

**On the necessity for contracting cavities between the venous trunks and the ventricles of the heart : on the use of venous sinuses in the head, on the wonderful provision made for the transition from the foetal to the breathing state, on palpitation, on death, and on life, with reflections on the treatment of animals / by John Walker.**

### **Contributors**

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Richard Thillioe 1800

ON THE

From Dr Walker.

NECESSITY for CONTRACTING CAVITIES 2

Between the VENOUS TRUNKS and the  
VENTRICLES of the HEART ;

ON THE  
USE OF VENOUS SINUSES IN THE HEAD ;

*On the Wonderful Provision made for the Transition*

from the

FOETAL TO THE BREATHING STATE ;

ON PALPITATION ; ON DEATH ; AND ON LIFE :

With

REFLECTIONS on the TREATMENT of ANIMALS.

BY JOHN WALKER.

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OMNIA enim quae quidem inclusa sunt ita nata atque ita locata sunt, ut nihil eorum supervacaneum sit, nihil ad vitam retinendam non necessarium ---doceat ergo aliquis potuisse melius : sed nemo nunquam docebit et si quis corrigere aliquid volet, aut deterius faciat, aut id quod fieri non potest, desiderabit.

Marc. Tul. Cicero

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HARVEY, LONDON.

1799.

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*A la SOCIÉTÉ de MÉDECINE de PARIS, à la SOCIÉTÉ MÉDICALE d'ÉMULATION, et au LYCÉE des ARTS de PARIS.*

**J**E ne voudrois pas en quelque manier livrer à l'oubli et à l'inutilité entier ce petit écrit que j'avois mis en Latin afin qu'il me servit de Dissertation inaugurale, mais que je ne fis pas imprimer à Leyde, faut de temps ; ainsi, je vous le présente, dans une langue moderne, qui n'est pas inconnue à plusieurs de vous. Il me fournira en même tems le moyens de vous transmettre quelques observations qui ont rapport au sentiment plutôt qu'à la physiologie.

Qu'il est agreable ! qu'il est consolant ! de voir  
“ que la veritable science ne connoit point d'en-  
“ nemis.” — Ma reception comme membre de vos Sociétés dans un temps ou le Gouvernement du país on vous tenez vos assemblées, et celui du país qui m'a vu naître cherchoient à se detruire mutuellement, en est une preuve trop grande et trop genereuse, pour la passer sous silence.

Helas qu'il est triste de voir les disputes politiques renvoyées à un tribunal que la philosophie disavoue, et que le droit ne se decide que par la force ! Quand cessera 't on enfin de repandre le sang humain, et de terminer leur differents autrement que la bete feroce !

Je vous presente ce coup d'essai avec cet espoir qu'il renferme quelques idées neuves ; il se peut pourtant que cet espoir n'est fonde que sur mon ignorance des ouvrages qui ont traité de ce sujet.

Quoiqu'il en soit de son merite j'espere que vous voudrez le recevoir au moins comme un foible témoignage de ma reconnoissance.

J. W.

*A Rotterdam, 14 Thermidor, an 7.*



TO THE  
ROYAL MEDICAL SOCIETY  
OF EDINBURGH.

WERE I to omit here the acknowledgment of your favour in voting the reading of this paper in your meeting, and appointing an extraordinary meeting for its further discussion, the omission might give an appearance of apathy on my part, which does not belong to me. I felt extremely sensible of your generous kindness to me at the time; and, if the remembrance of it be like to carry to my heart a soft, insinuating, flattering, gratification, I know, at the same time, that there are better feelings to be excited by it than those narrow ones founded only on self-love. If I look at your conduct aright, I may taste the pleasures and derive the profit which arise from the contemplation of the acts of liberal minds.

The first ideas, on the subject of this paper, arose, during a conversation in Holland on commercial affairs, in which, not feeling interested, I was led into a train of thinking on the motion of the heart and arteries, then moderately quickened by temperate draughts of wine.

It was written under circumstances which forbade my informing myself of most of what had been already written on the subject; and I was so ignorant, as to imagine that the idea which occurred to me on the most obvious use of alternating cavities at the heart was quite new.



Of the few books within my reach, at the time, Cheselden's Anatomy was useful to me on my commencement; and before I had completed it, I had an opportunity of consulting Blumenbach's Physiology. I also derived some information from the *Ontleedkunde van Plenk door Gescher*, from Gregory's *Conspēctus*, and from a few odd numbers of the *Monthly Review*, of which I do not now remember the dates.

If I have not availed myself of the criticisms made in your society, to the improvement of this paper, it is because I wished to give it in its original form, in order to afford to my particular friends the satisfaction of seeing, a little, what were my labours before graduating, and to secure from others the indulgence always due to an Inaugural Essay.

J. W.

Edinburgh, 21. xii. 1799.



The object in printing this Essay in different sized letters, was to make the parts of inferior importance, or of tedious detail, retire as it were from the eye under a small character, that the reader might the more easily connect the leading ideas, which are attempted to be exhibited, under a larger letter.

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There is an obscurity in the last paragraph of page 22. I suspect the accuracy of that reasoning, whereby I formed the conclusions therein contained, and propose the following change.

*For the tendency of the blood, &c. read,*

The resistance made to the blood's passing through the *foramen ovale* continually increasing from the first unfolding of the lungs, is effective from the moment of the closing of the *ductus arteriosus*. At this time the force of the right ventricle, employed previously to birth, upon the placental and greater systems, as well as upon the pulmonary one, being wholly spent upon the last, is competent to charge fully the left sinus—the *foramen ovale* is soon completely stopt, and the circulation, suited to the being of a breathing animal, is fully established.



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## I. ON THE MOTIONS OF THE HEART UNDISTURBED.

**I**N what way can we account for the tranquillity of the thorax, while the heart is in health and undisturbed, although the motions of this organ are vigorous and unceasing within it?

1. *a.* While every muscle, which is exercised only in obedience to the will, presently flags and tires, how wonderful, how astonishing, are the energies of the heart, which, whether we sleep or are awake, and even when by apoplexy the animal powers are suspended, unremittingly labours, or rather acts, and never becomes sensible of fatigue through all the changes of life!

*b.* For, however harrassing may be the anxiety produced by its obstructions, or morbid actions, it perhaps is not, itself, the seat of the sensation, at least the muscular part of it, which is not furnished with distinct nerve, but only with medullary pulp, a diffusion, however subtle, of nervous substance being perhaps always necessary to irritability throughout the whole of organised creation.—But I am wandering from the question.

How comes it, that while such vigorous action is carried on by this ever moving muscle, a corresponding appearance of motion or agitation is not produced on the thorax?

2. *a.* At the moment of my writing this, I touch faintly a branch of the temporal artery, and feel distinctly what is going on: I throw one leg over the knee of the other as I sit, and distinctly see the effects of the action of the heart and arteries, in the vibrations of my pendent foot over the floor;

*b.* While I find it impossible whether sitting, standing up, or lying down; wherever I apply my hand, and with whatever degree of pressure, to feel the least sensation of the motion of the heart.



3. *a. a.* Till running several times up and down stairs, the pulse rises to 148 strokes in a minute, and I distinctly feel, and imagine I also see on the thorax, the effect of the tumult raised within,

*b. a.* Exclusively of that of the anhelation under which I labour from the experiment.

*a. b.* The velocity of the pulse, it may well be conceived, was but of momentary duration; while the exercise which produced it was sufficiently violent to give me a head-ach during the whole day.

*b. b.* The cause of the anhelation is not the business of this paper; yet it may be briefly observed, that the necessity of quickened respiration may appear obvious, from the consideration, that whatever changes the blood have to undergo from the inspired air, if by any means it be made to pass quicker through the lungs, the air must be afforded proportionally quicker, the blood being in the same state as when it's motions were slower;

*b. c.* And as on such occasions the motions of the heart and arteries must become quicker or stronger, hereby producing distension of vessels and increased action in different parts, or acceleration of the natural functions,

*b. d.* Causing sensible heat, and expansion of the circulating fluid at the same time,

*b. e.* It seems not difficult to conceive, that this must need the renovating effects from respiration proportionally sooner, as the actions in the general system have been accelerated.

### *Necessity for an even number of alternating cavities.*

It hath been an axiom with Physicians, that nature abhors a vacuum.

That law in creation which gave rise to the axiom might as well be defined, A disposition in matter to unite itself closely, leaving the immensity of surrounding space to become void, the vacuum being only guarded against by motion being instituted, as far as we can observe, throughout the whole universe.

4. That law renders an alternation of motion in cavities necessary at the heart, which is the organ that gives the impetus which principally effects the circulation of the blood.

4 *a.* The motions of the ventricles of the heart being synchronous, if this vital organ (I mean here the heart as composed of two ventricles) were without appended contracting cavities, on the ventricles contracting and thus suddenly diminishing



its volume, the parts surrounding it would have as suddenly to close over it, to prevent a vacuum, and then to retire in yielding to its enlargement.

Each ventricle of the heart having at its entrance an auricle, which with the adjoining sinus forms one continued cavity---this whole auricular appendage of the ventricle or sinuous termination of the veins has been termed the atrium. It has also been distinguished by the general term sinus, which latter name is here adopted.

*b.* The sinuses enlarging during the systole of the ventricles, and contracting during their diastole, the hurtful agitation is prevented which would have arisen from a heart constructed with ventricles only :

Moreover, the heart being surrounded by the lungs, whose substance, or rather structure, is the most yielding of any solid in the body, cannot, when its actions become inordinate, produce so hurtful an agitation in the region which it occupies as it would have done had it been placed in any other part of the body.

*5. a.* Amphibia and fishes, different from mammalia and birds, are said to have only one ventricle and one auricle for the circulation of their comparatively cold blood ;

*b.* But the heart of some of the amphibia seems to be so constructed as to act as a single heart, when the animal is under water, though in the air it may be capable of effecting the long circulation.

"In a water tortoise, (says Cheselden in his Anatomy of the human body, book iv. near the end of chap. iii.) which I had an opportunity of examining with that most dexterous and indefatigable anatomist Dr Douglass, I found the two ventricles of the heart but half divided by a septum, and in the beginning of the pulmonary artery, several strong muscular rings, a little distant from each other, each of which, by contracting, would be capable of resisting a part of that blood, which otherwise would have been thrown into the lungs, when they were under water ; and this blood so obstructed must necessarily be thrown into the aorta, the two ventricles being in a manner one common cavity ; and when they are out of the water, this communication of ventricles will suffer but little confusion of the blood which flows into the ventricles, because each ventricle receiving and discharging the same quantity of blood, at the same time. they will balance each other, and thereby such a mixture will be very much prevented."

*c.* Insects and worms, which have not blood, but only a serous fluid circulating through their bodies, having only one ventricle, and no auricle or sinus, may seem to contradict the notion of the necessity of alternating cavities at the heart.

But it is easy to conceive that this enlargement of seriferous canal, by an undulating succession of enlargement and contraction, or by its peristaltic motion, may be com-



petent to effect the languid circulation necessary to their dull life: in which case, as we do not see one distinct contractile sack acting simultaneously throughout its whole length; so, neither does it appear necessary, that there should be a second contracting cavity to constitute evenness of number between vein and artery, as in warm blooded animals, where the circulation is rapid, and the contractions of cavity strong and distinct.

6. *a.* Would the agitation, which the ventricles may tend to produce, be still more effectually prevented, if there were another pair of contractile sacks between the veins and the ventricles? Perfectly the reverse, I believe. A second pair would produce the agitation which one pair (the sinuses) prevents, and would require a third pair to restore the equilibrium or tranquillity.

*b.* Thus then it appears to me, that the whole number of contracting sacks of the heart (ventricles and their appended cavities included here in the term heart) between vein and artery, as between the *cavæ* and pulmonary artery, and as between pulmonary veins and *aorta*;

*c.* Or, at least, between *cavæ* and *aorta*, must be even, in order that the motions may be performed without too much agitation.

*d.* It is almost unnecessary to observe, that the cavities here mentioned, suppositious or real, are considered as each transmitting the whole stream of blood. Analogous cavities on the venous trunks would require to be as numerous as the trunks. Thus, on the four pulmonary venous trunks, four sinuses, one on each, would only be equivalent to the sinus at the left ventricle, the one capacious cavity at their termination. As such equivalent cavities cannot be termed one cavity, they may be called, collectively, one set of cavities. Their motions are all synchronous, and are all combined to produce one effect.

7. *a.* If on the one hand the large veins near the heart possess muscular powers (as their structure seems to indicate) and perform a sort of contractions (as the more than natural venous pulse, observable in the upper *cava*, if at any time the blood be impeded in its passage into the lungs, seems to prove) while the sinuses are dilating, and thus seem to disprove the necessity of an *even* number of contracting sacks between vein and artery,—on the other, the contractions of the large arteries, alternating with such



venous contractions, may be considered as supplying the place of the *third* pair already mentioned. (6. a.)

b. Thus then while there is an *even* number of distinct contractile sacks (sinus and ventricle) between the largest veins and arteries, these themselves near the heart participating of the nature, or exercising in a certain degree, the functions of the contractile sacks may be considered as keeping up the necessary *evenness* in number of alternately contracting cavities, or sets of cavities, (6 c. d.) between the more multiplied and extended branches of the venous and arterial systems: (10, b. c. d.) and

8. a. While by yielding to dilation, and having consequently succeeding contractions, they diffuse throughout the system, the effects of the grand impetus at the heart, (the arteries progressively and with considerable force, the veins retrogressively, with small and scarcely sensible effect, and only to a small distance. (7 a.)

b. Do not the faint contractions of large veins, with the nearly synchronous ones of the ventricles, while all is tranquil, make a whole effect of contraction nearly equal to that of the sinuses (which is much feebler than that of the ventricles) together with that of the large arteries (which must be much stronger than what takes place on the venous side of the sinuses) and thus more effectually prevent agitation. (10. b. c. d.)

### *Effect of alternating cavities on arteries and veins.*

9. a. WHATEVER advantage is produced by the mechanism of alternating cavities, about the region of the heart, must also be felt more or less, nearly throughout the whole system; for, the instant when the large arteries swell is also the time when the sinuses by enlarging begin to diminish the volume of the large venous trunks, (7. a.) and thus make room for the swell of the arteries. (10. c.)

b. The arteries also in their swell as propelled



to the remote branches, seem by lateral pressure, on their accompanying veins, even in parts remote from the heart, to forward or accelerate their contained fluid, in its progress to this organ.

c. I am sensible that the flow of the arterial wave is exactly in a contrary direction to the venous current; but the *vis a tergo*, and opposing valves, forbidding a retrograde course of this, it must be forwarded to the heart where alone the veins are discharged. Besides, when lateral pressure is made by the pulsation of an artery on its accompanying veins, its contraction immediately following its undulatory swell, gives space for the venous current.

d. If there were not an alternation in the motions of the cavities at the heart in effecting the circulation of the blood; if the number of the cavities were not *even*, the agitation most strongly marked on the thorax, would be felt and even seen throughout the whole body. (4. 5. 6. 7. 8.)

e. (4. 5. 6.) The chest, which now swells and contracts in a manner evident to the view during the most easy respiration, would then, instead of exhibiting those free and gentle motions, which distil comfort to the sympathetic observer, so silently indeed that he scarcely marks it, but which he finds to have been present, when uneasy sensations are awaked in him; as by the presence of a person labouring under difficult respiration, or when contemplating on a dead body, and forgetting for a moment that it is inanimate, he is astonished that it does not respire, and feels a transient and evanescent horror, as if his own lungs were about to stop—the chest would be shaken in all its movements, the breast would quiver under inspiration, and the breath only escape in jerks.

f. (4. 5. 6. 7. 8.) Every systole of the heart would produce a turgidity in every member, and every diastole a diminution of volume. The existence of delicately sensible organs as of the eye and ear, is incompatible with such a structure; a firmer compages of vessels than that of the human body could not long sustain it.

h. In considering the compound motions of the heart and its appendages, is there not a fitness in associating the alternations of sack with sack and of tube with tube, rather than these of sack with tube or of tube with sack? for although the more sudden dilatation of arterial trunks may seem, better than that of the sinuses, to correspond with the systole of the ventricles in point of time, the case must be otherwise in point of space: for the immediate effects of the motions of the sinuses and ventricles must be local, while those of the arteries must be comparatively extended and diffused, promoting in their great trunks the alternations of the corresponding



venous trunks, and aiding, as already observed, the venous currents throughout their whole lengths.

*Advantage of the presence of sinuses.*

10: *a.* BUT if the motions of the ventricles had been alternate instead of synchronous, might not sinuses have been dispensed with, and would not the structure have been more simple, a quality of all the most excellent (in every organization where nothing is superfluous)—in every machine?

*b.* As the contractions and dilatations of the sinuses are not quite equal to those of the ventricles (these being furnished with valves, which in preventing the retrogression of the blood, during the contraction of the ventricles, may be said to prevent also its ingress from the sinuses at the same time; while the sinuses, even during contraction, as well as at the time of dilatation, remain open at their mouths for the admission of blood from the veins) so an advantage arises from the real structure of the heart which it could not have possessed from the more simple formation now proposed.

*c.* The larger arteries swell while the ventricles contract, sooner than the large veins contract, notwithstanding the continual openness of the sinuses, and more fully also because of this disposition in the sinuses.

*d.* It is therefore convenient that the sinuses do not become so much augmented in bulk as the ventricles are diminished by their contractions, in order that the equilibrium may be kept up between the simultaneous dilatations and contractions of different cavities. (8. *b.*)

*e.* It may be observed that the corresponding contractions and dilatations of the different cavities are not perfectly synchronous or of the same duration; for the contractions of the ventricles and dilatations of the large arteries are earlier and quicker also (13 *a.*) than the corresponding dilatations of the sinuses and contractions of the large veins:

*f.* But, from the circumstance of the ventricles and large arteries alternating in their motions, as do the large veins



and sinuses; or, from the association of venous trunks with ventricles, and of the sinuses with large arteries in their motions, the whole effect of contraction, in point of time as well as of space, in the contracting vessels during their systole seems balanced with that of the diastole of those which are dilated at the same time. (8. b. 10. b. c. d.)

In other words, is not the greater suddenness of contraction of the ventricles, than of dilatation of the sinuses, ballanced or compensated by the more sudden dilatation of arteries than of contraction of venous trunks?

g. And, equality of effect, in point of time as well as of space, or of motion as well as of quantity, must be necessary to prevent hurtful agitation.

h. Besides, the speedy contraction of ventricles when the arteries, as it were, swallow their contents, clears the way, if I may so express it, for the current from the inert veins and even comparatively feeble sinuses; and the speedy dilatation of arteries affords lateral pressure on the veins to quicken the said current through them. (13. a. 9. b.)

i. There may be other advantages also from the presence of sinuses, of which farther on.

### *Necessity for the presence of sinuses.*

11. If the heart had been formed without sinuses and the motions of the ventricles had been alternate instead of synchronous, the advantage already mentioned arising from the simultaneous filling and emptying of different cavities of the heart (4. 6.) and from the swelling of arteries simultaneously with the yielding of veins would have followed very effectually. (9. b.)

12. a. But the blood must have accumulated inordinately, by its sudden and total interruption at the entrance of each cavity, absolutely closed up by valves during each contraction, and a pulsation been felt in the large veins retrograding with violence.



*b.* This could not long have continued so--- The last portion of vein near the heart must have dilated, and acquired the contractile power, and performed the functions of the sinuses, *receiving while they discharge.* (10. *b.*)

*c.* By this disposition in the sinuses the necessity of larger cavities is superceded;

*d.* And by this also the shock from the impetus of the heart seems to be guarded against in the venous system, which otherwise might have pulsed strongly, even to some of the smaller branches, though in a retrograde direction.

13. *a.* The speedy contraction too of the ventricles (the systole employing about one-third of the time of the pulse of the whole heart, which might seem to agree with the observation, that the interval of the contraction of muscular fibres, after a relaxation, and before a new one takes place, is greater in strong than in weak subjects; but, that the contraction is performed with greater velocity; for the ventricles are certainly stronger subjects than the sinuses; but then the venous trunks act synchronously with the ventricles; while the arteries synchronise with the sinuses.)

The speedy contraction of the ventricles seems to contribute to prevent retrograde pulsation in the veins, by causing a shorter interruption of the current of the venous stream.

*b.* More particularly, if blood passes during diastole into the pulmonary artery, (23. *c.*)

*c.* While on the left side (21. *b.*) of the heart, where this does not happen, the largeness of the sinus, and the influx of the blood into it in four streams, seem adapted to prevent, at the same time, the reaction of the blood, from strong contractions of the left ventricle.

*d.* The pulmonary veins are of less capacity than those of the greater system,

With this view, perhaps, that the blood may not tarry, whether oxygenated, calorified, or both, to get carbonated and hydrogenated in any degree, before its entering the left ventricle to be distributed through the body;

*e.* And also that the lungs may not be charged with a weight, which might impede the vital functions.



*Defence of remote parts, and of the substance of the heart.*

13. *a.* THE strong contractions of the ventricles drives blood into the arterial system. By expansion of the arteries, as well as by the progressive enlargement of their capacities collectively taken, the force of the impetus is diminished in remote parts, and the exhalants and secreting vessels perform their functions uninterruptedly.

*b.* Do the arteries take twice the time of the ventricles to perform their systole, and is the current hereby rendered continual in remote parts, as in the exhalants and secreting vessels, and without sensible pulsation as in the veins.

*c.* Synchronous with the contraction of the arteries is that of the cardiac sinuses, which, while they are continually open on the venous side, whereby regurgitation into the veins is sometimes produced, (or at least accumulation happens in them,)

The coronary vein opening into the right sinus, is furnished at its mouth with a valve, with this design, perhaps, that it may not in any case receive greater distension, than what can be produced by the interruption of its own stream, distension which might be hurtful to the motions of the heart.

*Necessity for venous sinuses in the head.*

14. *a.* ALL the provision, of sinuses and dilatable veins at the heart, does not appear to be sufficient to guard so delicate a part as the brain from the effect of reaction, by interruption of the venous current at the heart.

*b.* For this reason it seems to be, that venous sinuses are formed in the head to such an extent as to contain, it is supposed, one tenth of the whole mass of blood in the body. Into these the veins,



arising from the brain, pour their contents, in rather a retrograde direction : and this may prove another guard against the effects of reaction, from interruption of the venous current at the right side of the heart.

15. The necessity for these sinuses may appear, when we consider that the pressure on the brain is continually changing.

*A. a.* The contents of the cranium swell gently under ordinary expiration, and are diminished under inspiration.

*b.* This may be a convenient mode of keeping up the intestine motion, necessary to living parts, which could not so well have been effected here, by strong circulation, as in muscular parts of the body.

*c.* But under long and deep expiration, a turgidity thro' compression of the brain, as well as an anxiety in the thorax, takes place, which is only to be relieved by long and deep inspiration.

*d.* Are not the compression and anxiety on such occasions produced by accumulation in the venous sinuses, thro' obstruction of the passage of the blood in the pulmonary artery, retrograding to the head,

*e.* (While the motions of the heart may in fact be impeded) by such constriction of the air cells in the lungs ?

*f.* And is not the relief afforded on such occasions owing as much to the simple mechanical enlargement of vessels and parts, by distension of the respiratory organs, thro' inspiration, as to the necessary supply of fresh air ?

*g.* While the disorder, created by too long a retention of inspired air seems entirely owing to the want of the necessary chemical change of the blood in the lungs.

*h.* Hereby the vital powers of the heart flag ; and while its left ventricle, in particular, not receiving, from the now undecarbonated stream of blood, its wonted stimulus, fails to propel it with its usual force.

*i.* The blood in the remote and minute arteries, and in the still more remote part of the vital stream throughout the venous system, having already received the impulse of



previous effective systoles and consequently continuing its course to the heart, an accumulation may at length take place retrograding from the right side of the heart (perhaps from the mouth of the left ventricle, as the right ventricle does not require decarbonated blood to stimulate it to the necessary contraction) by which the venous sinuses, at first diminished by strong inspiration, may become swollen.

*k.* And thus, at last, compression of the brain, with blackness of the face, *tinnitus aurium*, &c. not to be relieved but by complete expiration of the now lethal air in the lungs, and succeeding respirations of fresh air.

*B. a.* The contents of the cranium also swell, and the pulse quickens, under watching and exercise, till at length the refection of sleep is solicited.

*b.* If there be congestion of blood on the right side of the heart, the necessity of deep inspiration is yielded to, and marked, by a sigh or a yawn.

*c.* The organs of the senses and muscles of voluntary motion relax.

*d.* There is no longer that compression on the sanguiferous system of vessels on the trunk and in the limbs;

*e.* The blood consequently retires from the head,

*f.* And the brain loses the compression necessary to a state of wakefulness.

*g.* The organs of the vital and natural functions participate in the relaxation and perform their actions with diminished force,

*h.* Till the organs of the animal powers having acquired new tone or excitability, those of the vital and natural powers sympathise with them,

*i.* A larger quantity of blood is determined to the head,

*k.* And the whole man awakes into renewed life and animation.

### 16. *Different causes of motion.*

*A. a.* To the ventricles belongs the duty of propelling the blood to the different parts of the body, and in a certain



degree back again ; for other parts besides the ventricles, and other powers besides the contractile ones may contribute thereto.

### *Vital powers.*

*b.* If the contractile powers as the most eminent tests of life, or rather, if the irritability of physiologists as distinguished from contractility (can a distinct line be drawn between these two different affections of vital power or effects of life ?) may be here peculiarly distinguished by the name of vital, it may be said that chemical and mechanical causes contribute with the vital powers to effect the circulation of the blood, as well as the changes it has to undergo in its course.

*c.* These vital, or for distinction, the muscular, powers, eminently prevail through the whole arterial system. The large arteries are dilated and receive an accumulation of blood ; upon which they contract when the systole of the ventricles is completed. Their valves at the heart prevent the retrogression of the blood. It is driven along by muscular contraction of the arteries ; the dilatation and succeeding contraction being propelled throughout the arterial systems, after every systole of the heart.

*d.* Hence the pulsations in the parts of the body, remote from the heart, are later than in the arterial trunks. To produce synchronous pulsations (or rather jactations, for there would be no sensible pulse) would require arteries incapable of distension and a contained fluid perfectly non-elastic.

*e.* The muscular powers of the veins appear to be but small, and muscular fibres seem only discoverable, in their extremities more particularly in the great trunks at the heart. What there may be of muscular fibre in the minute branches, or rather roots, of the veins, as they arise from the arteries, may be considered, as a continuation of the arterial muscular coat, which ceases where the progressive pulsatory arterial impulse no longer has place.

### *Venous current aided by lateral muscular pressure.*

*B. a.* BESIDES the lateral pressure on veins from arterial pulsation, there is a more forcible mechanical pressure on some of them, produced by the action of surrounding



muscles. These veins have not only the force of the established current of the blood, but valves also to oppose its retrogression.

*b.* If the force of the pressure be equally employed in impeding the coming, as in forwarding the going, blood at the place of pressure, the accelerating effect goes on progressively to and through the heart, (*c.*) while the interruption though continued at the place of pressure, is only partially felt in the current, which now flows more fully through the cutaneous veins, preventing retrogression like unto, even more effectually than, the sinuses at the head and heart,

*d.* The cutaneous veins anastomosing, or having frequent communication, with the internal ones, whereby they also become distended, when the blood is expanded simply by heat.

*Filtration, lymphaticks, capillary attraction.*

*C.* BESIDES the sanguiferous veins and secreting vessels, the ferous ones also arise from the arteries.

*a.* Their diameters, it is said, are too small to admit the cruor: they receive only the thin part of the blood, which is diffused throughout the whole body, and moistens all internal surfaces.

*b.* What remains of this (changed in its nature, accordingly as it has been distributed to different parts of the body) is taken up by the lymphaticks.

*c.* It is supposed that capillary attraction contributes to this absorption:

*d.* That it is by the contractile power (as distinct from irritability) of the lymphaticks as well as of cellular membrane, which is like a spongy reservoir every where diffused, that it is principally forwarded towards the thoracic duct, where, together with whatever multifarious fluid is received from the surrounding atmosphere, &c. by the cutaneous absorbents, it mingles with the chyle, itself composed of the nutritive part of the aliment, of saliva, of gastric, pancreatic, enteric and bilious fluids, &c.

*e.* It seems difficult to conceive how this can be effected without distinct irritability, or distinct alternation of contraction and dilatation, in the absorbing vessels, unless the force of



the *vis a tergo* be supposed to be continued from the arteries into the lymphatics, which must appear impossible when we consider, that the roots of the absorbents terminate generally in cellular membrane :

*f.* And this cannot happen to the chyle, which is continually flowing from the alimentary canal, nor to the fluids absorbed at the external surface of the body ; at least at the extremities of these vessels where the absorption first begins.

*D. a.* To capillary attraction, has been referred the entrance of the blood into minute sanguiferous vessels.

*b.* But what can capillary attraction alone effect, in one case or the other, when the vessels are continually growing wider (singly) from the extremities of their roots ?

Again, if the filling of the exhalants were a mere affair of filtration, what prevents the red globules, if round and of a gelatinous substance, from stopping up the orifices of these vessels ? or are they only gelatinous when extravasated and dead ? and do they then only become spherical in yielding to the common law of aggregative attraction which determines all bodies not under the influence of chrySTALLISATION or vitality into spherical figures ? If so then may we suppose, that their containing vesicles endued with life give them a determinate form (as has been imagined sextuple, annular or lenticular, &c.) not corresponding with that of the mouths of the serous vessels, whereby the serum may enter while the cruroric particles are, if I may so express it, jammed in the round orifices---and, while all the other organised parts of the body are, through their mutual connexions with, and mutual actions upon each other, (every where giving and receiving, or transmitting fluids) tending every where towards spherical, cylindric, and conic forms, through dilatation from their contained fluids, these distinctly organised bodies, for such we must account every vesicular substance, these insulated living forms, removed from all such influence, and swimming in a yielding fluid, may bear their native figure so long as they continue insulated ; and may change it only perhaps when taking to themselves the candidates for life and organisation, the beginning fibres of the blood, the coagulable lymph, they, thus associated, attach themselves to connected parts ; or when attaching themselves, without such association, they themselves are united to connected parts, their places being supplied perhaps by the fibrous part putting on the cruoric form and nature ; or when dissolved, they, by a further elaboration, whether in the nervous system, or in whatever other way, constantly repair the continually consuming substance of all connected parts.

But if their spherical figure exist, only, in living or recently drawn blood, and if this figure be changed in permeating vessels of very small diameter ; then may it yet more earnestly be asked, what prevents their stopping up the serous vessels ?

*E. a.* Is it because the decarbonated blood cannot obtain charcoal in these vessels ?

*b.* And is the cruor particularly, on this account, drawn forwards by chemical attraction, along the venous system ? If this be the case,

*c.* Then, exclusively of the impetus given at the heart (which, notwithstanding the difference there may be between dead and living vessels, we must believe to be the grand proximate cause of the circulation, when we consider, that by injecting after death, by an artery, the injec-



tion may be pushed round to the heart, and microscopic vessels be filled with it at the same time,)

d. The blood must naturally tend forwards; for its power of absorbing carbone diminishing as it proceeds, arises from its receiving this element, as it passes along, from surrounding parts. It therefore must be continually attracted forwards to the part where the carbone abounds more than it ever can do, where the newly decarbonated stream is continually pouring along the arterial system.

e. But the human body is not sufficiently strong to undergo chemical process so rapid, intense, and extended. We might about as rationally suppose, that the lungs were a furnace, the heart a boiling kettle; and, that the systole of the ventricles was an explosion from ebullition, and their diastole a reception of fresh fluid, to be in its turn driven forwards, when sufficiently heated.

f. If the current of blood were capable of being dragged forward by chemical attraction, as above mentioned, then might we see another cause for its quick motion in the *cavæ*, and for its slow motion in the *vena portæ*, besides the structure or dimensions of these parts. We might suppose an indisposition in the blood (already so fully charged with carbone from the abdominal viscera) to enter the liver, where carbone so much abounds; unless indeed we should suppose that it would be drawn thither to get rid of carbone in this elaboratory of bile, a fluid so highly charged with this element: and, on the other hand, we might suppose a pressure forwards of the blood in the *cavæ* to the right side of the heart, through which alone it can find a passage to the air cells of the lungs, where there is a continual supply of matter, to which the carbone is more affinitive, than it is to the blood itself.

But, though it seem not possible that chemical attraction should exist in the body, powerful enough to produce progressive motion of the blood in this manner; yet it is probable, that in its intestine motions, all its changes, in every organ and part, are immediately under chemical influence. And, as in blood drawn from the body, the effects of chemical attraction, as well as of those of gravitation, are noticeable; those in the formation of the crassamentum, these in its seeking the bottom of the vessel; so the affinitive attraction of cruoric globules and lymphatic fibres, to each other, may perhaps be sufficiently strong, to prevent them from deeply entering any other vessels, than those which are large enough to transmit them, or than those where their presence may be required to become attached to connected parts, and to which they become connected, not perhaps without the aid of affinitive attraction and of that of cohesion (if there be any difference between the two) combined, as in every function of organised parts, with the inexplicable principles of life.

### *Vital appetencies and revulsions.*

F. a. CAPILLARY attraction, or the attraction of cohesion, alone, seem to have a greater tendency to arrest fluids in their cavities than to give them progressive motion.

b. And chemical attractions are constantly modified in organised bodies by the inexplicable principle of life.

c. The secretion in the different organs, not to be imitated by any art; and the progressive motions of fluids in the ab-



forbents, not by any mechanism, may be referable to certain appetencies and revulsions in the parts immediately concerned, which may, for any thing we know, have been originally felt in the embryo, when it, as it were, vegetated in the womb, (its roots being without its body,) with a sensibility perhaps as obtuse as that possessed by vegetable creatures; and, through the exercise of enlarged capacities of sensibility and intellectuality after birth, the perception of these most minute sensations may have been lost; as we are not now otherwise sensible of them than in their general effect; or rather, we are only conscious of their general effect, while they themselves, the causes of this effect, are undetectable.

*d.* It has been thought, that similar appetencies in veins and revulsions in the heart and arteries may also produce, with the other different changes of the blood, its simple circulatory motion through the veins, heart, and arteries.

*e.* But if we may thus carry into the organs of the vital and natural functions, the idea of will, however latent, must we not also suppose, that, like other parts evidently subject to the will, they must experience the changes, not only of action and rest, but also of watchfulness and sleep?

Adopting such idea then, all the moving fibres throughout the system, where vital and natural functions are going on, are, in their relaxations, falling asleep, and letting others fall asleep; in their distensions they are roused by their neighbouring fibres already awake and at work; and in their contractions, they are themselves at work and waking other fibres, by throwing upon them the burden of driving fluid along, till they take another nap.

In this way the fibres of the ventricles may, as working harder, take longer naps than those of the cardiac sinuses, or the arteries; and if the venous trunks, without working so hard, seem to take naps as long as the ventricles, not only may it be apologised for them, that the poor things are weak, and not so well able to hold out; but, it may also be added, that they do not sleep so sound. For, no sooner have they done their little work, performed their faint contractions, during the diastole of the sinuses, and become composed to sleep, than *bang* comes the blood, sent some time before, from the arteries, presently begins to wake them, and rests not till they be sufficiently roused, or stretched, to renew their contractions.

Thus, as in all just and well regulated associations, the rewards or comforts afforded to individual parts, are proportioned to their toils for the good of the whole, and suited to their capacities for duties and enjoyments.

*f.* If the idea of alternately sleeping and acting, do not embrace the notion of appetency and revulsion, it is only changing the terms a little, and, for greater correctness, we may then say, however gross the language may seem, that the vessels and parts of vessels, alternately drink and spew; that in falling asleep they begin to drink, not by distinct deglutition, but, by enlargement of cavity, through a gently relaxing fibre; that the neighbouring parts, already awake, and spewing into them their drink, cram them so full, that they have, in their turn, to spew into other parts, with such force as to produce an irritating distension with nausea, which makes these spew forwards their contents, in order to sleep and drink again: and



ter than justly regulated associations of men, bear comparison with the effecting of vital functions. But the discharge is not a revomition, but a propulsion. Revulsion, we may suppose, does not even take place in the system, but from morbid influence, or where by seasonable, even retrograding or repulsing, constriction, as in well regulated associations of men, that which would be hurtful is shut out, or even repelled. In cloyed voluptuaries, revulsion is a healthy effort of the system, to resist the violence which they offer to it, to throw off the load with which they oppress it.

*Origin of the contractile powers in the arteries and cardiac sinuses.*

WHILE the blood seems to stimulate the ventricles, not only chemically, but also sometimes mechanically from distension, to a vital contraction of their fibres, may we not consider, even without reckoning upon the mechanical stimulus, the contractile power of the arteries as well as of the sinuses, as growing (if we may attempt to find a beginning) out of their connexion with the ventricles.

17. *a.* To the ventricles belongs the duty of propelling the blood to the different parts of the body, and in a certain degree back again.

*b.* It is not a mere circulation of this fluid that is wanted. It must undergo changes in its course—it must lose parts of itself—it must gain accessions of new matter.

*c.* For these purposes, its degrees of velocity must vary. It must not be hurried along all the way by pulsations. Where, and how, is a resting place, or rather a slackening pace, to be obtained for it?

*d.* The ventricles contract with uncontrollable vehemence; the arteries receive their contents and are dilated.

*e.* The dilatation is propelled to the remote and minute branches with a force and velocity which diminish as it advances, because the branches do not diminish in capacity, in proportion as they increase in number, as well as because of their yielding to distension, from the systole of the heart.

*f.* If we except the pulmonary vessels, the venous system is more capacious than the arterial. (12. *c.*)

*g.* In it the blood runs without sensible pulsation.

*h.* It cannot, however, keep a steady and unremitting motion into the ventricles.

*i.* By the decrease of capacity in the veins, collectively, its rapidity increases, as it approaches towards the heart;



k. And, owing to its interruption at the mouths of the ventricles, the conducting vessels are dilated.

l. They contract, when, by the opening of the valves of the ventricles, the interruption is taken off.

m. And, to this, may we not ascribe the formation of the sinuses, which would have been equally found at the commencement of the arteries, if there had not been a free passage in them, an invitation (through a progressively relaxing fibre) to the large arteries, to throw their blood upon the smaller branches, thus dividing with them, or diffusing to the remote and minute arteries, the effect of the grand impetus of the systole of the ventricles?

*Necessity for the ventricles synchronising, from the structure of the heart.*

18. a. If the heart could have existed without sinuses, and its ventricles of consequence had been obliged to alternate in their motions, the contiguous fibres of the two ventricles, which, intersecting each other, contribute mutually to each other's aid, in the systole of the heart, would in that case have opposed each other's contractions. The structure of this vital organ must have been changed; or, instead of one double heart, there must have been two single ones.

b. The large sanguiferous vessels of the pulmonary system and those of the general system might have disturbed each other's motions; and if this had happened, the effects must have been felt in the remote branches.

c. Respiration might have been disturbed.

*Necessity for synchronising vessels on the birth.*

19. BUT, if the ventricles of the heart had alternated in their motions, even furnished as they are with auricles and dilating arteries, what had been the lot of the children of the first parents of the human kind?

a. *Nascentes moriuntur* had been literally true. Each in,



fant had gasped out its life, on its entrance into the world.

*b.* All that admirable œconomy in the structure of the heart which fits the animal, successively, for its foetal and enlarged state of being, could not have applied to a heart, whose ventricles alternated in their motions.

*c.* For, if a *foramen ovale* had been open, to have taken off the same quantity of blood, as is diverted in this way from entering the right ventricle, the further diversion from the yet unfolded lungs, through a *canalis arteriosus*, to be effected by contraction of the right ventricle, could not have taken place if the ventricles had alternated; because the time of dilatation in the *canalis arteriosus* would been the time of contraction in the *aorta*.

*d.* Consequently, the right ventricle failing to bear a part, in propelling blood to the parent, the *foramen* must have enlarged, the *canalis* closed; the powers and dimensions of the left ventricle must have increased, and those of the right ventricle diminished.

*e.* When the creature was born, the left ventricle must have thrown the blood with such impetuosity through the greater system, that, arrived at the right ventricle, striving with ineffectual powers to unfold the pulmonary system of blood vessels, it would have overwhelmed it, while the left ventricle would have been exhausted, (if the *foramen ovale* could have closed);

*f.* Unless indeed, this itself had been more suddenly and effectually overwhelmed, by the circulation through the *placenta* and *ductus venosus* being stopped,

*g.* Which is always, perhaps, the proximate cause of the immediate death of the foetus, on the stoppage of the circulation, through the umbilical cord, before its breathing --- viz. the deadly force of the reaction, thrown upon the heart;

*h.* But which in case of happy birth, no longer deadly, is principally employed by the right ventricle, upon the lungs, to give them their required enlargement;

*i.* While, the force of the current in the *aorta*



being thus, for a moment, diminished on the one hand ; and,

k. On the other, the no longer crumpled-up animal getting room for the enlargement of all its vessels and viscera,

l. The vital stream, in greater quantity, makes its way also through the greater system, distending its vessels for the reception and transmission of the whole vital stream, and,

m. Leaving those vessels that were intended to be sanguiferous, only during the foetal state, to gradually assume a ligamentous nature, suited to the new mode of being of the animal.

n. After a slight effort to breathe, the homuncule, with alternating ventricles, would have expired, suffocated by the unequal distribution of its own fluids or from the unfit distribution of power in its vital organs : for

o We can hardly suppose, if the *foramen. ovale* had been kept open, that the foetal life, sometimes afforded to the infant through the umbilical cord, for a short while after birth, ere it yet breathe, and even after breathing, could have continued, till it had so gradually died away, that by the left ventricle losing its excess of power, and by the right one's receiving this lost force, the necessary equilibrium, or due distribution of muscular energy, had been effected in this vital organ ;

p. While the vessels of the organs of respiration were gradually, instead of quickly, unfolded, and fitted to perform functions, essential to the existence of the animal, when separated from the parent.

The cavity of the thorax is expanded, and the lungs are consequently inflated with a force and velocity almost convulsive, by contraction of the diaphragm and other muscles, on the child's coming into the cold atmosphere, as are those of the adult on his plunging into cold water. The inflation in both cases is followed by quick expiration, and by successions of gradually tranquillising respirations, as the parts become inured to, or less sensible of, the stimulus of cold.

While the *ductus arteriosus* continues open after birth, the power of the right ventricle may be in part employed, together with that of the left ventricle, in expanding the vessels of the general system ; but when those of the pulmonary system



are sufficiently enlarged, the *ductus arteriosus* must close, equally from the *vis a tergo* of its current being diverted into the pulmonary system, and from the vessels of the greater system being filled by the left ventricle.

Thus, while the functions of these vital parts are so materially, so suddenly, and so forcibly changed, there seems to be an ample provision made, to prevent mortal effects from too sudden violence, in leaving open, at the same moment, the whole range of the two arterial systems (through the medium of a slowly contracting *ductus arteriosus*) to the systole of the right ventricle, which might have been too strong if it had been, at once and totally, thrown upon the lungs.

In proportion as the *ductus arteriosus* closes, the quantity of blood thrown into the left sinus is increased, hence less of the blood from the *cavæ* is admitted to pass through the *foramen ovale*, and more of it is thrown into the lungs---every drop of it, so diverted through the lungs, gives, on its arrival in the left sinus, additional force to the pressure on the valve of the *foramen ovale*.

The tendency of the blood, from the *cavæ* (*cava inferior*?) to pass through the *foramen ovale* continually diminishing, by the unfolding of the lungs, at least from the moment of the closing of the *ductus arteriosus*; and the resistance made to its passing through the *foramen ovale* continually increasing from the yet earlier moment that an increased quantity of blood arrives in the left sinus from the first unfolding of the lungs,---the *foramen ovale* is soon completely stopt, and the circulation, suited to the being of a breathing animal, is fully established.

But if the ventricles had alternated, the sinuses must also have alternated; and the immense *foramen ovale*, hereby



occasioned, must always have continued open ; for the right sinus would have always had, on contraction, a yielding left sinus ready to receive blood in the old foetal way ; so that, if the left ventricle could have withstood the first shock, from the reaction on the stoppage of the arterial currents in the umbilical cord ; and, if the blood from the *cava*, by going directly through the immense *foramen ovale*, had not overwhelmed the right ventricle, the short-breathed animal, so affected as the offspring of warm-blooded parents, labouring in vain for a supply of air, if its life had been continued, must have been changed.

In its nature it could not have ranked among warm-blooded animals. It might have classed with the amphibia, and gone down with the tortoise, into the coral groves of the deep, both being almost equally fitted to have the short circulation effected ; the quadruped, by the communication between its ventricles, (5. b.) the other by that between its cardiac sinuses. There, if it had retained any of its native superiority of capacity for doing mischief, as well as good, it might have committed depredations in another way ; might have contrived other means of enslaving and destroying its own species and other creatures ; might still have been a *sportsman* and pursued its *game* in both elements ; might still, as at present, and more extensively, have drawn fish from their watry beds, and dragged land animals thither ; it might have suffocated the tribes of cetaceous fish, in their own element, and contemplated, in the watry deep, their agonies with impunity ; but when *in at such a death*, it could not have celebrated its triumph and barbarous joy, by shouts and the sound of the horn. What a pity that the ladies who wear pearls, and the merchants who supply them, cannot find some such *lusus naturæ*, as a man with alternating sinuses at the heart ! Such a subject sent to the Persian Gulph, or other pearl fishery, might rescue divers there, victims to avarice and vanity, (commonly black slaves,) from having their lives harraised and worn down, when not more readily put an end to by suffocation, through their unnatural employ !

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## II. ON INORDINATE MOTIONS OF THE HEART.

**H**OW comes it that violent exercise produces a palpitation in the heart ?

### *Causes of palpitation.*

20. a. THE muscular pressure on the veins quickens the motion of the contained fluid. Their valves, which are most numerous where they are



most exposed to muscular pressure, utterly prevent its retrogression. It is propelled to the heart with augmented force or accelerated velocity.

*b.* It is difficult to conceive how quickened motion of the blood can produce palpitation in the heart, if all the motions of this organ be alike quickened. Must there not an irregularity, as well as a rapidity in its motions, have been produced?

The balance may have been lost, either in point of time or of force, between the contractions of the sinuses and ventricles.

*c.* While the sinuses, by their motions alternating with those of the ventricles, prevent the strong contractions and extensive dilatations of these, from producing a hurtful agitation, they seem to hold an intermediary station between the veins and the ventricles, not only in respect of place, but also in their use and nature.

*d.* By their being unfurnished with valves, they admit the blood, even during contraction, to pass through them to the ventricles, and thus prevent, during the contraction, too great and too sudden an accumulation in the vein. (10. *b.*) (12. *b. d.*) (13. *c.*)

*e.* They seem, then, peculiarly to afford aid or relief to the veins, preventing retrograde pulsation.

*f.* May it not be from their accommodating themselves to the necessities of the veins, or from their yielding to the increased velocity, or accumulation of blood in them, that so sensible an agitation is produced by muscular exertion, as in the case of running up and down stairs? (3. *a. a.*)

### *Balance lost in point of force.*

21. *a.* From the quickened motion of the blood in the veins, an inordinate accumulation commences in the venous trunks at the heart; the sinuses yield; their contractions are not so complete; they approach more, in their nature, the passive condition of the veins, than they did when, undisturbed, their contractions and dilatations were of such an extent, that they so balanced with those of the ventricles, that the motions of the heart were not discernible to the sight, the touch, nor to the pressure of the hand on the thorax, (2. *b.*)

*b.* While the energetic and uncontrollable ventricles (more especially perhaps the left one, if the mouth of the *aorta* be covered by one of the valves of the ventricle during its diastole?) make full contractions and dilatations.



c. In this case the balance is lost between the sinuses and the ventricles in point of force.

*Balance lost in point of time.*

22. a. But if the sinuses make proportionably stronger contractions under palpitation, as produced by muscular exertions, they may fill too quickly; not indeed

(13. a.) In less time, than that of the systole of the ventricles, when their valves are once shut, when their contraction has actually commenced; but the sinuses may swell and fill too soon, may be ready to burst, at that interval, when the fibres of the ventricles (pertinaciously retaining the property of strong muscle, (13. a.) the slowly relaxing fibre, not so easily yielding to be driven, to be stretched, as the weaker sinuses) are passing from a state of relaxation to that of contraction.

b. In this case, the balance is lost in point of time; and the systolic stroke of the ventricle is not balanced by the diastole of the sinus. The contraction and dilatation are not sufficiently synchronous.

In tranquil circulation, the blood is perhaps principally drawn into the ventricles, by their spontaneously relaxing fibres; while, in hurried circulation, it is driven into them, by the sinuses being strained to unusual contractions.

c. From the sinuses filling too soon, we might, at first view, suppose, that the last part of the systole must give the shock, which produces the sensation of palpitation, by its tendency to produce a vacuum. The shock, however, would rather produce a general shake of the thorax or its contents.

d. But the sensation is that of a local stroke, as of the apex of the heart knocking against the ribs. This is attributed, to the venous torrent pressing in forwards to the heart, and to the re-action, from the explosion of the blood from the heart into the arteries:

e. And if the sinuses fill too quickly, if they yield also and an accumulation consequently takes place in them, retrograding at the same time into the venous trunks; then, may not a sort of general, confused or indistinct, retrograding contraction upon such accumulation take place, instead of distinct contraction of sinus, alternating with that of ventricle and large vein, and synchronising with that of artery; and, a succeed-



ing general, confused or indistinct tumefaction, retrograding from the mouths of the ventricles into the veins, instead of contractions of vein, however faint, alternating with those of sinus and artery, and synchronising with those of the ventricles? hereby the moment when the large arteries swell is no longer the time when the large veins may contract. (9. a.) Consequently there is not room for the expansion of the arteries, or, there is a resistance to it; by which, the heart is thrown forward by the systole.

In other words, sack is no longer duly associated with sack in their alternations, nor tube with tube; but the sinuses and veins being violently dilated and oppressed, and, consequently, incapable of performing their actions distinctly, the heart is continually pushed forward during the whole pulse, and particularly so when, by the tumid state of the large veins, the arteries have not room to become expanded with sufficient velocity for the reception of the blood on the systole of the ventricles, and the apex of the heart is consequently driven against the ribs.

f. If there were not, while the sinuses fill thus quickly, accumulation in the large veins, impeding the expansion of the large arteries, on the systole of the ventricles, this, instead of driving the apex of the heart against the ribs would on the contrary, draw it from them. (4.)

### *Defence of pulmonary blood vessels from distension.*

a. DOES the right ventricle, from its not being closed at the mouth of the pulmonary artery, at the time of the diastole, let the excess of blood pass through it,

b. And, thus not so readily become distended to excess as the left ventricle? and is it to excess of force in the left that we ought to attribute, at least the commencement of palpitation?

c. This oeconomy (capacity of opening in the mouth of the pulmonary artery: for, from the slowness of dilatation of the ventricles, the systole of the pulmonary arterial trunk may perhaps be completed a moment before that of the ventricles commences) is perhaps established simply to moderate the arterial impulse through the lungs, which have to receive it in every state of their dilatation and contraction under respiration.

d. While the large sinus at the left ventricle, capable of extensive dilatation, may hereby more effectually prevent accumulation in the pulmonary veins.



c. Thus, on one side the lungs seem to be guarded from excess of force in the ventricles, on the other, from excess of quantity in the veins.

### *Palpitation from disturbed circulation.*

A. a If on the right and weaker side of the heart, which has only to forward the blood through the pulmonary system, we have a ventricle permitting blood to pass through it during its diastole; (23.)

b. And on the left and stronger side, which has to propel it through the greater system, a capacious sinus more strongly muscular than that on the right, and consequently better able to keep up the balance of power, and of time also, (if after all, there be any fitness in the idea of the balance being kept up or lost between the alternating cavities of the heart under different circumstances) against the energetic left ventricle, then may we expect in the healthy heart, shaken only by excess of exercise, that the right ventricles will contribute as early as the left to produce the sensation of palpitation.

c. The ventricles must act sympathetically. In time their motions must be synchronous; their increase of force proportionate to their strength respectively.

B. a. Do not the same effects take place, and in the same way, as by violent exercise, when the pulse is quickened to excess by violent affections of the mind, if, as is thought, these act upon the arterial system through the nerves? Or rather by such sudden and greater contraction of arteries, and their consequently greater and quicker expansion, the blood should be drawn, or as it were pumped, from the heart, as by muscular exertion it is driven to it: and in such case if it were possible to interrupt or destroy the close sympathy between the ventricles, (sympathy diffused perhaps throughout the two arterial systems) we might expect perhaps the agitation to begin on the left side of the heart; as whatever effect may by such mental affections be so produced in the whole greater system, it must immediately affect the left ventricle; while the pulmonary arteries can only so affect the right ventricle.

b. However this might be, on the first commencement of the agitation, the apex of the heart, must rather retire from the ribs than strike them on the systole of the heart, affection which becomes reversed, however, immediately on the quickened blood getting round into the venous trunks.

c. But have we not reason to think that the commotion produced in the circulation by mental affections, is effected through the medium of the organs of the animal functions? Is there any violent or earnest affection of the mind which does not sensibly affect the organs of voluntary motion; the invigorating passions, and even the most debilitating one (fear) in its first effect, (fright) producing a constriction in their muscular fibres sufficient to throw the blood with force on the heart, as in the case of violent exercise, and to make, perhaps, if it were possible, the palpitation begin on the right side of the heart?

C. a. Do not the same effects take place when the pulse is quickened to excess by pain, and by heat, &c. as when it is hurried by exercise?

b. And is not the case the same when it is quickened by stimulants taken inwardly, if, as perhaps always is the case, the effect be produced (be-



fore, or even without that, stimulant matter enter the blood) through the medium of the nerves, those of the organs of the animal functions sympathizing with those of the stomach; and thus passing to vital organs the stimulating effects which begun in an organ (less delicate) of the natural functions.

c. This kind of palpitation is a throbbing which rest, serenity, ease and temperance remove.

D. a. The same effects are often produced by certain diseases of the pyrexial class, of which pain, &c. are parts.

b. Diseases of other classes may produce pyrexial symptoms; may affect the circulation of the blood in the same way.

c. In all these cases it is evident, that the malady, which occasions the morbid irregularity in the circulation, must be removed, in order to produce a cure; and in this there must be effected a change in the general system.

### *Palpitations, strictly so called.*

ALL the instances of palpitation, yet mentioned, may be considered as throbbings produced by disturbed circulation.

25. a. There are others which seem to be rather the cause, than the effect, of disturbed circulation, and which are perhaps more strictly palpitations, than those already mentioned.

b. Under these the pulse may be violent, weak, unequal, intermittent.

c. Such are those which arise from malconformation, or diseases in the heart or its vessels, by constrictions, amplifications, polypi, ossifications, &c.

d. Under these the balance may be lost between the ventricles themselves, as well as between the ventricles and sinuses.

e. May both these kinds of palpitation be also produced, even mechanically, by impeded respiration, by distension of stomach, by derangement of other viscera?

f. Palpitations, strictly so called, appear to be produced also by nervous affections, where mind is not concerned, as from weakness alone, from spasmodic affections, if indeed the heart be not always acted upon in these cases through the organs of the animal functions.

Perhaps spasm does not ever take place in parts not subjected to the will, which is probably the case with the stomach, and the whole alimentary canal, with the urinary bladder and viscera in general, as well as with the heart, and all the vessels concerned in the circulation.

Are not rumination and all voluntary eructations effected, entirely, by such voluntary disposition of the diaphragm and the muscles of the trunk, as by the law of determination forces air or aliment from the stomach through the cardia, which stimulates the oesophagus to the necessary inverted motion? If they were effected by contraction of the stomach alone, that mixus which is made use of to produce them would not have place; but the diaphragm and muscles of the thorax and abdomen would be as tranquil as in ordinary deglutition. That the muscular fibres of the urinary bladder are not at all under the controul of the will, appears evi-



dent from the application of the catheter. And if the history of the English military tribune's having the power of suppressing, at his discretion, the motion of his heart and arteries, as related by Baynard and Cheyne be correct, must not this also have been produced by such disposition of the diaphragm and conspiring muscles, as would cause a constriction on the *cava ascendens* and *aorta descendens* in such a way as to interrupt distinct pulsation for a short while, by arresting, not wholly, the contraction of the left ventricle, and withholding, not wholly, from the right ventricle its stimulus, rather than from any effect, produced immediately upon the heart, and which might be attended with consequences mortal in the brain. Perhaps a total suppression of the heart's motions, and of the circulation of the blood in the brain, would, except under the relaxation of syncope, be attended with immediate death.

On consideration of the subject of palpitation, an unlimited field of insuperably difficult research presents itself, which I do not dare to enter any farther; already feeling myself bewildered, in attempting to reduce the different inordinate motions of the heart, to two distinct kinds of palpitation, and in attempting to refer differently produced agitations to one or other of these two classes, which are, perhaps, without any foundation in nature.

For if, after all, the muscular part of the heart be without sensibility, and without distinct nerve, and its irritability be only excited by the stimulus of the blood, or by distension from its received volume, then must not palpitation always be the effect, and not the cause, of disturbed circulation. Even in the case, if such there be, of the affection beginning through the coronary vessels being influenced by their nerves, must not we consider all this as passing externally, with regard to the muscular substance of the heart?

When palpitation arises from derangement in the structure, and from unequal or morbid distribution of vital power, in different parts of the heart, if this can have place, such, and perhaps such only, are the cases (at least with exception of stimulating matter getting into the system, whether from the alimentary canal or externally,) where it is the cause and not the effect of disturbed circulation.

### *Division of palpitations into permanent and excited.*

26. IN considering these things, another, a rather different, the more simple or strict, division into excited and permanent, presents itself.

On this more accurate division, I may repose a while, without such immediate danger of being bewildered.

Taking the word *palpitation* in the most extensive sense, I consider it to signify every deviation, from regular and undisturbed motion, in the heart.

27. Excited palpitation arises from excess or defect of stimuli of every kind, and of excitability.

In the case of excess, the pulse is vigorous and quick;

In the case of defect, it is tremulous; and, from the ventricles, feeble as are their contractions, having occasionally to wait for stimulus or excitability to accumulate, to effect them, intermittent.

Irregularities produced, in the motions of the heart, or in the circulation, by increase or diminution of excitement, may mark the progress of disease or infirmity, or the efforts (as some think) of the vital principle to restore health.



28. Permanent palpitation arises from derangement in the structure of the heart, or from disproportionate distribution of strength and vital power in the different parts of it.

Palpitation, by deranged structure, from a sensible agitation on the thorax, and in the general circulation, to scarcely distinguishable intermission, may sometimes be observed in people enjoying tolerable health.

In general they can badly bear violent exercise or other strong excitement. Sometimes, however, a certain increased, perhaps at others, a diminished, excitement overcomes the slight cause of regularity.

In this way the pulse sometimes ceases to intermit under disease; and on the patient's recovery, the intermission returns.

A certain degree of almost every description of disease may produce palpitation; and almost every cause of palpitation can also produce syncope.

29. Palpitation is sometimes a slight and temporary indisposition, sometimes an incurable malady; finally palpitations often accompany the labouring efforts of departing life; and, on the last expiration, a last thudder or palpitation is terminated by the syncope of death.

30. It is said that in the dying the left ventricle stops first, then the sinus on the same side, owing to the blood being effete or unfit for further use from the defect of breath, and from its being more sparingly transmitted through the lungs, afterwards the right ventricle, and lastly the right sinus cease to contract: that hence it sometimes happens, that the blood may in some measure be obliged to return in the ascending and descending *cavae*, and may affect a slight motion in them.

If such be the termination of life, we may see how the last palpitations of the heart may be stronger than those which preceded them, by the ventricles ceasing to act synchronously; for we can hardly refer such action to spasm, if this can have place in the heart. I have observed in case of trismus that, previous to death, the spasm has ceased and the jaw become loose; and in death is there not extreme relaxation in all the muscular fibres of the body from their being deprived of all excitement?

### *General observations on life.*

31. In this essay the sanguiferous system of vessels has been considered, chiefly as a complicated hydraulic machine, the stimulus of the blood, itself, exciting the propelling influence which effects its own circulation; and but little has been offered on the vital principle which modifies in so wonderful a manner the actions of chemical agents and even, in a certain degree, the effects of physical combinations, that we cannot reduce what passes in our bodies, to the rules which are observed in the inanimate creation.

Sensation, in the different parts of our bodies, which are sensible (for although the cause be incomprehensible, the different parts of it are well known to vary extremely in their sensibility; while in some parts this is exquisite, in others the sensation, if it have ever existed, is so lost, that we are not conscious of pain or injury, while their life and structure are a destroying.)

Sensation seems to be derived from the brain through the nerves; or rather, the brain itself, the seat of sensation, or the mind, as eminently residing, or concentrated in that organ, derives feeling or knowledge of the objects of the senses through the nerves.



And through the medium of the nerves, the muscles, obedient to the will, are called into action.

If nerves be destroyed, the life of the part to which they lead is lost.

32. Hence we might be ready to consider the brain as the source of vitality; but, among the various instances of monstrosity, the *fœtus in utero* without brain, in other respects well-formed, is found to live and thrive till the time of birth when it immediately expires, or rather dies, on coming into the world.

In this case the reaction of the blood, from the stoppage through the umbilical cord, towards unfolding the lungs is of no avail. (19. b.) It never respire.

While, as has already been observed, the muscular part of the heart seems to be without distinct nerve; and the lower classes of animals are many of them without brain, and approach so nearly to plants, in their nature and structure, that it becomes insuperably difficult to draw the line which divides the animal and vegetable departments from each other.

33. The medullary substance of the brain occupies the internal part; the cortical, the external.

This disposition of substance is transposed in the nerves, the medullary part being external.

Is it necessary to thought and to intense feeling, that there should be concentration of medullary substance as in the head, a root or source, while there is a more universal diffusion of it throughout the nervous branches or streams, by its forming the external surface, untenacious, and extremely affinitive with every fibre of living organised matter, (and covered only with an extremely fine continuation of the *pia mater*, which may be as pervious, to whatever is effused from the medullary substance, in order to nutrition, to muscular action, to susceptibility of impression, &c. as is the membrane of the air cells of the lungs, to whatever the blood has to give off or to receive, in its passage through that organ) that mind may act, and be acted upon more universally.

As liability to death, acuteness of sensibility and intellect seem to be great, in proportion as quantity of brain exceeds that of nerve, does tenacity of life, in the lower animals, arise from general diffusion of nervous substance throughout their bodies? Is it to this that parts, even limbs, of them being destroyed, new organization and restitution of parts take place, the life of these not depending so much on a distinct organ, as in large brained animals, in which a similar violence would produce exquisite pain and death?

Is the diffusion of nervous substance still more general through plants? are they, therefore, happily less susceptible of pain than animals, while their capacities for pleasure are so limited?

Is it owing to this universal diffusion of vital principle, in some plants, that on almost any part or fibre of them being placed under proper circumstances, a complete plant is thereby produced?

And while many animals sleep for a season, do not plants and their seeds sleep for ages? When parts in Holland that have lain so long under water are drained, chestnuts are found, and trees of this description spring up on the surface of the earth being exposed to the air.

34. Do the crystallisations, in the mineral department, in some instances, shew a tendency to organisation? Is that which is the life of the lowest or most simple plants, sometimes diffused to mineral arrangements of matter, so as to produce organisation? And do plants or vegetable fibres become animalised in like manner, without those changes being produced,



by elaboration of alimentary parts in bodies already organised and living, which process is the continual support, and the continual labour, of living bodies?

What may go on in parts, where the microscope does not reach, we can only judge of by analogy; and we do not see, in what falls under our view, any thing to render such conjectures probable. We feel ourselves obliged in consideration of these things, to refer the origin of every organised production, to a distinct creation of original parent, no other alternative offering itself, than the supposition that their succession has been continued from all eternity, and that there is no existence of first cause.

25 The vital principle in the human body may be strong, when the intellectual one is weak, (is strongest in those animals where this is the weakest) and the mind may be clear and comprehensive, when life is on the verge of departure from a body exhausted and tabid.

For human sagacity to attempt to develop the beginning of life, the nature of the vital and intellectual principles, their connection with organised matter, must always be as abortive, as would be the attempt in created beings to realise the monstrous fiction of Prometheus.

They are beyond the comprehension of the human understanding. We can do little more than observe their actions upon each other. The utmost conquest that can ever be obtained by the healing art is to give to them sometimes a little seasonable modification, to keep up the balance between different jarring functions, by affording aid to the part which is oppressed, or by taking away force from the part which acts with violence.

### III. ON THE TREATMENT OF ANIMALS.

**I** MIGHT here close this essay, but cannot feel satisfied in my mind, without saying something on the treatment of animals.

#### *Abuse and torture.*

**W**HEN these our humble partners in creation, are harassed for the gratification of the sportsman, or the voluptuary; when they are ill treated, from motives of avarice, we readily revolt at the cruelty: but when the physiologist puts them on the rack, he sacrifices their ease, and perhaps his own feelings, for the advancement of science, for the good of mankind. But has he a right to torture them for the



good of mankind? A conviction so strong rests upon my mind that we have no right to lessen their portion, while living, of the enjoyments of animal life, that I cannot consider hardships imposed upon them, in any way, greater than those we are ourselves willing to undergo, in proportion to our strength and powers, less acts of injustice, than if they had been exercised upon our own species. We have no right but that of force.

I believe there are no facts, brought forward in this paper, which may not have been derived from dissection of dead bodies, from observations made by surgeons on their patients, from seizing the occasions of watching what passes in dying animals killed by accident or design in the most rapid manner, and from analogical reasoning; and if the discovery of any physical truth, however important, can only be obtained by the infliction of an additional (involuntarily received) pang upon any fellow partaker of mortality, whether brute or human creature, it is the ardent desire of my heart that it may never be sealed upon my brain, that the world may never know it.

The reason offered for these remarks will be a sufficient apology with the candid, for the lism they contain, and will make them bear also with patience what I am yet going to observe farther.

### *Deprivation of life.*

37. If I be questioned, by what right I make use of animal food? My answer is,--I do not hereby break the eternal law of justice which requires us to do as we would be done by. For were a metempsychosis to exist, and could I choose what should be my lot in a future state of existence, when my spirit should animate the body of a brute creature, I should not have any objection against future men cutting short such manner of life for any useful purpose: I should even bequeath my future living body to physiologists, with as little reluctance, as I should now my present one when dead for dissection, provided they were not to alarm the fears of the mute animal: Let me now be assured, in such case, that they would decry the



unsuspecting brute to receive the effective mortal shock of an electrical battery, or to fall under the stroke which should instantly divide, or destroy, the structure of the brain or *medulla oblongata*, or remove the whole head, upon which they might seize the occasion of breaking open the quivering trunk to see what passed, and it would afford a gratification to me to know, that I should not have to bear the infirmities, nor to suffer the pains incident to old age. In short, such is the present lot of the sensitive part of the creation, that on man, who has the hope of immortality to console him, and who has also, during the tottering steps of his pilgrimage, the means of affording intellectual gratifications to his friends, of stirring up the most heavenly feelings of the soul, while he is himself cherished by their sympathies in declining life, — on man alone I can contemplate the marks of old age with gratulation.

*Respect to the social affections.*

BUT while man stands so eminently distinguished, above all his fellow creatures, there seems also some attention due to the affections and social feelings of the brute. Under the window where I write this paper, a horse shews evident marks of anxiety on the disappearance of his comrade horse, who has walked off with his load. On the sound of his returning feet, he lifts up his head with pleasure, and neighs his welcome, when he comes into view.

Ought I to be disquieted at the yelping of the dog, left alone aboard a vessel in the haven? He is wretched without company, and, on the return of the people, frisks about with joy, and lets me continue my paper without interruption.

All these emotions, however, and all other affections seem feeble when compared with the solitudes and raptures of dams tending their young.

Who, in considering these things, could unreluctantly break in upon the felicity of the bird's nest? Who could in any wise be willing to see the kid in the mother's milk?



## POSTSCRIPT.

IN the printing of this essay there has, by an oversight, been omitted the insertion of a part of it respecting the probable intention or use of the placental blood, being sent to the liver, instead of its being directly propelled to the heart or to the cava. If my conjectures on this have been right it forms a part not unimportant, of '*the wonderful provision for the transition from the foetal to the breathing state.*'—from that state in which the homuncule derived its nutriment like a vegetable through roots without its own body, to that of its feeding by the mouth, when its principal roots, the lacteals, and we may add also the pulmonary veins, are found within itself.

The blood coming from the parent is of the arterial kind, tho' not passing through the *placenta* with rapidity it be less oxygenated than that which is contained in the arteries of the parent. In fact there being no detectable passage of venous blood through the *placenta* to the mother, nor of arterial from her to the foetus, nutriment is distilled in a way so gentle as to prevent the detachment of the child from the parent. Its circulation goes on uninterruptedly, while that of the mother is liable to be quickened or to become irregular from various causes. The nutriment is supplied through channels so minute and by a fluid so ineffably fine, that both the vessels and their contents elude the research of the most acute observers. The changes then of the blood in the foetus and the parent, while the latter continually receives carbone from the former, and at the same time supplies it with oxygene, seem to be effected by juxta position of the maternal and foetal parts of the *placenta*.

The blood from the *placenta* passes through the umbilical vein, penetrates the body at the umbilical ring, seeks the liver, and is poured into the sinus of the *vena portarum*, whence it passes partly through the branches of the *vena portarum* distributed throughout the liver, and partly through the *ductus venosus* by a direct way to the *vena cava*.

Thus the vessels of the liver are kept sufficiently dilated, by oxygenated blood, for the reception of carbonated or hydrogenated blood after birth, in sufficient quantity for the necessary secretion of bile, when the animal separated from the parent, shall have to digest food for itself.

The younger the foetus is, the larger is the liver in proportion to the rest of the body. At an early period of its existence, it is chiefly placental blood which passes through it.

As the abdominal viscera are unfolded, and their venous blood in greater quantity consequently enters the liver, a greater quantity of placental blood is determined through the *ductus venosus*. Bile begins to be secreted, and passing into the intestines, forms the meconium.



Thus the digestive organs of the foetus begin to be exercised, and thus it is prepared for that period when it must take its nutriment by the mouth.

At that time it is only the most deeply carbonated, or hydrogenated, blood from the abdominal viscera that enters the system of the *vena portarum*, furnishes to the liver the elements of bile and thus effectually stimulates the organ to the necessary secretion.

Does this description of blood ever flow in too large a quantity previously to birth, or even for a short while after it? If so, it may find a passage through the *ductus venosus* before its closing.

Does this happen, particularly, at the moment of the birth, when the current in the *aorta descendens*, produced by the contraction of both ventricles, no longer finding a passage through the umbilical arteries, is driven with sudden and unusual force into the hepatic artery, producing, perhaps, such enlargement in its ramifications, which are hereafter solely to supply nutriment to this immense organ, as may cause the blood to be expressed from the larger vessels of the *vena portarum* retrogressively; while that in the smaller ones and in those which arise from the combinations of these, that is, in the large hepatic veins, may by the same force of pressure be accelerated to the cava.

*Edinburgh, 21. j. 1800.*—It has occurred to me that the blood which passes through the *foramen ovale* is sent principally from the inferior rather than from the superior *cava*, with the intention that the left ventricle may be accustomed to the stimulus of the blood, in some degree oxygenated, previous to birth; after which it will have to receive only that which has been oxygenated from respiration; and, that the right ventricle may, at the same time, in a great measure escape the effect of such stimulus, because it will, after birth, have only to receive the blood which has passed through the greater system, and which has consequently lost its oxygen.

Since my forming these conclusions, I learn that Winslow, Haller, Sabbatier, and a number of other Physiologists, have concluded that the use of the Eustachian valve, in conducting the blood in the *foetus* from the *cava inferior* through the *foramen ovale*, is to carry the blood (recently arrived from the *placenta*) more immediately, through the left side of the heart, to the head and upper parts of the body, before it enter the right ventricle, (which it principally does on its return through the superior *cava*) to be propelled by it through the *ductus arteriosus* to the *placenta*, and lower parts. To this also the *Tuberculum Loweri* seems to contribute, in diverting the blood from the superior *cava* from directly meeting that from the inferior *cava*: and these provisions for preventing the direct concussion of the streams from the two *cavæ*, useful throughout life, may be particularly so in the *foetus*, when, with its head downwards in the *uterus*, the larger



Previous to birth, the whole mass of blood has to pass through the inferior *cava*,---disposition which is afterwards, in some sort, reversed, when chyle and lymph, elements of the blood, passing continually through the thoracic duct, are distilled into the left subclavian vein, and thus become mixed with that part of the general mass which falls from the superior *cava*. But previous to birth, the general mass of blood, as regenerated in the *placenta*, has continually to pass through the inferior *cava* to the heart.

These provisions of valve and ventricle seem both to be produced by the opposing currents of the *cavae* which they regulate or guide; as, in the whole œconomy of undisturbed creation, every production seems to arise from the necessity there was for its presence, or rather it arises coevally with that necessity.

In reflecting upon this beautiful theory, I am led to think, that the placental blood, in so immediately entering the liver, nourishes that organ, or, may I say forms, as well as keeps sufficiently enlarged, its vessels intended for bilification; and that the nutriment to the different parts of the *foetal* system is afforded, in a quantity greater or less, accordingly as the blood arrives sooner or later from the *placenta*, or as it is less or more mixed with that blood which has already in circulation deposited its nutriment in other parts.

If so, then, we may easily see how it happens that the liver is so large during the foetal state.

The blood from the umbilical vein, in a state extremely nutritive, partly permeates the liver, and nourishes it; it partly passes through the *ductus venosus*, and with much greater velocity, to the inferior *cava*, where the separated streams again unite into one current.

The blood arriving here from the Hepatic vein, has been deteriorated in affording nourishment to the liver, and by the admixture of that blood which is conveyed from the abdominal viscera through the *vena portarum*: a small quantity of deteriorated blood also arrives from the abdominal *cava*. But owing to the great quantity of placental blood arriving here, in consequence of the superior velocity of the current in the *ductus venosus*, the whole mixed current entering the right auricle from the inferior *cava* is yet highly nutritive, not less so than the first mixture which had place in the liver. It makes its way principally through the *foramen ovale*, and left side of the heart, to the brain and the upper parts of the body. Hence arises very great enlargement of the liver, the head and thoracic viscera. The blood returns carbonated or deteriorated through the superior *cava* to the right auricle, in order to pass to the right ventricle, and thence to be propelled through the *ductus arteriosus*.



*placenta*. If the blood passing through the *ductus arteriosus*, completely filled the part of the *aorta*, which it enters and permeates, this would utterly prevent any blood from being propelled through it from the left ventricle: but the abdominal viscera, and lower extremities, have need of nutriment also; and part of the blood, sent from the inferior *cava* to the left ventricle, passes through the *aorta descendens*; moreover, as the blood from the inferior *cava* does not pass through the right auricle in a distinct canal, a part of it mixes with the blood from the superior *cava*, as it passes to the right ventricle. Thus through two sources is blood, highly nutritive, afforded to the remaining abdominal viscera, and the lower parts of the body; but from its being mixed with so large a quantity of carbonated blood, the parts, particularly the pelvis and lower limbs, are not so well nourished. Besides, the greatest part of this blood passes off through the umbilical veins to the *placenta*, to be regenerated. Thus too great a growth in the whole *foetus* may be said to be prevented, by the stinting of the parts not immediately essential to life; or rather, by this stinting, the greater quantity of nutriment is determined to the parts most essential to its existence.

It is necessary that the child breathe on its first coming into the world. It has immediate use for its digestive powers. Its organs of sense are one after another called into play. It must depend for a time on the breast for support; and, even in the act of sucking, its organs of speech acquire strength. In the mean time, the vivifying current, heretofore partially distributed through its system, now diffusing itself more equably, gives strength to those parts, which are shortly to relieve the fond parent from her burden still pleasing, but becoming, at length, too heavy for her arms. In the amusement of its early years, its organs acquire strength, its mental powers are awakened; but not, till the age of puberty, is the whole system evolved. Through ripening years, the heart still beats high, the arterial action is strong, the current sets through the venous system with considerable rapidity, till the veins, at length, sufficiently dilated, receive, in declining age, with less resistance, the crimson stream now sent with diminished force, by a heart which fails to give its former youthful stroke, and through arteries now enfeebled, and participating in the general weakness; while the mental powers also fail with increasing years, and unequivocally announce the approach of that event, which, whenever it arrives, levels every distinction of vain man.