules* are scattered here and there.

The *explanation* given of the change, until lately, *was this: the liquor sanguinis consists of serum holding fibrin in solution; the fibrin has a peculiar tendency to coagulate when at rest, & to contract; while coagulating, it entangles in its meshes the blood & lymph corpuscles and the serum; by its subsequent contraction the serum is pressed out of the clot.*

The *foregoing explanation* of the coagulation of the blood is, however, *no longer received* in its integrity; *indeed, the very existence of fluid fibrin in the blood is now disbelieved in, if not disproved.* Schmidt & Dr. Buchanan, of Glasgow, have shown that the addition of blood serum, or of red blood corpuscles to, or the contact of muscular or nervous tissue or of skin with, any serous effusion, or the admixture of serous effusions from different parts of the body, gives rise speedily to the formation of a clot. Thus fluids which have themselves little or no tendency to coagulate, can be made to produce a clot apparently identical with the blood-clot, by the simple addition of fluids which will not themselves coagulate, or of solids which are not known to contain fibrin. Schmidt supposes that the *formation of the fibrin of the clot is due to the union during coagulation, of two substances chemically very similar,* which he calls respectively the *fibrino-plastic & fibrinogenous,* the former of which may be obtained from almost all the tissues & fluids of the body, and is believed to be identical with the globulin of the red corpuscles. The real cause of the coagulation of the blood is still, however, a mystery.

In *inflammatory diseases* & in *low constitutional states,* a layer of white clot, the "*buffy coat,*" forms on the top of the red clot and soon becomes concave or cupped on its surface. The inflammatory clot also shrinks more than usual and becomes very firm and tough, which is due to its containing a large amount of fibrin; in the case of cachetic & anæmic persons the clot is large, loose, & soft.

The *white clot* is *due to* the *partial sinking of the red blood corpuscles before coagulation takes place,* and to the inclusion in the upper part of the clot of the white or lymph corpuscles only, which are much lighter than the red ones and incline to float. This sinking of the red corpuscles occurs in inflammatory diseases and in low constitutional states, because the corpuscles then manifest an increased tendency to coalesce in columns or "rouleaux," in which condition their rate of sinking becomes greater; in inflammatory diseases the blood also coagulates less rapidly, so that the corpuscles are allowed more time to subside before they are arrested by the formation of the clot. The *absence of the red corpuscles* from the upper layers of the clot, *explains* both their *pale yellowish or greenish hue, and* also their *greater contraction & the concave or cupped shape of the surface of the clot.* The greater or less amount of fibrin contained in the blood, or formed at the time of coagulation, explains the greater or less contraction of the mass of the clot and its variable consistency.

Coagulation is hastened by rest, moderate warmth, the contact of foreign bodies or rough surfaces, slight dilution with water, and by exposure to the air, as, for instance, when the blood escapes slowly from a small artery or vein and is collected in a shallow vessel. It *is retarded by* slight agitation, cold, contact with smooth surfaces, the addition of ammonia, of alkaline or earthy salts, or of the narcotic & sedative alkaloids, the exclusion of air, as, for instance, when the blood escapes rapidly from a large artery or vein and is collected in deep or closed vessels, or when oil is poured on its surface; it is retarded also in all inflammatory states of the system.

The *serum,* or that part of the blood which remains fluid after the formation of the clot, is *viscid, yellow, & alkaline,* and contains all the constituents of the blood, except the globules and the fibrin. *Its abundance depends on the degree of contraction of the clot.* Being very rich in albumen it *coagulates, when heated,* to such an extent that it is transformed almost entirely into a white jelly-like mass. The small portion of the serum which then remains uncoagulated is termed "*serosity.*"

Chemical Composition of the Blood.

The principal constituents of the blood are *water, albumen, fibrin, red globules, fatty and extractive matters, salts, & gases.* The relative proportion of some of these constituents may vary considerably, but the average composition of the blood as a whole is pretty constant.

Water.—*From 700 to 800 parts in 1000.*—Its *deficiency* is indicated by a sensation of *thirst*, which becomes more & more urgent as the deficiency increases. *When it is in excess*, it is rapidly *excreted in the shape of sweat & urine.* Thus, uniformity is maintained in the density of the blood, and in the fulness or tension of the vessels, and, consequently, in the rate of exudation from the vessels into the tissues, & in the rate of absorption from the tissues into the blood.

Albumen.—*From 60 to 70 parts in 1000.*—Is probably *in a state of combination with soda, or with the tribasic phosphate of soda,* which assist in keeping it dissolved.

Fibrin.—*From 2 to 3 parts in 1000.*—The proportion cannot, however, be very accurately ascertained, as in analyses fibrin cannot be separated from the white globules. Is much *increased in inflammatory diseases*, but, as in such cases, the white globules are much increased also, it is probable that the apparent increase of the fibrin is partly due to its being weighed along with the white globules.

Red Globules, containing *Protagon, Paraglobulin or Fibrino-plastin, Hæmoglobin or Cruorin*, and also *fatty matters & Salts.*—130 *parts* (dried) *in* 1000.—The quantity of red globules is *increased in plethora* and much *diminished in anemia & chlorosis*, in which latter state the globules have been found reduced to the proportion of 60, 50, or even 27 parts in a 1000 (Andral & Gavarret).

Fatty Matters.—*Average proportion,* $1\frac{1}{2}$ *parts in* 1000—Consist of cholesterin, cerebrin, serolin, the phosphorised fat of the brain, margaric, and oleic acids, and of a volatile fatty acid, to which the odour of the blood is mainly due. They are subject to great variations in quantity, their proportion being *much increased after meals*, when the fatty particles of the chyle are added to the blood.

Extractive Matters.—*About 6 parts in* 1000.—The most important are *kreatin, kreatinin*, sugar, lactic acid, casein, *urea, uric acid*, ammonia, and colouring & odoriferous matters.

Salts.—6 parts in 1000.—The salt found in the blood in by far the largest proportion is the *chloride of sodium.* Among the salts of special interest are the *carbonate and phosphate* and the *tribasic phosphate of soda*, which *give rise to the alkalinity of the blood* and *preserve the fluidity of its albumen.* These salts have the property of *absorbing large quantities of carbonic acid gas, and of readily giving it off* when agitated in atmospheric air, and it is believed by Liebig that the *carbonic acid gas of the blood* is principally *combined with them.*

Gases.—100 *volumes of blood contain, collectively, from 40 to 50 volumes of oxygen, carbonic acid, and nitrogen*, the mean relative proportions of which are about as 4, 12, and 1. Arterial blood contains, however, more oxygen & less carbonic acid than venous blood. *The carbonic acid & the oxygen are partly free and partly in a state of weak chemical combination, the carbonic acid being combined with the carbonate & phosphate and the tribasic phosphate of soda, the oxygen being chiefly absorbed by the red globules, and being combined with the cruorin*, which has been shown by Professor Stokes to exist in two states of oxidation corresponding to the scarlet & purple tints of arterial & venous blood.

The Action of the Heart.

The *whole heart* is *relaxed & passive immediately after its beat* against the side of the chest.

During the period of repose or "*pause*," the auricles gradually fill, and a portion of the blood passes through them into the ventricles.

When the *auricles* are distended they *contract*, propelling nearly the whole of their blood into the ventricles.

The contraction, or *systole, of the auricles* is of very *short* duration; it commences at the orifices of the great veins, and is *propagated towards the auriculo-ventricular openings*, the auricular appendices being the last to contract. The reflux of the blood into the veins is thus checked, as it is also by the simultaneous contraction of the muscular coats of the veins, and, with regard to the right side of the heart, by the Eustachian & Thebesian valves, & by the valves near the point of junction of the internal jugular & subclavian veins; a small quantity of blood does, however, regurgitate.

The *ventricles, on being distended, immediately contract*, so immediately, indeed, that no interval can be perceived between their contraction and that of the auricles, the two concurring "in such wise that but one motion is apparent" (Harvey).

The *ventricles contract slowly*, and empty themselves completely. *During their contraction they rotate screw-wise to the right* on account of the spiral arrangement of their superficial fibres, *bulge out*, and *tilt forwards the apex & lower part of the anterior surface of the heart*, producing the well-known impulse of the latter against the side of the chest.—The force with which the blood is propelled into the aorta by the left ventricle is calculated to be equal to about 4 lbs., and the force with which it is propelled into the pulmonary artery by the right ventricle, is calculated to be equal to about 2 lbs. The force of the auricular contractions cannot be measured.

The *pause* or the period of relaxation, during which the cavities of the heart are again filling, *recommences for the auricles, during the contraction of the ventricles*, and *for the whole of the heart, immediately after such contraction.* The cavities of the heart are now no longer believed to dilate actively; their diastole, though taking place spontaneously, is nevertheless a mere passive phenomenon, due simply to the relaxation of the previously contracted muscular valves.

Action of the Valves of the Heart.

The *mitral and tricuspid valves* close the auriculo-ventricular openings during the contraction of the ventricles, and prevent regurgitation from the ventricles into the auricles & great veins. The semilunar valves close immediately after such contraction and prevent regurgitation from the arteries into the ventricles.

The *closure of the tricuspid valve* is *said*, however, *to be imperfect, and to allow of a certain degree of regurgitation during violent exercise, and also when the circulation through the lungs is impeded*, a pulsation synchronous with the beat of the heart being then observable in the jugular veins. *Over distention of the cavities of the heart & of the capillaries of the lungs is prevented by* this "*safety valve action*" as it is sometimes called.

The auriculo-ventricular valves are closed by the pressure of the blood in the contracting ventricles, their elevation being aided by the action of the elastic tissues which they contain. The *eversion* of these valves is *prevented by the chordæ tendineæ*, which are kept tense by the contraction of the musculi papillares, which contraction takes place simultaneously with that of the walls of the ventricles.

The *semilunar valves* are thrust asunder by the impetus of the blood outflowing from the ventricles.—The lateral pressure of the blood propelled into the arteries distends their elastic walls, but it does not distend, or at least it does not distend in an equal degree, the unyielding valves and the rings to which they are attached. *Three pouches, the sinuses of Valsalva, are* thus *formed behind the valves, while the valves themselves are drawn inwards towards the centre of the artery*, and are thus favourably disposed to be pressed down and closed, as soon as the ventricles cease to contract and the dilated arteries are able to recoil. The *pressure of the blood in the recoiling arteries*, as has been shown by Mr. Savory, is *not sustained by the valves alone, but also by the thick upper edge of the ventricles*, upon which the pouches of the distended artery & the outer part of the semilunar valves repose. The *margins of the valves* meet in three converging lines, along which they *come in contact* with each other, *not only by their edges but also by the ventricular surface of the lunulæ.* The *corpora Arantii meet in the centre* of the artery & *probably assist in the closure of the valves.*

Cause of the Action of the Heart.

The contractions of the heart are *not governed directly by the cerebro-spinal nervous centres*, for injury to the latter, amounting even to total destruction, does not, if gradually inflicted, stop the heart's action, and, if suddenly inflicted, generally occasions but a temporary interruption due to *shock*, especially if, in the case of warm-blooded animals, artificial respiration be resorted to. The action of the heart continues even after that organ has been completely disconnected from all other structures and removed from the body, and continues under such circumstances for several minutes in the case of warm-blooded, and for several hours in the case of cold-blooded animals.

The *immediate cause of the heart's action lies*, therefore, *within the heart itself.*

This cause resides *in the numerous ganglia of the sympathetic system* which Goltz & others have shown to exist *around the boundary-rings between the auricles & ventricles*, ganglionic nerves emanating from which ganglia are distributed throughout the substance of the heart. *As long as these ganglia are left uninjured all the portions of the heart which remain in connection with them* through the ganglionic nerves *will continue to contract*, whatever degree of injury be sustained by the cerebro-spinal nervous centres, or by the remaining portions of the heart itself. If these ganglia be destroyed, or if the connections between them and any part of the heart be severed, then and then alone, will the heart, or such part of the heart, definitively cease to contract. Thus the *heart may be bisected, the right and left halves being separated from each other, or the auricles being separated from the ventricles*, without the heart's action ceasing in either of the two halves; but if the heart be divided in such a way that the one piece comprise the auricles and the base of the ventricles and the other the rest of the ventricles, then the latter part will cease to act while the former will continue.

Irritation of the nerves which connect these ganglia with the other parts of the sympathetic, stimulates the action of the heart, increasing both the frequency & the strength of its contractions.

Influence of the Cerebro-Spinal System over the Action of the Heart.

The stimulation of the heart's action by cerebral inflammation, and its partial or total arrest by cerebral apoplexy, concussion, compression, or injury, and the results of the irritation of the pneumogastric nerves, show, however, that the *heart* is *not entirely independent of the cerebro-spinal nervous system.*

English physiologists generally believe with Budge, Weber, Bezold & others that an *inhibitory influence* is exercised over the action of the heart through the *pneumogastric nerves:* if the pneumogastric nerves be divided the heart beats with greater frequency & strength; if they be stimulated by the galvanic current or otherwise, the contractions of the heart become weaker & less frequent, or even entirely cease for a time, the heart remaining meanwhile in a state of diastole. *Longet, Béclard, Schiff, Moleschot, &*

others contend, however, that it is only when a *strong* current is applied to the pneumogastric, that the above effect is produced, and that the same result follows the application of a *strong* current to the sympathetic, the strong current producing *a shock*, such as may be produced by many other causes (as a blow on the abdomen, or any violent pain), with the same inhibitory effect both on the heart's action and also on the respiratory movements: *weaker currents increase the strength & frequency of the heart's action both when applied to the pneumogastric, and when applied to the sympathetic.*

With regard to these contradictory statements the Author begs to call attention to the well-known fact that the cerebro-spinal nerves are good conductors, and the sympathetic nerves bad conductors, both of sensory impressions and motor impulses.—It is not to be denied, on the one hand, that when the same *ordinary* stimulus is applied in succession to the trunk of the pneumogastric, & to the cardiac branches of the sympathetic, it depresses the heart's action in the one case, and stimulates it in the other. But, on the other hand, it is, in the Author's opinion, equally certain that the heart's action is increased by the stimulation of the pneumogastric nerve, *provided the stimulus be sufficiently mild,* and that it is, on the contrary, arrested by a stimulation of the sympathetic, *provided the stimulus be sufficiently powerful.*—Why this difference, if, as the Author believes, the influence of the two nerves over the action of the heart be essentially the same? Because the same irritation, when applied to the pneumogastric nerve, *which is a good conductor*, must produce a deeper impression, and, if sufficiently violent, a greater shock, than when applied to the sympathetic nerve, through the instrumentality of which nerve none but intense & prolonged impressions are conveyed to the sensorium, and none but *relatively intense & prolonged irritations are productive of motion.*

Cause of the Rhythmic Action of the Heart.

Why there should be a rhythmic succession in the contractions & dilatations of the heart is still a thing that is but imperfectly explained. That the *successive distension of the cavities of the heart by venous or arterial blood is not the sole cause* of the rhythmic action of that organ is superabundantly proved by the fact of the heart's continuing to beat when removed from the body. *Sir James Paget* believes that the explanation lies in the *rhythmic nutrition of the heart, i.e.,* " in a method of nutrition in which the acting parts are gradually raised with time-regulated progress to a certain state of instability of composition, which then issues in the discharge of nerve-force by which the muscular walls are excited to contract."—A similar explanation was given some time ago by Vaust & Brücke, & was supported by an alleged arrangement of the semilunar valves, said to result in the rhythmic circulation of the heart, the valves being believed to cover & close the openings of the cardiac arteries, when pressed against the walls of the aorta during the contraction of the ventricles. The support given to this explanation by Vaust & Brücke, was founded on an anatomical error. It cannot be denied, however, that *every part of the heart is adjusted so as to contract in, and for only, a certain time, and that that time is the same for every part:* if, in a heart which has just ceased to contract, a point of the surface of the ventricles be irritated, that point will immediately contract, & so will the whole of the ventricle directly afterwards; but at the close of this, and every subsequent general contraction, the part which was irritated & which contracted first, will be found to be the first to dilate.

Sounds of the Heart

Are *two* in number, follow *in quick succession*, and are *succeeded by a pause.*

1st. Sound.—Is *deep, dull, prolonged,* coincides withthe impulse of t heart, & just precedes the pulse. Is best heard in the 5th intercostal spa two inches below & one to the inner side of the nipple.

2nd. Sound.—Is *shorter, sharper, higher in tone,* and has a somewhat flapp character. It immediately follows the pulse, and is best heard at the upp border of the 3rd costal cartilage of the left side, close to the sternum.

The two sounds & the pause *correspond in point of time as follows :—*

1st. Sound—with :

A. The *contraction of the ventricles,* the closure of the auriculo-ventricu valves, the opening of the semilunar valves, & the projection of the blo into the arteries.

B. *The first part of the dilatation of the auricles.*

2nd. Sound—with :

A. The *cessation of the contraction of the ventricles,* the recoiling of the arteri & the closure of the semilunar valves.

B. The *continued dilatation of the auricles,* the opening of the auriculo-v tricular valves, & the commencing dilatation of the ventricles.

The pause—with :

A. The *distention and subsequent contraction of the auricles.*

B. The *distention of the ventricles.*—During the pause the semilunar val are closed and the auriculo-ventricular valves are open.

The two sounds *are determined as follows :—*

1st. Sound.—By several coincident causes, the principal of which is *vibration of the auriculo-ventricular valves* at the moment of their closu and also, perhaps,the vibration of the walls of the ventricles, aorta, pulmonary artery. That such is the grand cause of the first sound of heart is rendered more than probable, if it is not absolutely proved, by following experiment of Valentin :—Valentin filled with a moderate quan of water without any admixture of air a portion of a horse's intestine tied at both ends ; the stethoscope being applied to one of the ends, towards wh end the water is propelled by sudden pressure at the other, a sound is he very similar to the first sound of the heart ; this sound is evidently produ by the vibration of the walls of the intestine. It is admitted, however, t other causes assist in producing the first sound ; among these second causes the most efficient are probably the *contraction of the muscular fibre the ventricles,* the *shock of the heart against the walls of the chest,* & the *vibra of the blood itself* when suddenly compressed and ejected into the arteries

2nd. Sound.—By the *vibration of the semilunar valves* at the momen their closure. This is proved by another of Valentin's experime Valentin passed curved needles through the walls of the arteries & semilunar valves, thus rendering these immovable, and stopping t action ; after the operation the second sound was no longer heard.

The *contraction of the auricles* is *inaudible through the walls of the chest,* but when heart is exposed & the stethoscope is applied to it, a slight sound is heard preced & being continued into, the louder sound of the ventricular contraction.

Impulse of the Heart against the walls of the Chest

Is felt most distinctly *between the 5th & 6th left ribs, one or two inches from sternum.*

It is *determined by* the *bulging out of the heart* during the ventricular contract & also by the *tilting forwards of its apex* in a screw-like manner, due to the sp arrangement of the superficial fibres of the ventricles. The tendency of the a to straighten itself, when distended by the action of the ventricles is, perh another cause of the impulse of the heart, but only a very secondary one, for same tilting forwards occurs when the apex of the heart is cut off and the cav of the ventricles are laid open.

he Structure of the Arteries

resents for examination *three coats*, the *vasa vasorum*, & *nerves*.

Inner, Serous or Epithelial Coat—Consists of *two essential structures* between which, in the large arteries, a third structure is interposed.—The two essential structures are :—

1. A *single layer of pavement epithelium*, the cells of which are slightly elongated, and present very distinct nuclei.

2. An *elastic* layer which may be either, as it usually is, a delicate *reticulated membrane perforated here & there, the striated or fenestrated coat of Henle*, or *a mere network* of anastomosing fibres of elastic tissue longitudinally disposed; orthe two forms of elastic tissue may coexist, the former internally, the latter externally.—The intermediate structure observable in the large arteries is a longitudinal stratum (striated layer of Kölliker) of ill-developed elastic & connective tissue fibres, which stratum is often nearly homogeneous in appearance.

This coat is a *thin, brittle, colourless* membrane, remarkable for the *smoothness of its inner surface*. It can easily be separated from the middle coat by maceration.

Middle or Circular Coat—Consists of *alternate layers of circular muscular fibres* and of *circular fibres of yellow elastic & white fibrous tissues*. The relative proportion of these different elements varies according to the size of the vessel, the *muscular fibres* being most *abundant in* the *small arteries*, and forming almost exclusively the middle coat of the smallest ones, the *elastic & white fibrous tissues* being predominant *in* the *larger vessels*, and existing almost exclusively in the main trunks.

This coat is relatively *very thick*, and is the principal cause of the great thickness of the walls of the arteries. It is *elastic, but brittle*, of a yellowish or tawny colour in large arteries, redder in the smaller ones. It is easily separable from the outer coat.

External or Cellular Coat, or Tunica Adventitia—Consists of *connective tissue longitudinally or obliquely disposed*, and containing, except in the smallest arteries, elastic fibres and elongated nuclei. In the larger arteries the inner layers of this coat are formed of elastic tissue only, while the white fibrous tissue predominates in the outer layers.

This coat is proportionately thickest in the small arteries. It forms a tough investment, continuous externally with the sheath, by means of loose areolar tissue. It is in this coat that the vasa vasorum & nerves are principally seen to ramify.

Nutrient Arteries or Vasa Vasorum—Arise from the neighbouring branches, break up in the loose cellular tissue within the sheath, *ramify in the external coat*, and give off *a few twigs to the middle coat*. The corresponding venules open into the veins which accompany the artery.

Nerves—Are derived *principally from the sympathetic*, but, also from the cerebro-spinal system. They form plexuses on the large trunks; small bundles of fibres run along the smaller arteries, single fibres along the smallest. These penetrate into the middle coat, to which they are principally distributed.

Arterial Circulation.

The two properties by which the arteries influence the circulation are *elasticity* & their *contractility*.

Elasticity of the Arteries.

The contents of the ventricles are forced into the arteries more rapidly than can be discharged. The elasticity of the arteries therefore :—

1. *Prevents the arteries from bursting.*—The elasticity is most developed large arteries, especially in those near the heart, in which the variati internal pressure are the greatest. The degeneration of the walls arteries is the principal cause of aneurism & apoplexy.
2. *Equalises the circulation* by maintaining pressure on the blood durir intervals of the ventricular contractions; the jetting stream is thus con into the continuous and equable current observable in the capillaries.
3. Tends with the contractility to *maintain uniformity in the fulness & tens* and consequently in the rate of exudation from, and of absorption int vessels.

Contractility of the Arteries

Is most *developed in the small and in the middle-sized arteries.*—The contracti the middle-sized arteries becomes evident to the naked eye when the denuded and exposed to the air, or when they are cut through; in the latte it tends to stay the hemorrhage, especially when cold or any irritating subs is applied. The contractility of the very small arteries is rendered still evident by the microscopical examination of the mesentery of the frog & small animals when either cold or heat, or mechanical, chemical, or el stimuli are applied. It may last as long as 48 hours after death.

It is governed by the vaso-motor nerves, and is called into play by reflex actio *regulates*, according to the requirements of the moment, the *quantity of that each part is to receive.* It co-operates with the elasticity in *adapti calibre of the vessels to the total mass of the blood*, and in maintaining uniform the tension or tone of the blood-vessels.

Force of the Blood in the Arteries.

The onward force of the blood in the arteries has been measured by Poiseui means of the hæmadynamometer, and more recently by several experim by means of the kymographion.

It was *said* by Poiseuille *to be the same in all the arteries*, & to be capa supporting, while the ventricles are contracting, a *column of mercury six inches* or a *column of water about seven feet in height.* It is now, ho known to vary considerably in the different parts of the arterial s It is increased by the injection of water or blood into the veins, and dimi by bleeding. It was said to be increased during expiration, and dimi during inspiration; the action of the respiratory movements appears, ho to be rather complex, the arterial pressure usually increasing, acc to Dr. Burdon Sanderson, during inspiration and the commencem expiration, and diminishing towards the end of the expiratory movem during the period of repose of the thorax.

The force with which the blood is propelled into the aorta by the *left ventricle* culated to be equal to *about 4 lbs.*, & the force with which it is propelle the pulmonary artery by the *right ventricle* to be equal to *about 2 lbs.*

Velocity of the Blood in the Arteries.

Volkmann has shown with the hæmadrometer that the velocity of the blood is greater in the arteries than in the capillaries, and also considerably greate in the veins; that it is *greatest near the heart & during the ventricular contr* and *least during the ventricular diastole & in parts distant from the heart*, t extremes being respectively *about* 10 & *about* 2 *inches per second.* The velo the blood is also slightly increased during expiration, and diminished inspiration.

he Pulse.

he jetting movement of the blood *dilates the arteries in all directions*, increasing both their *diameter* and their *length*. The lateral dilatation of the arteries is only about 1-15th (Vierordt) or 1-22ndth (Poiseuille) of their diameter. The *elongation* (which has not been accurately measured) *produces curvature or increases the natural curves, and causes* a *much greater displacement* of the arterial walls.

he pulse may be defined as *the beat of the arteries produced by their sudden dilatation and displacement, the latter due to the curvature produced by elongation, which dilatation & displacement are rapidly propagated in a wave-like manner* from the heart immediately after each ventricular contraction.

he nearer an artery is to the heart, the sooner after the ventricular contraction is the *pulse perceptible in it;* thus the pulse in the carotid precedes that in the radial, which in its turn precedes that in the dorsal artery of the foot. The delay of the pulsation in the distant arteries never exceeds, however, 1-6*th or* 1-8*th of a second*.

he improved *sphygmograph* & the beautiful investigations of Mr. Marey have inaugurated a new period in the progress of our knowledge of the phenomena of the arterial circulation. The sphygmograph itself cannot be described here, nor can any but the most prominent results of the investigations of Mr. Marey and others:

1. The *distention of all the arteries begins at the same moment* & coincides with, or instantaneously follows, the contraction of the ventricles; it is *only the maximum* of dilatation and displacement which maximum alone is perceptible to the finger, *that is attained almost instantaneously in the proximate arteries, and slightly delayed in the distant ones.*

2. The *delay is thus accounted for:* the blood propelled by the ventricle into the aorta meets the blood already contained in that vessel, and is impeded by it in its course. This causes *a part of the force*, communicated to the blood by the ventricular contraction, to be *expended laterally in the dilatation of the first part of the aorta*, and *gives rise to the formation of a wave.* It is *this wave*, which, advancing at the rate of about 30 feet per second, *dilates in succession the different parts of the artery as it passes rapidly through them.*

3. The passage of each successive wave through an artery, or each pulsation, is marked in the pulse-tracing by an *upstroke;* a *downstroke* marks the intervals of the pulsations. The *upstroke ought not to be too vertical*, for deficiency of tone in the arteries is thus indicated. The *downstroke always presents a slight re-ascent*, which is probably due to the momentary rebound throughout the arterial system, occasioned by the closure of the aortic valves, which closure suddenly stops the incipient regurgitation of the blood into the ventricles. *When there is much loss of tone*, as in low fevers and after great loss of blood, this *re-ascent is exaggerated* and can be perceived by the finger; the *pulse is then* said to be *dicrotous.*

he frequency of the Pulse.

he pretty uniform *relative* average observed in health, between the number of the *beats of the heart* & the number of the *respirations*, is *about* 4 *or* 5 *to* 1.

n round numbers the *average frequency of the pulse is:—*

Before birth	150	beats per minute.
At birth	140	,, ,, ,,
1st year	120	,, ,, ,,
7th year	90	,, ,, ,,
14th year	80	,, ,, ,,
Adult age	70 to 80	,, ,, ,,
Old age	60 to 70	,, ,, ,,
In decrepitude	65 to 75	,, ,, ,,

The Structure of the Veins

Differs more than that of the arteries according to size and situati In *most veins three coats* can be recognised; they are, however, mu thinner than those of the arteries.

Veins immediately above the Capillaries—Consist sim of a layer of *pavement epithelium*, supported on a stratum *nucleated fibrous tissue*, longitudinally disposed, and genera divisible into two layers.

Middle-sized Veins—Present:

INNER COAT.—Formed from within outwards by a layer of *pavem epithelium*, one or more layers of *nucleated fibrous tissue* lo gitudinally disposed, and a longitudinal layer of reticula *yellow elastic fibrous tissue.*

MIDDLE COAT.—Formed of *alternating longitudinal & circular laye* the former consisting of white & reticulated yellow elas *fibrous tissues*, the latter of the same tissues with circu *muscular fibres.*—The muscular fibres are most developed in t splenic & portal veins.

OUTER COAT.—Consists of *connective tissue* longitudinally or obliqu disposed.

Larger Veins—Have a *thick middle coat*, in which, however, t muscular tissue is but scanty.

Very Large Veins—Have a remarkably *thick outer coat*, whi especially in the large veins of the abdomen, contains a consid able number of *longitudinal muscular fibres* (Remak).—The ve cavæ & pulmonary veins present near their termination a layer striated muscular fibres continued upon them from the auricles.

Plain *muscular fibres* are *abundant* in the veins of the *gravid uter* They are, on the contrary, *wanting* in the veins of the mater part of the placenta, in most of the cerebral veins, the sinuses the dura mater, the veins of the cancellous tissue of bone, and the venous spaces of the corpora cavernosa.

The *valves* of the veins are formed by a reduplication of the inne middle coats.

The coats of the veins, as well as those of the arteries, are suppl with nutrient vessels, the *vasa vasorum.* Small nerves have been traced on some of the larger veins of the abdomen.

[V]enous Circulation

Is *equable*, slower than the arterial, but much quicker than the capillary.

Its *average velocity* is *about* 1-3*rd of* that of the *arterial in* the *corresponding peripheral veins*, the aggregate capacity of which is about three times that of the arteries. This velocity *increases*, however, as the blood advances *towards the heart*, in proportion as the aggregate capacity of the veins diminishes, and in the venæ cavæ it approximates that of the blood in the aorta. The motion of the blood in the veins is subjected, however, to many disturbing causes, such as the intermittent effects of muscular pressure, and the opposite influences of expiration & inspiration.

The pressure or *onward force* of the blood in the peripheral veins varies *from* 1-10*th to* 1-20*th* (Poiseuille), *or* is *about* 1-12*th* (Valentin) of that of the blood in the corresponding arteries. *Near the heart it diminishes* still more, and in the upper part of the vena cava scarcely any pressure can be detected; but then it must be remembered that the auricles dilate spontaneously, if indeed, they do not assist, the flow of the blood towards the heart.

The *venous circulation* is *aided by* the action of the *valves* of the veins, and by the *respiratory movements*.

The Valves—Are found *in all* the *veins subject to pressure from the surrounding muscles*, and also in the *superficial veins*, and are most abundant in the extremities, particularly in the lower ones. They are *absent* in the *veins* of less than a line in diameter, in the veins *within the cranium, spinal canal, & abdomen*, in the pulmonary & umbilical veins, the veins of the cancellous tissue of bone. A few valves exist, however, in the spermatic veins, and one is found at their respective points of junction with the inferior vena cava & the left renal vein.

They are *semilunar* in form. Their free concave margin is directed towards the heart; they are attached by their convex margin to the wall of the vein, which is dilated immediately above them. They generally lie in pairs.

They are *formed by* a *reduplication of the two inner coats* of the veins, and consist of connective tissue and elastic fibres covered with a layer of pavement epithelium.

The design of the valves is twofold:

1. They divide the column of blood and *save the walls of the veins from the entire pressure of the whole column;* they are, therefore, on the latter account most needed in the unsupported superficial veins, where they are also most numerous. It is, however, inaccurate to say that they are intended to do away with the obstacle presented by gravitation to the venous circulation; this obstacle has no real existence, since the column of blood in the veins is supported by the equal weight of the column of blood in the arteries.

2. *In* the *deep veins* their action, combined with that of the surrounding muscles, is a *powerful assistant to the venous circulation.* When a vein is compressed by an adjoining muscle in a state of contraction, the first pair of valves in the direction of the capillaries closes immediately; the blood is then forcibly driven in the direction of the heart. It will easily be seen that it is the rapid succession of muscular contractions, and not their duration, that assists the venous circulation; were it not for the anastomoses of the veins the prolonged duration of the muscular contractions would even have a contrary effect.

The Respiratory Movements.

Inspiration.—It was *Sir D. Barry* who first showed the *aspiration or suction of the blood into the thorax during inspiration*, by the experiment of a bent glass tube introduced at one extremity into the jugular vein of a horse, & immersed at the other extremity in some coloured fluid: the fluid was drawn up into the tube during each inspiration. It is, however, *only in the veins of the base of the neck*, the walls of which are more or less attached to bones and are supported by the deep cervical fascia, *that* the influence of inspiration *extends to any distance out of the thorax;* the opening of any such veins often gives rise to the now well-known phenomenon of the aspiration of air into the circulatory system.

Expiration.—*Favours the arterial circulation* by increasing the pressure in the arteries; its *effect on the venous circulation* must be the *reverse*. The action of the *valves prevents*, however, any *rapid expiratory movement from* seriously *impeding* the *circulation;* prolonged expirations rapidly produce congestion of the head & neck.

The Capillaries

Form a *microscopical network,* which is everywhere interposed betwee the arteries & the veins, except between some of the arteries an veins of the erectile structures and of the spleen & maternal part o the placenta.

This network is much more *uniform in the size & shape of its meshe* than that which is formed by the anastomoses between the smal arteries & the veins; the vessels which form it maintain the sam diameter throughout. In *form* it presents *three principal varieties* the meshes being either *rounded,* as they commonly are, or *elongate* as they are in the muscles and nerves, or arranged *in loops,* as the are in the papillæ of the tongue & skin.

The more active the functions of an organ or tissue are *the more numerous* a its *capillaries.* In the *lungs,* the *liver,* & the *choroid coat* of the eye, i which the capillary network is closer than in any other structur the interspaces between the capillaries are smaller than the capillari themselves; *ligaments, tendons* and allied structures are but slightl vascular.

The *usual diameter* of the capillaries is *about* 1-3000*th* of an inc Among the *largest* capillaries rank those of the *skin,* and those the *marrow* of the bones, which are sometimes 1-1200th of an inch diameter; among the *smallest* are those of the *brain* & of the *muco membrane of the small intestine,* the diameter of which sometimes do not exceed 1-4500th. The so-called *serous vessels,* which we described in the cornea, and which were said to be too small transmit the red globules of the blood, are now not general believed to exist.

The *walls* of the capillaries have until lately been believed to cons simply of a *transparent structureless membrane,* formed of a sing layer of flattened nucleated cells, *which are* so perfectly join together that their nuclei alone can be distinguished like so ma *minute oval corpuscles,* imbedded at intervals in the otherwise hom geneous wall. *Externally to this* membrane there is *now believed* exist *another homogeneous structure,* on the inner surface of which t epithelial scales are laid down.

Two varieties of large capillaries, or *vessels of transition* between t ordinary capillaries and the arteries & veins, are described by so authors. On the smaller of the two a thin layer of circular muscu fibres can be seen; on the larger variety an additional covering connective tissue begins to appear.

Circulation in the Capillaries

Can *easily* be *observed* with the microscope *in all thin, transparent parts,* such as the web of a frog's foot, the tail and gills of tadpoles or small fishes, or the mesentery of small quadrupeds.

Is *remarkably slow;* and it is *uniform,* at least in the strong and healthy adult.

Its *velocity* is *greatest in the centre* of the stream, which is occupied by the red globules. *At the sides* is a *"still layer" of liquor sanguinis,* apparently motionless, in which lymph corpuscles may sometimes be seen moving slowly along, or even adhering to the walls of the vessel.

In *very young animals,* and also in adults when much blood has been lost, or when the heart's action is weak, the motion of the blood in the capillaries, on account of the incomplete distension and imperfect elastic recoil of the arterial walls, becomes *pulsatory,* and *even intermittent* when the degree of exhaustion is very great. The red globules are even seen occasionally to recede a little during the intervals of the arterial pulsations.

The rate of the capillary circulation in the *frog* is about 1 *inch per minute, or* 1-60*th of an inch per second, in the systemic capillaries,* and about *five times as great in the pulmonic capillaries.* It is estimated that the velocity of the capillary circulation *in man and in warm-blooded animals* is about *two or three times as great.*

The slow course of the blood in its passage through the capillaries is confined to a very short space, for the *whole length of the capillary vessels through which in any one part of the body the blood has to pass* before reaching the veins, *does not exceed* 1-30*th of an inch;* the *time during which the blood is detained in the capillaries* does *not* therefore *exceed one second.*

The *slowness* of the capillary circulation is *due to* the *widening of the stream* of blood in the capillaries, the aggregate sectional area of which is much greater than that of the arteries or veins, and also to the greatly *increased resistance arising from friction.*

When *cold or any irritating substance* is applied to a part, the capillaries are seen to *diminish in size.* They, however, properly speaking, cannot be considered to contract. It is the arteries alone that contract; less blood then passing through the capillaries, the elasticity of the latter causes them momentarily to shrink. The capillaries do not, therefore, appear to exert any direct mechanical influence over the movement of the blood. It is probable that it is some increased tendency of the globules to adhere to each other & to the walls of the capillaries that causes the partial or total arrest of the circulation in inflamed parts, & also in the lungs during asphyxia.

It is in the capillaries that the blood comes in closest contact with the tissues, that those interchanges principally take place which ensue in the processes of nutrition & secretion.

Allantoid or Placental Fœtal Circulation.

(Taken from among the Tablets on Development.)*

The arterial blood returns from the placenta through the *umbilical vein,* which vein in the longitudinal fissure of the liver :—

A, gives off *a few small branches to* the lobus quadratus & the lobus Spigelii of the *liver,* and a few small branches and one large one to the left lobe (which latter large branch becomes after birth the left branch of the vena portæ) ;

B, *divides into two* terminal *branches,* of which

One, the larger, *joins* the upper part of the fœtal *portal vein* (which upper part subsequently becomes the right branch of the portal vein of the adult)—while

The other, the smaller, termed the ductus venosus, *joins* the *left hepatic vein* at the point of junction of the latter with the inferior vena cava.

All the blood from the umbilical vein passes therefore *into the inferior vena cava, either directly or indirectly.*

The blood passes from the inferior vena cava into the *right auricle* and is guided from thence by the Eustachian valve and the foramen ovale into the *left auricle,* from which latter cavity it descends into the *left ventricle.*

It is propelled by the left ventricle into the *arch of the aorta,* from whence it ascends almost entirely to the *head, neck, and upper extremities,* a very small quantity passing down the descending aorta to the remainder of the body.

From the head, neck, and upper extremities the blood *returns by the superior vena cava to the right auricle.*

This time it passes into the *right ventricle.*

From the right ventricle it is propelled into the *pulmonary artery.*—Very little blood goes to the lungs, which are almost impervious ; nearly all passes through the *ductus arteriosus* into the *descending aorta,* by which it is conveyed to the *trunk and lower extremities, a part returning to* the *placenta by* the *hypogastric arteries, and their continuation, the umbilical.*

In this course the arterial blood is several times admixed with venous blood, no part of the body, except a small portion of the liver receiving absolutely pure arterial blood ; thus :—

On entering the liver the principal current of arterial blood is mixed with the blood of the portal vein ;

On entering the inferior vena cava the mass of the arterial blood is mixed with the blood returning from the lower extremities ;

When traversing for the first time the right auricle, the arterial blood probably bears away with it a part of the blood returning to the heart by the superior vena cava.

It is this "*arterial*" *blood, three times admixed with venous blood,* relatively pure, however, that passes up *to the head, neck, and upper extremities,* hence the relatively greater development of these parts.—It is *only after* this blood has *circulated through the head, neck, and upper extremities that* it is returned to the heart, and is thence *directed, after having received but two slight additions of purer blood* in the right auricle and from the arch of the aorta, *towards* the *trunk and lower extremities ;* hence the lesser development of the latter.

At birth an *increased amount of blood passes* from the pulmonary artery *to the lungs;* as this blood *returns aerated* to the left auricle by the pulmonary veins, an *increased supply of pure blood is received by the left side of the heart ;* the *closure of the foramen ovale* soon *stops the arrival of the mixed blood,* which previously distended that cavity.—The *pure arterial blood* is soon propelled *equally into* the arteries of the *head, neck, and upper extremities and into the descending aorta,* for the closure of the ductus arteriosus stops the arrival into the latter vessel of the current of mixed blood from the right side of the heart, which current had hitherto impeded the descent towards the lower extremities of the blood propelled by the left ventricle. All the parts of the body then receive equally pure blood.—The placental circulation ceasing, *the umbilical arteries & veins and the ductus venosus* become obliterated and *transformed into fibrous cords,* the arteries remaining pervious, however, under the name of *superior vesical,* as far as the bladder, the upper part of which they supply.

---

* Vide among Tablets on Development "*First on Vitelline Circulation,*" and "*1st Tablet on Second Fœtal Circulation.*"

Mechanism of Respiration.

The air is alternately drawn into and expelled from the lungs by the two successive movements of *inspiration & expiration*, which movements are *separated* from each other *by a pause* or period of repose of the thorax.

Inspiration—Consists in the *dilatation of the thorax by muscular action*, and in the *consequent distention or inflation of the lungs*, by the air rushing in through the windpipe to fill up the threatened vacuum.

In inspiration, the *thorax* is *enlarged in each of its three diameters* :—

The *enlargement in the vertical direction* is always the *greatest*, especially in the young, and is due to the descent of the *diaphragm* during its contraction.

The enlargement in the two *horizontal diameters*, viz., the antero-posterior and the transverse, is *most marked at the lower part of the thorax* in the *male*, and at the *upper part* in the *female*, the difference constituting the two grand types of respiration, the *abdominal or inferior costal* and the *superior costal or pectoral*. It is *due* to the *elevation of the ribs and* consequent *elevation & projection forwards of the sternum*, and also to the *rotation of the ribs upwards round an axis passing through their anterior and posterior extremities* somewhat after the fashion in which the handle of a bucket is raised.

The principal inspiratory muscle is therefore the *diaphragm*.

The *auxiliary inspiratory muscles* are the muscles that raise the ribs.—They may be divided into *three groups*, which are respectively called into play: in ordinary tranquil breathing, in deep inspirations only, and in extreme emergencies only. These groups are :

1. The *external intercostals*, with perhaps the part of the internal intercostals, comprised between the cartilages of the ribs, and the levatores costarum. It was supposed at one time that the internal intercostals could not raise the ribs unless the uppermost rib were first fixed by the scaleni (and also that the internal intercostals could not depress the ribs unless the lower ones were maintained by the abdominal muscles), but this has been shown to be inaccurate both theoretically and by observations on living animals.

2. The *anterior & posterior scaleni*, the cervicalis ascendentes, the posterior superior serrati ; and also the *pectorales major & minor*, *serratus magnus*, latissimus dorsi, & *subclavius*, when the scapula & clavicle, and consequently the humerus, are fixed by the trapezius, sterno-mastoid, levator anguli scapulæ, & rhomboidei.

3. *Nearly all the muscles of the body* may assist *in violent inspiratory efforts* by removing from the thorax, and fixing at a distance, the points of origin of the foregoing muscles, and thus rendering their action more efficient : the head is thrown back and the arms are frequently uplifted in fits of dyspnœa.

Expiration—Consists in the *elastic recoil of the whole respiratory apparatus*, which recoil may be *aided*, either to a slight or to a considerable extent, *by the compression of the thorax by muscular action.*

The *ordinary expiratory muscles* are the *internal intercostals* (with the exception, perhaps, of their fore part comprised between the costal cartilages), to which may be added the infracostales, the triangularis sterni.

The *auxiliary muscles of expiration*, which are called into play in voluntary expiratory efforts, as in speaking, singing, blowing, etc., or in dyspnœa, are all the other muscles that depress the ribs, such as the *abdominal muscles*, external & internal oblique, transversales, recti, pyramidales, & quadrati lumborum, the *posterior inferior serrati*, the erectores spinæ, and, when the scapula is fixed, the *upper part of the serratus magnus*. *Nearly all the muscles of the body* may, however, assist in violent expiratory efforts.

Influence of the Nervous System over the Respiratory Movements.—Vide Physiology of the Medulla Oblongata & of the Pneumogastric Nerves.

The Act of Breathing

Is accomplished *from* 14 *to* 18 *times per minute* in the adult, a little more frequently in extreme old age, about three times as often immediately after birth. Breathing is accelerated, however, by exercise, stimulants, great altitudes, moderate cold; it is a little quicker in females generally and in persons of small stature. The normal *ratio* between the number of the *respirations* and that of the *beats of the heart* is about 1 *to* 4 *or* 5 *in adult age*, and 1 to 3 or $3\frac{1}{2}$ in childhood.

The complete respiratory act is divisible into three parts, *inspiration*, *expiration* & a period of repose or *pause*, the relative durations of which are respectively estimated by Dr. Burdon Sanderson to be *as* 4, 2, 9, the duration of the whole respiratory act being represented by 15. According to Dr. Sibson & Vierordt, however, inspiration is to expiration (pause included) as 10 to 14.

During *each respiratory act* an average of *from* 30 *to* 40 *cubic inches* of air (Ed. Smith) are *inspired and expired*. This volume of air is termed the **Breathing or tidal air.**

Complemental Air—Is the volume of air, about three or four times greater, or, on an average, *about* 120 *cubic inches* (Hutchinson), which can be *drawn into the lungs by a forcible inspiration.*

Reserve Air—Is the volume, on an average *from* 75 *to* 100 *cubic inches* (Hutchinson), which, though remaining in the lungs after an ordinary expiration, *may*, however, *be expelled by a* more *forcible effort.*

Residual Air—Is the volume, also, on an average, *from* 75 *to* 100 *cubic inches*, which still *remains in the lungs after the most violent expiratory effort.*

Comparing the amount of the breathing or tidal air with the total amount of the reserve air & the residual air, or, in other words, with the volume of air which usually remains in the lungs, it appears that *not more than* $\frac{1}{4}$ *or* $\frac{1}{5}$ of this volume can be *displaced during each respiration.* It is only, therefore, the contents of the trachea, bronchi, and larger bronchial tubes that are mechanically expelled and replaced by fresh air. It is the *diffusive power of the gases* themselves that causes the renewal of the air in the smaller bronchial tubes and air-cells: the oxygen, which is more abundant in the larger tubes, diffuses itself towards the smaller passages and air-cells; the carbonic acid, which is more abundant in the air-cells and in the smaller tubes, and also the watery vapour given off from the mucous membrane, diffuse themselves in the contrary direction, or towards the larger bronchi & the trachea, from whence alone they are removed mechanically.

The *volume of air* **which can** be *expelled* from the lungs *by the fullest expiration, preceded by the deepest inspiration* of which a man is capable, is the measure of the **Vital capacity** of the chest (Hutchinson). In the male adult of the average stature of five feet seven inches the vital capacity is *about* 230 *cubic inches*. The vital capacity diminishes or increases with the stature by about 8 cubic inches for every inch in stature between the heights of five & six feet. It increases up to the age of thirty-five and then diminishes. In the female it is hardly more than ½ what it is in the male.

It is not proportionate to the size of the chest, or to the general muscular power of the individual, and is greatly diminished in pregnancy, and in all abdominal diseases. The value of its admeasurement as a means of diagnosis of the earlier stages of phthisis has, therefore, been exaggerated. A diminution of 16 per cent. appears, however, to indicate a diseased condition of the lungs.

The *total volume of air which passes through the lungs of a male adult in twenty-four hours* is estimated by Dr. Ed. Smith at *from* 700,000 *to* 1,700,000 *cubic inches, or from* 400 *to* 1,000 *cubic feet*, the quantity varying according to the amount of muscular exercise taken. The average quantity of air breathed *per minute* by a male adult *at rest* is, according to the same author, 500 *cubic* ***inches*** *in the day-time* and 400 *during the night.*

The *greatest force with which, in a male adult, the air can be drawn into the lungs*, is capable *of elevating a column of mercury usually about* 2 *or* 3 *inches*, sometimes as much as 6 or **7**. When a column of mercury is elevated three inches, each square inch of the thoracic walls must support an atmospheric pressure of more than 23 oz.; adding to this pressure the elastic resistance of the thoracic walls, it is calculated that the *power then developed by the inspiratory muscles* must be *more than* 1,000 *lbs*.—The *force with which air can be expelled* from the chest is *about* 1-3*rd greater*, on account of the co-operation, during expiration, of the elasticity of the lungs and chest walls with the muscular effort. The power of the respiratory muscles is greatest in men of from 5 feet 7 inches to 5 feet 8 inches in height.

The *muscular force employed in ordinary inspiration* is calculated to be *about* 170 *lbs*. (Hutchinson.)

The entrance of the air into, and its exit from, the lungs produce the *respiratory sounds or murmurs*, which in health are of *two kinds:* the bronchial or tubular sounds, which are of a blowing character, and are best heard between the scapulæ and over the upper part of the sternum; and the vesicular murmur, which is heard as a gentle breeze all over the thorax.

The *rima glottidis* dilates in inspiration, as do also the *nostrils* when respiration is hurried.—The contraction of the bronchial tubes is believed to regulate, in accordance with the supply of blood, the quantity of air that the different parts of the lungs are to receive.

Changes of the Air in Respiration.

Expired air differs from inspired air in three respects :—

Its *temperature is raised;*
Its *degree of moisture is increased;*
Its *chemical composition is modified.*

Temperature.—Is *raised to nearly that of the blood,* especially in slow and tranquil breathing.

Degree of Moisture.—Expired air is *nearly saturated with watery vapour.*—The quantity of *water* thus *excreted* increases with the temperature of the atmosphere, and decreases as the atmospheric moisture increases; it *averages* 9 *or* 10 *oz. daily,* but may vary from 6 to 27 oz. Some of this water is probably formed in the respiratory process.

Chemical Composition.—Is modified by the *subtraction of oxygen* and by the *addition of carbonic acid, of a little nitrogen, and of various excretory principles.*—The *change is effected by* the process of *moist diffusion; the diffusion volumes of the oxygen and carbonic acid are, however, modified by the remarkable affinity of the blood for oxygen,* the former diffusion volume being increased and the latter diminished.

Oxygen.—5 *out of the* 21 *volumes of oxygen are abstracted from every* 100 *volumes of air. From* $\frac{1}{5}$ *to* $\frac{1}{7}$ of this amount *does not reappear in the carbonic acid expired,* but remains in the system where it combines with hydrogen to form water, and with the sulphur and phosphorus of the albuminoids to form the acids of the sulphates & phosphates excreted in the urine. The *amount of oxygen consumed daily varies inversely to that of the carbonic acid excreted,* and is inversely influenced by the same under-mentioned causes.

Carbonic Acid.—*About* 4 *volumes only are added to the* 79 *already contained in every* 100 *volumes of air;* there is therefore at each expiration a loss of 1 per cent. of the air inspired.

It is calculated that on an average 32,000 *cubic inches of carbonic acid, containing about* 8 *ounces of carbon, are given off daily* through the lungs by a strong male adult of the average size. These quantities of carbonic acid & carbon are subject, however, to *considerable variations* due to the following causes.

Age.—The quantity of carbonic acid excreted *increases up to* 30 years of age, is *stationary from* 30 *to* 40, *decreases in old age.*—It is largest in children proportionally to the weight of the body.

Sex.—In females the quantity of carbonic acid excreted is less after the eighth year; it remains *stationary during the whole period of menstruation,* increasing temporarily, however, if menstruation be arrested by pregnancy or by any other cause; it increases for a time when menstruation ceases, and diminishes again in old age.

MUSCULAR EXERCISE—*Increases the quantity of carbonic acid exhaled by* $\frac{1}{3}$ until an hour after the exercise has been relinquished (Vierordt); it *may increase it two, three, or fourfold* (E. Smith). The increase depends both on the increased amount of the air breathed, and on an increased per-centage of carbonic acid found in the expired air.—The quantity is diminished by prolonged exertion, occasioning fatigue.

ALIMENTATION.—The quantity is *increased by good living & after meals*, especially when much nitrogenous food has been taken, and is diminished by fasting.—Tea, coffee, cocoa, pure alcohol, produce a sudden increase; certain liquors, such as brandy, whisky, gin, appear, however, to produce the reverse effect (E. Smith).

TEMPERATURE & HYGROMETRIC STATE OF THE ATMOSPHERE.—The quantity is *greatest in winter* & in cold climates, and *in damp weather*.

TIME OF DAY.—The quantity *diminishes in the evening*, & is least at midnight; it *increases in the morning* until midday, when it appears to be as $1\frac{1}{4}$ to 1 when compared to what it is at midnight.

PURITY OF AIR RESPIRED.—The quantity *diminishes rapidly when the same volume of air is breathed over and over again*, the gaseous interchanges in the lungs entirely ceasing when the air contains 10 per cent. of carbonic acid, by which time it has lost about $\frac{1}{3}$ its normal quantity of oxygen.

RAPIDITY OF THE RESPIRATORY MOVEMENT.—In abnormally *hurried breathing* the quantity *increases absolutely*, but it *decreases relatively* to the amount of air respired.

Nitrogen.—A *minute quantity*, about $\frac{1}{50}$ or $\frac{1}{100}$ of the quantity of oxygen consumed, *appears to be given off* from the lungs. The source of this small excess of nitrogen was at one time believed to be the nitrogenous elements of the food & tissues, a part of which elements were supposed not to be excreted with the urea, uric acid, & extractives of the perspiration, urine, & other secretions, but to be retained in the body until completely consumed or broken up by the respiratory process into their simple or primitive constituents. All the nitrogen of the food now appears, however, to be accounted for in the excretions, so that this nitrogen might be derived simply from the atmospheric air which is swallowed with the saliva, the food, & the drink.

Various excretory principles.—Expired air contains, in minute proportions, *several of the principles met with in the secretions of the skin & kidneys*, such as chloride of sodium, uric acid, urates of soda & ammonia. It also contains a nitrogenous organic compound, very prone to putrefy, and sometimes carbonate & hydrochlorate of ammonia and carburetted hydrogen; various odorous substances may be derived from the food and drink that are consumed.

Changes of the Blood in Respiration

Are the changes in *colour & temperature,* and in the *proportions of the fibrin, & of the gases.*

Colour.—It has been shown by Hoppe-Seyler & Professor Stokes, by means of the spectrum analysis, that the change of colour, which takes place in the lungs, from the dark purple of venous blood to the bright scarlet of arterial blood, and the reverse change, which takes place in the capillaries, are *due* respectively to the *oxidation & deoxidation of the hæmoglobin or cruorin* :—Dilute solutions of blood when examined with the spectroscope give rise to two dark lines or absorption bands, situated in the green and yellow of the spectrum between the D and E lines of Frauenhöfer. When a reagent capable of abstracting oxygen, such as protosulphate of iron or protochloride of tin, is added, the solution becomes darker in colour, and the two dark lines disappear in the spectrum, and are replaced by a single broader band occupying an intermediate position between them. On exposing the deoxidised solution to the air it again brightens in colour, while, in the spectrum, the two first lines reappear; the alternate change may be repeated several times. The *hæmoglobin or cruorin* exists, therefore, *in two states of oxidation,* forming in the one case the "*purple hæmoglobin or cruorin,*" in the other the "*scarlet cruorin or oxy-hæmoglobin.*" *Arterial blood* contains *more of the scarlet cruorin* and *less of the purple* than venous blood; *both kinds of blood, however,* contain normally *more of the former than of the latter*, for they both give rise to the two dark lines in the spectrum.

Temperature.—The *blood in the left side of the heart* was long believed to be warmer by 1° or 2° than that in the right; it is now known to be *about $\frac{1}{5}$th of a degree cooler.*

The Fibrin—Is *increased in quantity* in arterial blood, which, therefore, yields a firmer clot than the venous. The normal proportion of fibrin may be doubled in rabbits by causing them to breathe pure oxygen.

The Gases.—*Venous blood* contains, according to Magnus, but $\frac{1}{2}$ *as much oxygen* as, and $\frac{1}{4}$ *or* $\frac{1}{5}$ *more carbonic acid* than, the arterial.

Asphyxia.—Death by Drowning.

Asphyxia.—The essential symptomatic characters of asphyxia are the *loss of muscular power and consciousness*, and the *cessation* of the *respiratory movements* & of the *pulsations of the heart*. Its essential pathological character is the *accumulation of dark blood in the right side of the heart and in the venous system generally*, which blood remains fluid for a long time.

The mode in which death occurs, though remaining essentially the same, differs slightly in the rapid and slower forms. In both cases the *first morbid process* is the *stagnation of the blood in the capillaries*.

In the *slower forms*, this stagnation *first* takes place in, or first shows itself *in*, the *systemic capillaries*. The *arteries and* the *left side of the heart* then become *distended*, and the *heart beats with greater power and frequency* to overcome the resistance.

In the *rapid form* the stagnation *first* takes place in, or first shows itself in, the *lungs*. The *heart* then *receives* but *little arterial blood* and soon *no arterial blood at all*.

Then, on the one hand, *the pulmonary artery*, the *right side of the heart* and the *venous system generally*, become *gorged with dark venous blood;* and on the other hand, the *nerve-centres*, the *muscular system* generally, and the *heart itself, no longer* receive their *due supply of arterial blood, and* they gradually *cease to perform their functions*.

Finally the *arteries, and* the *left side of the heart, empty themselves into* the *veins and* into the *right side*.

In cases of *recovery* from asphyxia *the process* just described *is reversed:* On the introduction of air into the lungs oxygen is once more absorbed and carbonic acid given off. The flow of blood through the capillaries of the lungs is then resumed under the influence of the pressure of the blood in the pulmonary artery and in the right side of the heart. Thus while the right side of the heart is unloaded and relieved the left side again receives its proper stimulus. The heart then resumes its action. The nerve-centres and the muscular system are restored. Respiratory efforts are now resumed, and consciousness and motor power reappear.

Drowning—Is *asphyxia with an additional obstacle to recovery*, viz., *the partial filling up of the air passages with water*, which obstacle prevents the reintroduction of air into the lungs when the body is brought to shore.—Animals *die much sooner from drowning than from simple apnœa*. In the experiments recently made by the Committee of the Royal Medico-Chirurgical Society it was found that the average duration of the respiratory efforts after simply plugging the trachea was about 4 minutes in dogs and 3 in rabbits, and that recovery might take place after deprivation of air for 3 minutes 50 seconds; immersion in water, however, for 1½ minutes was usually fatal.

Ordinary cases of *submersion in man are nearly always fatal after* 4 *or* 5 *minutes*, and *frequently after scarcely* 1 *minute*. *Recoveries have, however, taken place after* ¼ *of an hour*, and, it is said, even after ½ an hour; but in such cases it is probable that *syncope* took place upon falling into the water. Man would then be assimilated, with respect to drowning, to a hybernating mammal or to a cold-blooded animal, in both of which, the nutritive functions being less active, respiration may be suppressed without inconvenience for a considerable time; *complete intoxication* might produce the same effect. *Animals under the influence of chloroform*, and unable to make any violent inspiratory efforts, can resist submersion for a considerable time; so can, also, *newly born animals*, animals whose temperature has been lowered by several degrees, and animals in which the trachea has been plugged before they have been immersed.

Numerous experiments have been made with a view to ascertain the *best mode of treatment* in the case of drowned and asphyxiated persons: inflation of the lungs with hot air, oxygen, or ozone, injection of arterial blood, hot water, or vapour into the veins, galvanism, etc., may temporarily excite the action of the heart & of the respiratory muscles, but they all fail to restore life when the circulation through the lungs has been totally arrested. The *rules of the Royal Humane Society* very justly *recommend*, as the first means to be employed, the performance of *artificial respiration by Dr. Sylvester's method*, that is to say, by *alternately pressing the arms against the sides of the chest and then raising them gently above the head fifteen times per minute*, while the patient is lying on his back.

Effects of Overcrowding, and those of Breathing Impure Air

Are *twofold*, and are respectively due:

1. To the *insufficient aeration of the blood;*

2. To the consequent *imperfect oxidation, elimination*, and *destruction, and* to the, therefore, *inevitable accumulation, both in the blood and in the surrounding atmosphere, of the effete organic substances arising from the disintegration of the tissues of the body, and from the disintegration of the absorbed products of the alimentation.*

I. Effects of the insufficient Aeration of the Blood.—The *absorption of oxygen & the elimination of carbonic acid diminish considerably, and morbid symptoms begin to appear*, when the air, through being previously vitiated by respiration, is charged with carbonic acid even to the apparently slight extent of $\frac{1}{3}$ *per cent., or* 3 *parts in* 1,000 (Marshall). *When* the *air contains* 10 *per cent. of carbonic acid, in which case it has lost about* $\frac{1}{2}$ *its normal proportion of oxygen*, it becomes *totally irrespirable*, and is immediately fatal to man.—The Black Hole of Calcutta was a room 18 feet square, having two small windows, in which room, in 1756, 146 prisoners of war were confined during one night: by the next morning 123 of them had perished. A similar occurrence, in which 70 out of 150 passengers perished, took place in the Irish steamer Londonderry in 1848.

The *morbid symptoms* appear to be *due not only to the insufficient supply of oxygen, but* also *to the* directly *poisonous effects of carbonic acid;* animals cannot live in an artificial atmosphere of carbonic acid and oxygen, in which the latter is contained in the proportion of 21 parts per 100, as it is in atmospheric air. After one bronchus of a tortoise had been tied by Rolando, the animal continued, apparently without any inconvenience, to breathe with the lung of the opposite side; the animal soon died, however, when pure air was allowed to enter one lung, and carbonic acid the other.

It is not enough for the purposes of health & life that a room be supplied once for all with the quantity of pure air that its inhabitants can consume during the time they remain therein; for the diffusion through the mass of the air of the room of the carbonic acid expired and the general diminution in the proportion of oxygen which would take place, would very soon interfere with the due aeration of the blood. For the same reason, it is not enough either *that minute by minute there should be withdrawn from the air of a room and replaced by pure air, as many times as there are individuals in the room, the volume of from 400 to 500 cubic inches of air* that is respired by each individual minute by minute. From about 20 to 40 times such an amount of air, that is to say, *from 4 to 10 cubic feet of air per minute* (which latter amount would yield an atmosphere containing about 15 parts of carbonic acid in 10,000), are *needed for each person.* In hospitals double that quantity is required.—A certain amount of *breathing space* ought also to be allowed. The general practice in England up to a recent date was to allow *not less than* 800 *cubic feet* of breathing space for each person; but *in Hospitals* 1,200 *cubic feet*, at least, ought to be allowed (Marshall).

II. Effects of the imperfect oxidation, elimination, and destruction, and of the inevitable accumulation both in the blood and in the surrounding atmosphere, of the effete organic substances arising from the disintegration of the tissues of the body, & from the disintegration of the absorbed products of the alimentation.—

The *complete oxidation* of the effete products of organic disintegration transforms them into *carbonic acid, water, urea, uric acid,* and *other extractive matters,* which are all easily excreted through the lungs, skin, and kidneys. The *imperfect oxidation* of the above transforms them into those *numerous* but still imperfectly known *offensive products,* which Liebig compares to the soot or lamp-black of an ill-burning furnace or lamp.

These products *accumulate in the atmosphere of crowded cities, and, doubtless, also in the blood:* the proportion of animal matter in the air is in the town of Manchester 1 grain in 8,000 cubic inches, and on the hills above, 1 grain in 200,000 (Dr. Ang. Smith). Hence, in addition to a *depressing influence over the functions of the body generally,* that *peculiar liability to the zymotic diseases* under which labour the poor of our large towns, and also the unfortunate inmates of barracks, hospitals, workhouses, etc., where modern sanitary improvements have not yet been introduced.

Animal Heat.

The production of animal heat is a *universal function* throughout the entire animal kingdom, and animals have been divided according to their usual temperature into *warm-blooded*—mammalia & birds; and *cold-blooded*—fishes, amphibia, reptiles, and the invertebrata.

The *temperature of warm-blooded animals* is relatively *high*, and, though different in the various species, is very *nearly the same in each species under all normal conditions of life* it being almost independent, within the limits of the climateric variations, of the temperature of the surrounding medium.

The temperature of *cold-blooded* animals is relatively *low*, and *varies with*, and nearly to the same extent as, *that of the surrounding medium*, being, however, in all usual circumstances, higher than that of the medium by a certain number of degrees, which number is the same in all animals of the same species.

The second of the two correlative terms above used—"warm-blooded" & "cold-blooded"—is, therefore, in one sense incorrect. So is also, in another sense, the second of the two designations more recently proposed by Bergman, viz., "*animals of constant temperature*" & "*animals of variable temperature*;" for though the temperature of the latter varies absolutely, its surplus over and above that of the surrounding medium, which surplus is due to individual production of heat, is relatively invariable. The two correlative terms the Author would propose are those of "*Animals of high & completely individual temperature*" and "*Animals of incompletely individual & usually low temperature.*"

Average Animal Temperatures.

Temperature of Warm-blooded Animals, or Animals of Constant Temperature, or of High & Completely Individual Temperature.

Birds .. .. 100° to 108°, or even 111° in the small species;
Mammalia 97° to 104°.

Surplus of Temperature over & above that of the surrounding medium in Cold-blooded Animals, or Animals of Variable Temperature, or of Incompletely Individual & usually Low Temperature.

Reptiles .. 7° to 15°;
Amphibia .. ½° to 1½° in summer, and 2° to 3° in winter;
Fishes usually ½° to 1°, sometimes 2° to 3°, in the tunny & bonito, 18°.

Average Temperature of the Different Parts of the Human Body.

Average Temperature of the Blood, 100° to 102°.—In the peripheral parts of the body the *blood in the veins* is *cooler* than that in the arteries by 1° *in the deep veins, by several* degrees *in* the *superficial ones;* in the deep or central parts of the body the difference is usually but slight. The blood in the *renal veins* is, however, considerably warmer than that in the renal arteries, and the blood in the *hepatic veins* is not only *warmer* than that in the portal vein, but it is warmer by 1° th an that in the aorta (Bernard); the blood in the *right side of the heart* is 1.5*th*° *warmer* than that in the left.

Average Temperature of the Organs & Tissues, 98° to 100°. It is always lower than that of the blood, and varies according to vascularity, distance from central parts, proximity to surface, and degree of exposure:

Temperature of the Abdomen (taken in the bladder) 102°;

Thorax	Rather lower on account of the heat lost by expired air.
Rectum	100°;
Mouth (under the tongue) ...	98°;
Axilla	96°;
Hands & feet	90°.

Conditions which modify the temperature of the Body.

The temperature of the body is, within very narrow limits however,
Elevated by external heat, exercise & good living;
Depressed by cold, inaction, & bad fare;
Variously influenced by time of day, age, sex, & disease.

External temperature.—The *extreme climateric variations,* though they range from $-70°$ in the arctic to $+130°$ in the tropical regions, *do not influence the temperature of man to the extent of more than* 3° *or* 4°, provided he have, on the one hand, command over food & raiment, and provided he can, on the other hand, protect himself against the direct rays of the sun. This stability of the bodily temperature is *due,* in the one case, *to* the *power of producing a greater amount of heat* by an increased activity of the respiratory functions, and by a greater consumption of calorifacient food, and, in the other, to the *loss of a great amount of heat by the continual evaporation of the profuse perspiration,* with which, in hot climates, the skin is constantly moistened. All warm-blooded animals also possess, but to a less and variable extent, the power of maintaining their normal temperature in very different latitudes and under great variations of external temperature.

This *power of maintaining a uniform temperature has, however, its limits,* and the experiments of Magendie & others have shown that *animals die rapidly when submitted to degrees of heat or cold capable of raising their temperature about* 9° *or* 10°, *or of lowering it about* 20°.—Large bodies of troops, and even whole armies have thus been "frozen to death," especially when overcome by fatigue, or when ill-fed, ill-clad & ill-protected.—The *contact of excessively hot dry air can* however *be borne* by man *for short periods:* Sir Ch. Blagden & others have supported for a few minutes temperatures of 198°, 211°, 260°, 284°, and a man named Chabert has penetrated into ovens heated to from 400° to 600°; when however the air is moist, so as to prevent evaporation from the surface of the skin, a temperature of 120° very soon becomes unbearable.

Exercise.—Prolonged muscular action elevates by one or two degrees the temperature of the contracting muscle. Exercise, however, *elevates* but *slightly* the *general temperature of the body,* but it may by quickening the circulation, raise by several degrees, the lowered temperature of the extremities.—Inaction produces the contrary effect, and *during sleep* the *temperature falls* 1° *or* 2°.

Food.—*Good living keeps up a high bodily temperature,* but the immediate effect of a full meal is to lower the temperature a little.—Stimulants produce a slight immediate rise in the temperature.—*Bad fare depresses the temperature,* and diminishes the power of resisting cold.

Time of Day.—The *temperature* is *highest in the morning,* varies slightly during the day, falls in the evening, and is *lowest towards midnight.*

Age—*Modifies the temperature but slightly;* the temperature of children is, however, about 1° higher, and that of the aged a trifle lower, than that of the adult. But the power of the very young and of the aged to resist the action of cold is much less than that of the adult.

Sex.—Its *influence* is *very trifling* indeed, and it has frequently been denied. It is believed, however, that the average temperature of the female is a trifle lower than that of the male.

Disease—Influences the temperature of the body more than any other cause; the *temperature rises* considerably *in* all *febrile affections,* and often reaches 106° or 107° in scarlatina & typhus, & sometimes 111°. It is *depressed in* cases of *syncope & apparent death,* in the *morbus cæruleus* or blue disease, and in *cholera,* in the stage of collapse of which latter disease it is often lowered to 77° or 79°

The Source of Animal Heat.

The French chemist Lavoisier, the discoverer of the composition of air, propounded the first scientific theory of the production of animal heat, which is the chemical theory now universally received.

Before Lavoisier, the production of animal heat was referred to the various movements which take place in the body & to the consequent *stretchings & recoilings of the several tissues*, to *friction* generally, and in particular to the friction of the blood against the walls of the blood-vessels, and to *the influence of the nervous system & of the so-called vital force.*

The theory of Lavoisier, though received in its main traits, must however be corrected or supplemented in two points: the union of oxygen with carbon & hydrogen does not take place solely, or even principally, in the lungs; and the nervous system, though its action cannot now be considered as the primary source of animal heat, governs the chemical changes upon which the production of animal heat depends, and thus modifies the production of heat both locally and generally.

The chemical theory of animal heat, as it now stands, is that the *oxygen taken into the blood at the lungs combines in the circulatory system, and more particularly in the capillaries, with the carbon and hydrogen, and* also with the small amount of *sulphur and phosphorous*, both *of* the *disintegrated tissues &* of those *elements of the food*, termed calorifacient, which are not, or which are but partially, transformed into tissue; and that such combination, or combustion, is the real & true source of the heat of the body.

That such combination does take place appears evident from the facts that an *average-sized* male *adult absorbs daily about* 40,000 *cubic inches of oxygen*, and *excretes* in the same time by his lungs, skin, & kidneys, *about* 32,000 *cubic inches of carbonic acid gas & from* 75 *to* 95 *ounces of water, of the disposal of which oxygen, and of the origin of which carbonic acid & of no less than* 3 *or* 4 *ounces of which water, no account can be given, if it be not admitted that such combination takes place*, and that the above-mentioned quantity of carbonic acid & the three or four surplus ounces of water are the products thereof.

That such combination, or respiratory combustion, as it is now termed, is the source of animal heat is rendered more than probable by the fact that the *direct combination with the above-mentioned quantity of oxygen, of the quantities of carbon & hydrogen necessary to produce the above-mentioned quantity of carbonic acid & the above-mentioned surplus of water would give off very nearly the quantity of heat generated in the body in* 24 *hours*;—and by the fact that the whole amount of caloric generated in the body can be accounted for by taking into consideration the *heat evolved by the combustion of the sulphur and phosphorus* (to which combustion is due a part of the acids of the sulphates and phosphates excreted in the urine) and *a few* other secretions, and also by taking into consideration the fact that more heat is produced by the combustion of certain alimentary compounds than would be produced by the separate combustion of their component parts.

The experiments, upon the results of which the above assertions are based, were begun by Lavoisier by means of his ice calorimeter, continued by Dulong & Despretz, and completed by the experiments of Liebig and by those of Fabre & Silbermann upon the combustion heats of carbon & hydrogen.—Lavoisier overlooked the combustion of hydrogen, taking into account the combustion of carbon only; he thus explained the production of but $\frac{4}{6}$th, of the heat evolved in the body.—Dulong & Despretz took into account the combustion of both carbon & hydrogen, but they underestimated the combustion-heats of carbon and hydrogen; they thus explained the production of $\frac{8}{10}$ths or $\frac{9}{10}$ths of the heat evolved in the body. Liebig arrived at the above-mentioned results by repeating the experiments of Dulong & Despretz, and by using in his calculations the more accurate numbers given by Fabre & Silbermann to represent the combustion heats of carbon & hydrogen.

Collateral evidence in support of the chemical theory of animal heat *is derived from the observation of the different physiological habits & corresponding average temperatures both of animals & of man, thus :*

1. The *division of the animal kingdom into warm and cold-blooded animals*, or into animals of constant & animals of variable temperature, corresponds to the relative activity or inactivity of the nutritive & respiratory functions, and to the amount, relatively great in the one case, very small in the other, of carbonic acid given off through the respiratory organs;

2. The *mean temperature of the different classes of warm-blooded animals, and* the *mean surplus of temperature over & above the temperature of the surrounding medium observable in cold blooded animals,* correspond likewise to the greater or less activity of the above mentioned functions : the temperature of birds is higher than that of the mammalia; that of reptiles is higher, under similar climateric conditions, than that of the amphibia, the temperature of which latter is higher than that of fishes & and of the invertebrata;

3. In warm-blooded animals the production of heat, and the activity of the nutritive & respiratory functions, are similarly affected by the various conditions of *age, sex, alimentation, muscular activity, external temperature or season, time of day & purity of inspired air,* both being increased to a maximum in young well fed, active males, during cold & dry days & seasons and in open air, and both being reduced to a minimum by the contrary conditions and during sleep and hibernation;

4. The *temperature of any one part of one of the higher animal organisms*, and the temperature of the blood in the same, is greatly dependent upon the activity of the chemical processes of which such part is the seat : the highest temperature observable in the mammalia occurs in the liver and in the hepatic veins.

Influence of the Nervous System over the production of Animal Heat.

The influence of the nervous system over the production of animal heat has been *greatly exaggerated.*

Though in abnormal states of nervous excitement, heat may perhaps be evolved in the nervous substance itself, owing to the rapid metamorphoses to which the latter is liable, and though some eminent authorities still hold that heat may occasionally be produced by some transformation of the ordinary nervous action into a heat-producing process, it nevertheless appears to be more than probable that the action of the nervous system with regard to the production of heat is reduced under ordinary circumstances to the *governing influence* it exerts *over the action of the heart, and over the arterial circulation by vaso-motor reflex action, and to its consequent indirect influence over the chemical processes of nutrition.*

That the *vaso motor nerves of the sympathetic system govern the arterial circulation and,* among other processes, the *heat-producing process,* is superabundantly proved by the results of the *division of the cord of the sympathetic in the neck, or* those of the *removal of the superior cervical ganglion:* the corresponding side of the face then becomes greatly congested, and its temperature rises by several degrees; irritation of the peripheral portion of the sympathetic causes the part to resume its normal appearance & temperature (Bernard).

That *such influence is exerted by reflex action,* and also that such reflex action has an especial bilateral character, is proved by the following facts—viz., when a *freezing mixture* is *applied to the ulnar nerve at the elbow,* the temperature of the two inner fingers, which momentarily falls, subsequently rises by several degrees; *if one hand, or the extremity of the wing of a bat, be immersed in the same mixture,* the temperature of the other hand, or of the corresponding point of the other wing, will be lowered at the same time as that of the immersed part, no change of temperature taking place elsewhere (Brown-Sequard).

The *temperature of a limb falls* therefore *after the division of its nerves, or of the posterior roots of the same,* on account, probably, of the then suppressed centripetal conveyance of the sensory impressions by which dilatation of the arteries is called for: paralysed limbs are known to be cold.

Division of the nerves of a limb close to their exit from the intervertebral foramina produces, however, the *contrary effect,* on account of the simultaneous division of the sympathetic fibres, which have just joined the nerve from the neighbouring ganglion (Bernard).

The administration of *narcotics, shock, severe injury to the nerve-centres,* occasion a *general fall of the temperature of the body* on account of the above sensory impressions being no longer perceived by the nerve-centres & on account of their being no longer reflected upon the vaso-motor nerves.—*Severe injury to, or division of, the spinal cord* appears *however* to produce a *temporary elevation of the temperature of the parts below;* so does also the section of the anterior roots of the spinal nerves (Bernard).