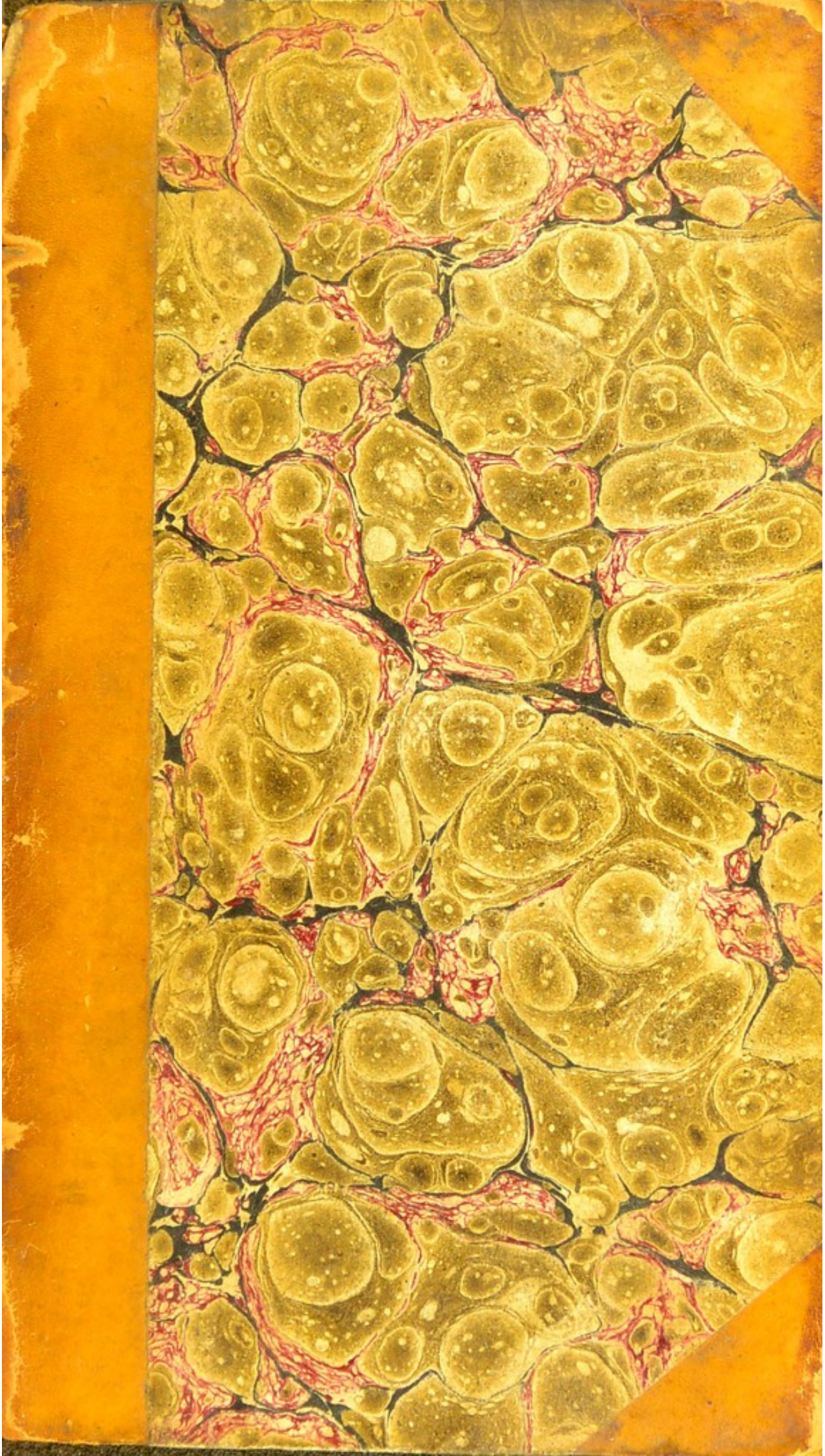
Observations on the Harveian doctrine of the circulation of the blood : in reply to those lately adduced by George Kerr, Esq. / by Alexander Ewing.



OBSERVATIONS

ON THE

HARVEIAN DOCTRINE

OF THE

CIRCULATION OF THE BLOOD.

"A person who makes no pretensions to any extraordinary endowments, either of body or mind, but who, with the help of a telescope or a microscope, sees the eclipses of Jupiter's Satellites, or the *Circulation of the Blood in the limb of an insect*, may, *without arrogance*, disregard the assertions even of the greatest philosophers, if any should be found so unreasonable as to deny the reality of those things, because they had not been able to see them, either with their naked eyes, or with such glasses as they had been accustomed to use. Such philosophers, it may be presumed, would hardly escape censure for their arrogance and obstinacy."

Essay on the Difference between the Relation of Motive and Action, and that of Cause and Effect, in Physics; on Physical and Mathematical Principles, by Dr. James Gregory, of Edinburgh.

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OBSERVATIONS

ON THE

HARVEIAN DOCTRINE

OF THE

CIRCULATION OF THE BLOOD:

IN REPLY TO THOSE LATELY ADDUCED

BY GEORGE KERR, ESQ.

BY ALEXANDER EWING, M.D.

MEMBER OF THE ROYAL PHYSICAL SOCIETY, EDINBURGH.

Νυκτὸς—Αἰθηρὶ καὶ Ἡμέρᾳ ἐξεγενοῦτο—HESIOD.

Opinionum commenta delet dies, naturæ judicia confirmat.—CICERO.

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1817.

TO

THOMAS ALEXANDER FRASER, Esq.

OF

LOVAT, STRICHEN,

&c. &c.

THIS VOLUME

IS INSCRIBED,

IN TESTIMONY OF THE RESPECT

OF

THE AUTHOR.

ERRATA.

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PREFACE.

In the course of my medical education, I never had reason to doubt the truth of the Harveian doctrine of the circulation of the blood; but, on the contrary, heard it always confirmed by the strongest arguments. I was, on this account, astonished when I found this doctrine controverted by Mr. Kerr. As I am not convinced that his arguments are sufficient to subvert the Harveian doctrine; and as he invites all who are so disposed, to refute or confirm them, by fair induction, believing and avowing that the truth must prevail, I have judged it expedient to submit to the public the following observations. If I shall be able to show, that his conclusions are not fairly deduced from known facts and experiments,

and

and that some of his reasonings are founded on assumptions, which have never been established, I shall have the satisfaction of preventing the younger Students in Medicine from being misled by what I consider as an ingenious and plausible, though erroneous theory.

Certainly if Mr. KERR thought he had *data* to prove the Harveian doctrine to be false in its principles, and that he could substitute a new or more perfect theory in its place, and thus give a true foundation to regulate our physiology and practice, he was justified in publishing the present Essay, even though it was only to excite investigation. But it must have been expected that such a doctrine as his Essay contains would not be readily followed by any person well acquainted with Harvey's, and that a refutation of it would be attempted.

It appears to me rather foreign to the present enquiry to enter into any minute discussion of the charge urged by Mr. KERR against Harvey, of impiety and materialism, or the numerous fanciful speculations of many of the ancients on that and several subtile controverted points which Mr. KERR has adverted to in his Preface. It is true, as he has stated, that several of the ancient philosophers, without the aid of divine revelation, believed in the immateriality and immortality of the soul, as Socrates, Plato, and Pythagoras.* But, on the other hand, I see

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* Plato (who has been honoured with the epithet *divine*) has transmitted to posterity the following beautiful declaration of the belief of the immortality of the soul, as expressed by his master Socrates :

Ταῦτα μὲν τοίνυν προθυμητόμεθα, ἔφη, ἔτω ποιεῖν. Θάπτομεν δὲ τίνα σὲ τρόπον; Ὅπως ἄν, ἔφη, βέλητθε· ἐάν πέρ γε λάθητέ με, ἢ μὴ ἐκφύγω ὑμᾶς. Γέλασας δὲ ἅμα ἡσυχῇ, ἢ πρὸς ἡμᾶς ἀποβλέψας, εἶπεν, Οὐ πείθω, ἔφη, ὦ ἄνδρες, Κρίτωνα, ὡς ἐγώ εἰμι ὅτος ὁ Σώκρατης, ὁ νυνὶ διαλεγόμε-

I see no reason to doubt that Harvey was equally persuaded of these important truths. I do

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νος, κὴ διατάξων ἕκαστα τῶν λεγομένων· ἀλλ' οἴεταί με ἐκεῖνον εἶναι, ὃν ὄψεται ὀλίγον ὕστερον νεκρὸν, κὴ ἐρωτᾷ πῶς δεῖ με θάπτειν. Ὅτι δε ἐγὼ παλαι πολὺν λόγον πεποίημαι, ὡς ἐπειδὰν πίω τὸ φάρμακον, οὐκέτι ὑμῖν παραμενῶ, ἀλλ' οἰχήσομαι ἀπιὼν εἰς μακάρων δή τινας εὐδαιμόνιας, ταῦτά μοι δοκῶ αὐτῶ ἄλλως λέγειν, παραμυθούμενος ἅμα μὲν ὑμᾶς, ἅμα δ' ἐμαυτόν.

* * * * *

Μανθάνω, ἦ δ' ὅς· ἀλλ' εὔχεσθαι γέ πω τοῖς θεοῖς ἔξεστι τε κὴ χρὴ, τὴν μετοίκησιν τὴν ἐνθένδε ἐκεῖσε εὐτυχῆ γενέσθαι· ἃ δὴ κὴ ἐγὼ εὔχομαί τε, κὴ γένοιτο ταύτη. Καὶ ἅμα εἰπὼν ταῦτα, ἐπισχόμενος, κὴ μάλα εὐχερῶς κὴ εὐκόλως ἐξέπιε.

Plato.—ΕΚ ΤΟΥ ΦΑΙΔΩΝΟΣ.

The dying words of Cyrus to his family and friends, as related by Xenophon, also express very beautifully his belief of the immortality of the soul:

Αλλά πρός θεῶν πατρώων, παῖδες, τιμᾶτε ἀλλήλους, εἴ τι κὴ τῶ ἐμοὶ χαρίζεσθαι μέλει ὑμῖν· ὃ γὰρ δήπω τοῦτό γε σαφῶς δοκεῖτε εἰδέναι, ὡς οὐδὲν ἔσομαι ἐγὼ ἔτι, ἐπειδὰν τῶ ἀνθρωπίνω βίω τελευτήσω· οὐδὲ γαρ νῦν τοι τήν γ' ἐμὴν ψυ-

I do not see that any part of his doctrine implies materialism ; and his own pious life leaves

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χὴν ἑωρᾶτε, ἀλλ' οἷς διεπράττετο, τούτοις αὐτὴν ὡς ὕσαν κατεφωρᾶτε. Τὰς δὲ τῶν ἄδικα παθόντων ψυχὰς ὅπως κατενοήσατε οἵας μὲν φόβους τοῖς μιαίφονοις ἐμβάλλουσιν; οἵας δὲ παλαμναίας τοῖς ἀνοσίοις ἐπιπέμπουσι; Τοῖς δὲ φθιμένοις τὰς τιμὰς διαμένειν ἔτι ἂν δοκεῖτε, εἰ μηδενὸς αὐτῶν αἱ ψυχαὶ κύριαι ἦσαν; Οὔτοι ἔγωγε, ὦ παῖδες, οὐδὲ τοῦτο πώποτε ἐπείσθην, ὡς ἡ ψυχὴ, ἕως μὲν ἂν ἐν θνητῷ σώματι ᾖ, ζῇ· ὅταν δὲ τούτου ἀπαλλαγῇ, τέθνηκεν. Ὁρῶ γὰρ ὅτι καὶ τὰ θνητὰ σώματα, ὅσον ἂν ἐν αὐτοῖς χρόνον ᾖ ἡ ψυχὴ, ζῶντα παρέχεται. Οὐδέ γε ὅπως ἄφρων ἔσται ἡ ψυχὴ, ἐπειδὰν τοῦ ἄφρονος σώματος δίχα γένηται, οὐδὲ τοῦτο πέπεισμαι· ἀλλ' ὅταν ἄκρατος καὶ καθαρὸς ὁ νοῦς ἐκκριθῇ, τότε καὶ φρονιμώτατον εἰκὸς αὐτὸν εἶναι. Διαλυομένου δὲ ἀνθρώπου, δῆλα ἐστιν ἕκαστα ἀπιόντα πρὸς τὸ ὁμόφυλον, πλὴν τῆς ψυχῆς· αὕτη δὲ μόνη οὔτε παροῦσα οὔτε ἀπιοῦσα ὁρᾶται.

* * * * *

Τὸ δ' ἐμὸν σῶμα, ὦ παῖδες, ὅταν τελευτήσω, μήτε ἐν χρυσῷ θῆτε, μήτε ἐν ἀργύρῳ, μηδὲ ἐν ἄλλῳ μηδενί· ἀλλὰ τῇ γῇ ὡς τάχιστα ἀπόδοτε. Τί γάρ τούτου μακαριώτερον, τοῦ γῇ μιχθῆναι, ἣ τάντα μὲν τὰ καλὰ, πάντα δὲ τἀγαθὰ φύει τε καὶ τρέφει.

Xenophon.

leaves us no room to charge him with infidelity. Dr. Gregory has mentioned Harvey in the most respectful terms, when endeavouring to refute an unjust aspersion thrown upon the Profession, of infidelity and contempt of religion. He says, "I think the charge ill founded, and will venture to say, that the most eminent of our faculty have been distinguished for real piety. I shall only mention, as examples, *Harvey*, Sydenham, Arbuthnott, Boerhaave, Stahl, and Hoffman."* Indeed a physician is the last person whom we should suppose capable of entertaining such erroneous sentiments. This has been very happily expressed by the author just quoted. "The study of medicine," says he, "of all others, should be the least suspected of leading to impiety. An intimate acquaintance with the works of nature raises the mind to the most sublime

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* Lectures on the Duties of a Physician.

lime conceptions of the Supreme Being, and at the same time dilates the heart with the most pleasing views of providence."

"There are, besides, some peculiar circumstances in the profession of a physician which should naturally dispose him to look beyond the present scene of things, and engage his heart on the side of religion. He has many opportunities of seeing people, once the gay and the happy, sunk in deep distress, sometimes devoted to a painful and lingering death, and sometimes struggling with the tortures of a distracted mind. Such afflictive scenes, one should imagine, might soften any heart, not dead to every feeling of humanity, and make it reverence that religion which alone can support the soul in the most complicated distress; that religion, which teaches to enjoy life with cheerfulness, and resign it with dignity."*

* Gregory on the Duties of a Physician.

As to the comparative learning and attainments of the ancients and moderns, particularly in the physical sciences, which must include medicine, I shall take the liberty to transcribe the following observations of Mr. Playfair, whose name it is only necessary to mention. The interesting nature of the subject, the beauty of the language, and the extraordinary ability with which the whole is written, giving a perspicuous and impartial view of the ancients, will, I hope, be an excuse for the length of the quotation.

" Though the phenomena of the material world," says he, " could not but early excite the curiosity of a being who, like man, receives his strongest impressions from without, yet an accurate knowledge of those phenomena, and their laws, was not to be speedily acquired. The mere extent and variety of the objects were, indeed, such obstacles to that acquisition, as could not be

surmounted

surmounted but in the course of many ages. Man could not at first perceive from what point he must begin his enquiries, in what direction he must carry them on, or by what rules he must be guided. He was like a traveller going forth to explore a vast and unknown wilderness, in which a multitude of great and interesting objects presented themselves on every side, while there was no path for him to follow, no rule to direct his survey, and where the art of observing and the instruments of observation, must equally be the work of his own invention. In these circumstances, the selection of the object to be studied was the effect of instinct rather than of reason, or of the passions and emotions, rather than of the understanding."

* * * * *

"In a science which treated of events and of change, the nature and properties of motion came of course to be studied, and

Mr. Playfair, after particularizing some of these fine ideas of the ancients, proceeds with the following :—" But, notwithstanding the above, and a few other splendid conceptions, which shine through the obscurity of the ancient physics, the system, taken on the whole, was *full* of *error* and *inconsistency*. Truth and falsehood met almost on terms of equality ; the former, separated from its root, experience, found no preference above the latter ; to the latter, in fact, it was generally forced to give way, and the *dominion of error was finally established*.

" One *ought* to *listen*, therefore, with *caution* to the ENCOMIUMS sometimes bestowed on the philosophy of those *early ages*. If these encomiums respected only the talents, the genius, the taste of the great masters of antiquity, we would subscribe to them, without any apprehension of going beyond the truth. But if they extend

tend to the methods of philosophizing, and the DISCOVERIES actually made, we must be excused for entering our dissent, and exchanging the language of panegyric for that of apology. The infancy of science could not be the time when its attainments were the highest; and before we suffer ourselves to be guided by the veneration of antiquity, we ought to consider *in what real antiquity* consists. With regard to the progress of knowledge and improvement, "*we* are more ancient than those who went before us."* The human race has now more experience than in the generations that are past, and of course may have been expected to have made higher attainments in science and philosophy. Compared with natural philosophy, as it now exists, the ancient physics are rude and imperfect. The speculations contained in them are vague and unsatisfactory, and of little value, but as

* Bacon.

as they elucidate the history of the errors and illusions to which the human mind is subject."

* * * * *

"Extreme credulity disgraced the speculations of men who, however ingenious, were little acquainted with the laws of nature, and unprovided with the great criterion by which the evidence of testimony can alone be examined. Though *Observations* were *sometimes made*, *Experiments* were *never instituted;* and philosophers, who were little attentive to the facts which spontaneously offered, did not seek to increase their number by artificial combinations. Experience, in those ages, was a light which darted a few tremulous and uncertain rays on some small portions of the field of science; but men had not acquired the power over that light which now enables them to concentrate its beams, and to fix them steadily on whatever object they wish

to

to examine. *This power* is what distinguishes the modern physics, and is the *cause* why *later* philosophers, *without* being *more ingenious* than their predecessors, have been *infinitely more successful* in the *study* of *nature.*"*

I was desirous to have written, and first did intend to write this Essay, merely as exhibiting my own idea of the circulation of the blood, without even mentioning Mr. KERR's work, as I am particularly solicitous to avoid giving offence to him, or any who may agree with him in the opinions which he has so ingeniously stated against the Harveian doctrine. But I found that in this

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* Dissertation Second, exhibiting a general view of the progress of Mathematical and Physical Science, &c. by John Playfair, Professor of Natural Philosophy in the University of Edinburgh, &c. &c. &c. Vide Vol. ii. Part i. Supplement to the 4th and 5th editions of the Encyclopedia Britannica.

this manner of writing I could not fairly meet Mr. KERR's arguments, and shew, by analyzing them, wherein I conceive their fallacy to lie. Conscious that nothing disrespectful is intended on my part, I trust that the freedoms which I have been obliged to take, can give no offence to an author, who rather invites than shuns such investigations.

"*Nos et refellere sine pertinacia, et refelli sine iracundia parati sumus.*" CICERO.

As I have had but very little practice in writing, for numerous defects of style and composition in this confessedly hurried production, I have every apology to make. But I have one great encouragement in venturing to publish the following imperfect observations; that the undertaking itself has met the approbation of those whose opinion I thought most worthy of confidence, and to whom I communicated my design. I particularly allude to one gentleman,

tleman, who, in point of science in general, but particulraly in minute and accurate knowledge of anatomy and physiology, is at least equal to any of the present day; and who assured me of his entire approbation of the present undertaking.

Verba gignunt verba.

BACON.

OBSERVATIONS,

&c.

In endeavouring to investigate the validity of Mr. Kerr's reasoning against the Harveian doctrine, it will be necessary often to refer to many passages of his work, and to comment upon them. This I shall attempt to do, without clogging my remarks with unnecessary quotations.

In the first place I consider that every doctrine or theory, however specious, if it be inconsistent with plain matter of fact, and inconsistent with itself, must necessa-

rily be false; and in the following discussion, I trust it will appear that Mr. KERR's doctrine is both inconsistent with fact, and inconsistent with itself.

Though Mr. KERR sets out with an unwarranted and unlimited praise of the ancients, and compares their medical works with their works of genius, as music, poetry, painting, and other fine arts, which is glaringly an incorrect analogy and comparison, I shall wave all discussion on this subject, thinking it foreign to the present enquiry, and shall only remark that works of genius, such as I have mentioned, may be carried, and have often been carried, to the highest pitch of possible perfection, by the endowments of a single man, uncommonly gifted by nature; but he can never transfer this wonderful art to another, and it dies with him. The fine arts, on this account, have not made an improvement commensurate with the time

that they have existed, or been studied by mankind. It is otherwise with such a science as medicine; for the works and labours and discoveries of every individual may be preserved and recorded for the benefit of posterity; and each generation, by adding something to the stock of knowledge, makes the improvement, however gradual, still in some measure certain. It is thus that medicine has been a science progressively improving, since its first rude and imperfect beginnings, to the present day; when it must be allowed that it has attained a high degree of perfection, though many things still remain very obscure, which we hope will be yet explained as science advances.

"Veniet tempus, quo posteri nostri tam aperta nos nescisse mirentur."*

Mr. KERR, after giving us a brief statement of Harvey's doctrine,† tells us, that,

 "with

* Seneca. † Kerr's Essay, p. 10.

" with the exception of Riolanus, and a few others, physicians and surgeons immediately concurred in the new theory, which, for the last two hundred years, has been made to account for many of the phenomena of physiology, and *powerfully* influences *practice* in *all* its branches." This I partly believe ; but I rather think there were a good many who exerted their utmost efforts to overturn the doctrine of Harvey ; and this they did, not by studying the anatomy of the human body, and, after giving a faithful description of the structure of the parts, endeavouring to draw sound conclusions concerning their functions ; but by feigning all kinds of impossibilities, making pores and side passages through the *septa* of the heart, and substituting hypotheses the most gross and absurd for his true and beautiful theory.*

If

* " Riolanus," says Bell,* " was the bitter enemy of Harvey and his noble doctrine ; and this is the miserable

* Vide J. Bell's Anatomy, vol. i. p. 459.

If the Harveian doctrine, since its introduction, "has been made to account for many of the phenomena of physiology, and *powerfully influenced practice* in all its branches," I think the inference is clear, that it must have produced some powerful change in practice, either to the better or to the worse; but we are told in the next

 paragraph

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and confused notion, not to call it a doctrine, which he trumpeted through Europe in letters and pamphlets. To make good this miserable hypothesis, Riolanus, Gasendus, and many others, saw the necessity of having side passages through the septum of the heart. I really believe, from their mean equivocating manner of talking about these passages, that they had never believed them themselves. 'The chyle,' says Bartholine, 'and the thinner blood, passes through the septum of the heart, when the heart is in *systole*, and the pores and passages are enlarged.' Thus did the celebrated Bartholine believe the septum perforated. Wallæus and Marchetti, Mollinettus and Monichen *believed it*, and Mr. Broadbecquius of Tubingen *proved it*." Boerhaave says of Riolanus, "Non ipse callidus cavillationum artifex Riolanus," &c.

paragraph, that it brought about no important improvement; and in the subsequent pages, that there was little or no change in practice, but that they continued to bleed from the veins and arteries (though the latter do not contain any blood!!) as before; and with equally accurate conceptions of what they were doing: "that the cure of diseases was as well ('not better') understood in their times as now:"* in short, that the reasoning and practice of the ancients was as sound and successful as of the moderns, since the introduction of the Harveian doctrine. It will at least be allowed, that our practice is not worse than the ancients, and Mr. KERR has proved that it is not better, (which every body else will be ready to deny,) and from this statement I should be happy to learn how we are to infer "the powerful influence on practice" which we were previously informed the Harveian doctrine had produced.

I agree

* Kerr's Essay, p. 12.

I agree with Mr. KERR that there are a great many excellent observations, and judicious practical remarks, in the writings of Aretæus, Galen, Oribasius, Paulus Ægineta, Actuarius, and others; but it must be allowed that the moderns have the advantage of their knowledge, with innumerable discoveries and improvements superadded since their time.

That Harvey founded his reasoning on the most direct and conclusive experiments, and not "on probabilities,"* is most clear from every part of his book. And the validity of his reasonings, and the truth of his conclusions, will, I believe, be denied by none, but those who are biassed by scepticism.

Nor has Harvey overlooked the most formidable objections to his doctrine; for he was at pains to explain those which occurred to

* Kerr's Essay, p. 15.

to himself, and those also which were pointed out to him by others. But we are rather surprised when Mr. KERR informs us, what are "the most formidable objections to his doctrine," in a foot note.* "For example," says he, "when we find in a case of phthisis pulmonalis, that an entire lobe of the lungs has been destroyed for some time before the patient's death—a case that not unusually occurs—how then is the continuity of the circulation preserved? In such cases, it is true, Mr. Abernethy has found the foramen ovale open; but that circumstance will not explain why effusion of blood does not take place in the thorax, or why penetrating wounds in the lungs are not attended with a fatal effusion of blood." I think it will not be difficult to prove that this paragraph is very incorrect in many respects. In the first place, I believe the plainest man alive will see, at the slightest glance,

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* Kerr's Essay, p. 15.

glance, that there is here, not only not "the most formidable objection" to the Harveian doctrine, but that there is not the shadow of an objection; nay, that there is actually a confirmation of that doctrine evinced in it; for in answering the question we include a strong proof of the circulation. If Mr. KERR be minutely acquainted with the anatomical structure of the various organs of the human body, and, among the rest, that of the heart and blood-vessels, as I believe he is, and as every Surgeon ought to be, he should have considered that the pulmonary artery, soon after emerging from the right ventricle, divides into two main branches, below the concave arch of the aorta; the right branch, passing behind the curvature of the aorta and superior vena cava into the right lung, in which its ramifications are dispersed to a very great degree of minuteness: the left branch is rather shorter, and is distributed through the left lung, in a similar manner as the right branch.

branch. Two venous trunks return the blood from the right lung, terminating in one side of the left auricle; and in a similar manner two venous trunks return the blood from the left lung, terminating in the opposite side of the auricle. It plainly appears, that if one of the lungs be destroyed by disease, the remaining branch of the pulmonary artery will convey the blood, from the right ventricle into the sound or remaining lung; and that it will be returned to the left auricle by the two corresponding veins, which terminate there. Here we have as complete a circle for the blood as ever; and it is so plain a matter that he who runs may read. This explanation equally applies, whether a whole lung is destroyed, or only a lobe, as Mr. KERR mentions. We are told also, that the remaining vessels of the lungs are not enlarged* in these cases. This is, certainly,

contrary

* Kerr's Essay, p. 95.

contrary to all analogy; for we find, when a trunk of an artery is obstructed, that the small collateral branches which carry on the circulation are always very much enlarged and tortuous, according to the exigency of the case, or the quantity of blood which they have to transmit. There is no doubt of the truth of the observation of the celebrated Mr. Hunter, " that vessels have a power of increase within themselves, both in *diameter* and in *length*, which is according to the *necessity*, whether *natural* or *diseased*." This enlargement is a process which, of course, requires time. That no similar enlargement would take place, in the pulmonary arteries, in a sufficient length of time, is not to be believed. But in these melancholy cases it is too well known that the patient, in general, does not long survive such injury to his vital organs; and during the time that he does live, it must be remembered, that the circulation, though carried on, is so but very imperfectly, as well

well as the function of respiration, from want of sufficient room in the lungs to admit a full inspiration; from their being loaded and oppressed with tubercles, usurping the place of their air cells, as well as from their real deficiency of substance. As a proof of this, we see the patient harassed with difficult respiration, often orthopnæa, with great anxiety, lividity about the lips, cheeks, and eyes, and the pulse very much affected. In short, the circulation and respiration, though they are carried on imperfectly for a time, are in every such case more or less impeded and deranged. Dragging such a miserable existence, the sufferer may well be supposed to express himself in the following plaintive strain:

"Now spring returns; but not to me returns
"The vernal joy my better years have known;
"Dim in my breast life's dying taper burns,
"And all the joys of life with health are flown."*

In

* Bruce.

In such cases it is easy to see how the circulation is carried on, though imperfectly; and it is as plain, how useless the foramen ovale would be, though it were open, as Mr. Abernethy has found it. The evil is more from want of respiration than circulation, and to think that the inconvenience to the living functions would, in such an instance, be compensated by the foramen ovale being open, when it is plain it can be of no use, would be as absurd as Count de Buffon's plan of making excellent divers, by causing a greyhound litter among warm water, and afterwards putting the puppies among warm *milk;* so that they were immersed in a fluid of nearly equal temperature with that of the amnios. He used milk in preference to water, in order (as he tells us) that the poor animals might have an opportunity of taking some nourishment occasionally, " if they *found* a desire *for it,*" as well as of learning to swim and dive; and thus he killed two birds with one stone! After telling a very pretty story about the whole phenomena

which happened, he concludes by informing us "that, by employing certain precautions, it is, perhaps, possible to keep the foramen ovale open! and thus to produce excellent divers, or a species of amphibious animals."*

Mr. KERR, after informing us of the utility of the foramen ovale being open in such cases, or hinting at it, makes a very curious observation, by adding that "that circumstance will not explain why effusion of blood does not take place in the thorax, or why penetrating wounds in the lungs are not attended with a fatal effusion of blood!"--- Truly it cannot. Nor can a mill-wheel explain how the stream of water going to it is stopt, or allowed to flow; but we all know that the mechanism of a sluice will do that. In the

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* See a very excellent exposition of this ridiculous notion of Buffon, and of similar ones, about the circulation through the lungs, entertained by others, as Hales, Des Cartes, Derham, &c. in J. Bell's Anat. vol. ii. p. 47.

the same way we know, that the foramen ovale has nothing to do with the matter; but there is a natural process takes place in every such case, when certain circumstances do not concur to prevent fatal effusion. When a lobe of a lung is gradually wasted by suppuration and ulceration, and absorbed, a degree of inflammation always precedes and accompanies these changes; and by this, coagulable lymph is thrown out around the blood-vessels and within their coats, so that adhesion of their opposite sides, and obliteration of their cavity, takes place; and they contract for some length, like a firm solid chord, exactly in the same way, as we know that an artery becomes obliterated by tying a tight ligature round it, though it is immediately loosed. If the ligature has cut its internal coat, so that inflammation and an effusion of coagulable lymph follow, the artery adheres at that part in its opposite sides, and it becomes impervious for a certain space. We see

here a very beautiful contrivance in nature; and the reason why, in cases of abscess of the lungs, we often find the vessels as described by Baillie, in his Morbid Anatomy:* "When blood-vessels," says he, "are traced into an abscess of the lungs, I have found them, upon examination, very much contracted just before they reach the abscess; so that the opening of their extremities has been closed up entirely. On such occasions, it will require a probe to be pushed with a good deal of force, in order to open again their extremities. In these contracted vessels, the blood is coagulated, as it is, under similar circumstances, in other parts of the body † The membranes of the viscera, and particularly the pleura, when inflamed, throw out a mucus, which, in such cases, would unite and shut up the mouths of the vessels,

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* Vide p. 68.

† See Dr. Stark's Work, p. 28.

vessels, where part of the lungs have been wasted by disease. This change in the blood-vessels is, no doubt, with a view to prevent large hemorrhages from taking place, which would be almost immediately fatal."

But though this takes place in many cases, yet the patient is not always so fortunate; for when ulceration of the lungs has proceeded very rapidly, or some large abscess has burst suddenly, owing to some violent exertion of the patient, a large blood-vessel has been eroded or burst by this, and a great effusion of blood taking place into the chest, and choaking up the bronchi, the patient has instantly died. As to penetrating wounds of the lungs, we may be certain, that if they divide any of the large arterial or venous trunks in the chest, they will be fatal. How they are not so, when only penetrating the substance of the lungs, and not wounding any im-

portant vessel, we may easily understand, by considering how hemorrhage is stopt by a natural process in general, and how the lung falls collapsed till the wound is healed. We have many extraordinary instances of this in our books of surgery.

We come now to that part of our author's publication which requires the most pointed refutation.—"Thus,"* says he, "the circumstance of the arteries being found empty after death, with the exception of some grumous blood, found in the left ventricle, and commencement of the aorta, is explained upon the Harveian hypothesis, by the assumption that, at the approach of death, when the extreme vessels are losing their action, and the limbs turning cold—yet, at the very last moment, the *nisus* of the heart and vessels is sufficient to throw the whole contents of the arterial system into the veins.

"But

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* Kerr's Essay, p. 15.

" But the veins are not found distended after death; on the contrary, they shrink in many parts of the body, the cold condensing their contents; nor are they in capacity equal to receive, in addition to their usual contents, a quantity of blood sufficient to fill the arterial system, as the simple inspection of a blood-vessel subject sufficiently shows. In cases of suspended animation, when the motion of the heart has ceased, it is reasonably to be supposed that the whole blood has then accumulated (as we say) in the venous system, although no marks of distension appear in the veins; yet in such cases life may be restored: and, according to Haller, no patient is to be despaired of, whose skin does not retain a pit from the pressure of the finger, shewing that the fat contained in the cellular substance is congealed, when perhaps we may also infer that the blood has become grumous in the veins.

" In

"In this instance, the assumption made by Harvey appears, at once, unphilosophical, and contrary to fact; for whether a man dies by protracted struggles, or is instantly killed by lightning, or the equally sudden effects of a noxious gas, still the blood is found in the venous system, and is never detained as if *in transitu* through the arteries, unless these vessels have suffered injury, or death has been occasioned by suffocation."

We shall here give a sketch of the arterial and venous system, which will serve as a foundation for our reasonings in the remaining part of this Essay.

The arterial system resembles the trunks and branches of two trees: one, arising from the right ventricle of the heart, is called the pulmonary artery, which ramifies through the lungs; another, taking its origin from the left ventricle, called the aorta, and whose

whose branches are ramified through all the parts of the body. The branches, after dividing successively, become at last as minute as hairs. The combined area of the branches is always greater than the area of the trunk from which they spring: but this seems in no regular proportion. After the branches of arteries have exceeded a certain degree of minuteness, we are incapable of seeing them by the naked eye, or by a microscope; but by an injection of a thin solution of size coloured, we render the most minute capillary branches visible, by applying a microscope, especially in parts naturally transparent; though they can seldom be seen by the naked eye. "From injections of this sort" (Dr. Gordon remarks) "all our knowledge of the ultimate ramifications of the arteries has been derived."*

After

* P. 55.

In this description I have to observe that I am indebted chiefly to Dr. Gordon's first vol. of Anatomy, lately published, which I consider by far the best and most correct performance on that subject.

After the branches of the arteries have diminished to a very great degree of minuteness, "all the capillary arteries are seen to terminate in one or other of two ways; they either pass distinctly into the capillary branches of veins, or end abruptly, unconnected with any other vessel."* Perhaps, in this latter case, they are continued much farther than they are seen to do by microscopes. The *termination*, however, of *arteries* in *veins* is most satisfactorily demonstrated; and it is the only one which is clearly demonstrated.† Dr. Monro, jun. says, "most of the branches of the arteries, whether conveying the red or the colourless

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* Gordon's Anatomy, vol. i. p. 56.

† "The termination, then, of arteries in veins is the only one admitting of being satisfactorily demonstrated."—Gordon's Anatomy, p. 56. Every anatomist of modern date acknowledges that this termination of arteries in red veins is demonstrated by the microscope. *Fyfe, Bell, Monro,* &c.

colourless part of the blood, terminate directly in those veins which convey the red part of the blood." And, when speaking of the veins, he says "the smaller branches of the arteries are continuous with the veins."*

Ruysch thought he could perceive arteries distinctly terminating in what are called excretory ducts; but, although this termination is not doubted, it does not appear to be fairly confirmed in the way of demonstration.

Upon the whole, it is most probable that there are exhalent vessels, minute terminations of arteries called serous arteries, which are not directly continued into veins; but which terminate upon the external surface of the body, or upon the internal cavities, discharging their contents there; in which

* Vide Outlines of Anatomy, vol. ii. p. 343 and 344.

which latter case the fluid so discharged is absorbed again by the lymphatic absorbent system, and conveyed round to the subclavian vein, where the trunk of the absorbent system terminates. It is also probable that there are colourless capillary branches of arteries, which convey only the colourless lymphatic or serous part of the blood, not being large enough in their sound and natural state to admit the red globules or particles of the blood; but which have corresponding minute colourless branches of veins, which return their contents into the more capacious red veins. Such a structure and circulation we must suppose to exist in the cornea, cartilages, and in all the colourless parts of the body. These opinions are supported by many of the most eminent anatomists of modern times.

The sides of the branches of an artery are always thinner than the sides of the trunk

trunk of the artery from which they arise. Arteries are endowed with a remarkable elasticity, which they possess both in the longitudinal and transverse direction; but it is not exactly ascertained whether they are uniformly more elastic in one direction than another. We never find arteries after death, even the larger ones, though empty, collapsed; when cut across, they appear cylindrical, and this is entirely owing to their elasticity. Of how opposite a nature the veins are we may easily conclude from this—that, when empty, we always find them collapsed and folded. Some experiments made by Dr. Gordon shew, that the carotid and iliac arteries, cut out a few hours after death, bore weights of 30 and 48 lbs. before they broke.

The arteries are distinctly seen to have three coats. The inner coat is a transparent membrane, very thin, smooth, and dense, like the lining membrane of the

ventricles of the heart, and prevents the blood from transuding.

" The middle coat of an artery is the thickest, being about twice the thickness of the *outer* one ; and this proportion it seems to me to maintain, in the smaller, as well as in the larger vessels.

" It consists of a stratum of slender fibres, laid closely together, side by side, without any intermediate connecting matter, and placed uniformly in a circular direction, surrounding the artery, and in a plane perpendicular to its axis.

" In the large arterial trunks the fibres are firmer in their consistence, and of a yellowish or straw colour ; but as the vessels diminish to a middling size, they become gradually softer, and more flesh-coloured, and then resemble very much the *muscular*

fibres

fibres of the heart."* This coat is very vascular, as is shewn by injection.

The external coat is extremely dense and tough, composed of white shining fibres, closely compacted, and interwoven in every direction. Arteries, absorbents, and nerves, are seen in this coat. It is by far the strongest and most elastic coat, though the other two coats also have a degree of elasticity. It is much owing to the elasticity of this external coat, however, that arteries, when they receive the blood from the heart, become elongated and dilated; and start suddenly, as it were, out of their place, forming the pulse or diastole of the artery. By the same power, and the contraction of the muscular coat, they suddenly recoil. This coat is quite different from the common coat, usually described as of cellular membrane surrounding the artery; a cellu-

 lar

* Gordon's Anatomy, vol. i. p. 59.

lar covering only surrounds some arteries, but this external coat is constant, though, by confounding the one with the other, many have overlooked this important external coat. As far as can be observed by the microscope, the most minute arteries have the same structure.

VEINS.

The veins may also be said to be like the trunk and branches of a tree; but the order is here reversed as to the course of the circulation.

"All the *veins* of the body, therefore, are said to arise from the minute *capillary branches* of the *arteries;* and, uniting one with another, to form, at last, seven principal trunks."* The veins are, in general, cylindrical;

* Gordon's Anatomy, p. 62.

cylindrical; but they often swell out into sinuses, very frequently owing to the valves with which they are provided. The commencements of the veins from the minute capillary arteries, though sometimes, yet are seldom perceptible to the naked eye, owing to their minuteness. But these origins of the veins may be shewn and demonstrated in the same way as the capillary terminations of arteries, viz. by a fine injection, and the microscope. "When we apply the microscope, then, to a part properly injected, we can *distinctly* trace every *capillary vein* which is visible, into some *corresponding capillary artery*. All the veins appear to be continuations of the arteries; if they have any other origin, it has not yet been satisfactorily demonstrated."* Dr. Monro's words are these: "the blood which is distributed by the branches of the arteries, is brought back again by the veins,

* Gordon's Anatomy, vol. i. p. 63.

which are continued from the smaller branches of the arteries, as may be seen in the pellucid parts of animals; and, by throwing a penetrating liquor into an artery, it flows into the veins."*

The combined area of the branches of the veins is, like arteries, always larger than their trunks; not in an uniform ratio, but often as two to one. The larger branches of veins anastomose much more frequently than the arteries do. Throughout the body the venous trunks are more numerous and larger than arteries of equal diameter. The combined area of the veins, compared to that of the arteries, over the body, is supposed by the calculation which we have from Haller, and which is allowed to be pretty near the truth, to be as nine to four. If we were to take the bore or calibre of these vessels, without taking into the account

* Outlines of Anatomy, vol. ii. p. 356.

count the coats, though in truth the one cannot exist without the other, I would suppose the ratio of the veins to the arteries would be as nine to three, or as three to one. The greatest part of the veins in the external parts of the body are furnished with valves of a semilunar or parabolic shape, either single or double, which last is the most common, or triple, which is the least common arrangement. They prevent the reflux of the blood from the trunks towards the branches of the veins; though they seldom are so nicely adapted to each other as completely to obstruct the return of the blood. They are most numerous in the small veins. Some of the veins of the viscera, or internal parts, also have valves; as the spermatic veins, sometimes the branches of the vena azygos, and internal mammary veins.* When the veins are distended,

* The valves of the veins were discovered by Fabricius ab Aquapendente, though he was ignorant of the circulation, or their proper use.

tended, they swell out at the valves, forming small sinuses of an oval figure. Though veins are, in some degree, elastic, they are not nearly so much so as arteries, which is proved by a very common circumstance; for the arteries, though empty, and cut across, gape, and retain their cylindrical appearance; whereas veins, when empty, fall collapsed. Arteries appear also to be more dense in their coats than veins. The veins have two proper coats, which are thin, membranous, and transparent, so that the colour of the blood is seen through them. A fibrous structure, somewhat intermediate between the nature of the middle and external coat of an artery, is traced in the large veins, viz. the venæ cavæ, near the heart. The veins have no muscular contraction similar to arteries.

In giving this short account of the system of arteries and veins, as all our arguments

ments must rest more or less on it, I did not think myself at all warranted to do so from my own observation; I have, therefore, chiefly taken it from Dr. Gordon's System of Human Anatomy, lately published, which I believe to be the most correct.

Having premised this account of the blood-vessels, I think it is easy to account for the circulation of the blood, and the appearances after death.

The blood being returned from all the parts of the body by the two venæ cavæ, and the vena cornaria cordis, passes into the right auricle of the heart, which it distends, stimulates, and excites to contraction; by which it is propelled into the right ventricle, which, in its turn, being filled, the valves allowing this to take place, contracts and sends its blood through the pulmonary artery, whose branches are ramified minutely

nutely in the lungs. From this the blood passes by the four pulmonary veins (a free anastomosis existing between the capillary branches of the pulmonary arteries and veins) into the left auricle, which, being stimulated to contraction, like the right side of the heart, throws its blood into the left ventricle, which, by a very powerful contraction, propels its blood into the aorta, to be, by the assisting contraction of the arteries themselves, distributed over all the body. At last, part of the blood passes, by the minute capillary branches of the arteries, into the corresponding anastomosing minute beginnings of the veins, to be returned again to the right side of the heart.

Part of the blood must also be expended in forming the various secretions performed in some inscrutable way by certain of the minute capillary arteries, and which continually renovate and supply the place of the wasted, effete, or absorbed parts of the system,

system, which process of waste and renovation we believe is continually going on. Part of the blood must also be expended in forming the various secretions, as in glands, which are carried away by ducts into their receptacles, and finally discharged from the body, as the urine, saliva, tears, bile, and semen; or more immediately the perspirable matter continually exhaling from the skin, and which, from certain causes, often amounts to an enormous quantity in a day. Part of the blood must also be expended in forming the fluids which are continually exuding on the cellular membrane and cavities, and which are taken up by the valvular lymphatic absorbents, and finally discharged into the venous system, though not directly, as in the common way of circulation.

The heart, which is a most powerful muscle, and of the involuntary kind, sends a quantity of blood equal to two or three

ounces,

ounces, at each contraction, from the auricles into the ventricles; and the same quantity from the ventricles into the pulmonary artery and aorta.

The heart is as it were a forcing machine, placed in the centre of the circulating system, to restore the due motion to the blood, which it is always losing in its course through the arteries and veins. The action of the heart is not under the controul of conscious volition, nor in general influenced by the mind; but indirectly, as by various passions, which excite the nervous system, when the circulation is quickened; or by others, having a sedative power, which render the circulation more languid and slow. The nervous and vascular system seem also to have a mutual sympathy, or to affect one another *invicem.* Dr. Monro, sen. found that, by injecting a solution of opium under the skin of the leg of a frog, the leg so treated, and also the most distant organs,

were

were affected; which, he concludes, must have been from sympathy of nerves: because, when the heart was cut out, or the blood-vessels of the thigh tied, no such affection ensued. The action of the heart seems to depend upon, and to be produced by various causes very different from other muscles. It seems to be so far independent of the brain or nerves, as it continues its action, when cut out of such a creature as a frog, for some time; or when the head has been cut off, and the heart left; or after the nerves going to the heart have been cut.* Both Bichat and Brodie have shewn that the influence of the brain is not so essentially necessary to the motion of the heart, as we should suppose, the latter continuing after the influence of the brain was cut off, and ceasing only when the respiration was suspended; also continuing longer, if the

* Monro.

latter was kept up artificially;* which shews that the action of the heart is connected with the change which respiration produces on the blood. Its contraction in the living body is caused by the blood; in the dead body, by other stimuli applied.

In a state of perfect health, the blood in general flows pretty equally in the branches of the arteries; but many accidental causes tend to disturb this equal flow, and to produce partial actions. It flows more rapidly in the trunks than in the branches of the blood-vessels, because the combined area of the latter is wider.

As the arteries are endowed with a muscular coat, and also a very elastic one, they contract and relax themselves alternately, according to the condition of the exciting cause:

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* Bichat's Anatomy—Phil. Trans. London, 1810—and Med. and Phys. Journal, vol. xxvi.

cause: on this account they pulsate, and propel the blood with much greater velocity than they could otherwise have done. As the veins have no muscular coat, and comparatively little elasticity, they do not pulsate, nor transmit their blood so rapidly, but it flows in an uniform stream towards the heart. The slow progression of the blood in the veins, and their want of muscular contractility, is compensated, in carrying on the circulation, by their valves, their greater number and size. For it is evident, as the veins of any member must return in any given time as much blood as is transmitted to it by the arteries, that, therefore, the veins must be proportionally larger and more numerous, as a compensation of velocity; otherwise an accumulation and regurgitation would take place.

All these curious phenomena of the blood, going out florid by the arteries, and returning purple by the veins, and the ex-

citement from local stimuli, is beautifully seen by a microscope in the web-foot of a frog.

The circulation of the blood is also proved in the clearest manner, when we add all the circumstantial and corroborative evidence. It is proved by the structure of the valves, which, being placed in the beginning of the pulmonary artery and aorta, prevent the regurgitation of blood back into the ventricles, and allow its progress out from the heart; and in the veins, over the external parts of the body particularly, which, by their peculiar arrangement, prevent the return of the blood, and allow its progressive motion towards the heart. It is proved by ligatures put on arteries and veins, which make the former swell on the side nearest the heart; and the latter on the side farther from the heart. We have already said that it may be seen in the pellucid parts of animals, particularly in the

web-

web-feet of the frog, and others of similar structure. It is also beautifully seen in the membranous lungs of the lacertæ by a magnifying glass, or even by the naked eye; the very course of the blood from the extreme pulmonic arteries into the veins is seen in the membranous lungs of these animals.*

"When we open a frog, or a newt, or other amphibious creature, we see a long and slender artery, accompanied by a slender vein, running from top to bottom, along the whole surface of their lungs; and, while the heart continues to beat, we see this pulmonic artery black, the veins red, the lungs themselves most delicate and pellucid, like the swimming bladder of a fish."†

* Charles Bell, vide Anatomy, and others.

† J. Bell, vol. i. p. 476.

The circulation is imitated by throwing an injection into arteries; and it is proved also by the hemorrhage from an artery which is divided.*

The veins and ventricles, the auricles and arteries, are said to contract simultaneously, though, as the veins do not properly contract, but merely convey their blood chiefly by other powers than their own contraction, it would be more proper to say, they deliver out their blood in this order of succession, which is certainly an additional proof of the progressive motion of the blood. In *articulo mortis*, or in the moribund, the left ventricle first ceases to act; I suppose partly from a want of a due supply of blood, to distend the ventricle, and partly from what blood is in it being effete for want of that change which respiration produces upon it in the lungs, and which

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* Monro's Anatomy.

which imparts to it its proper stimulant power, or quality. The auricle of the same side is observed to shew some slight signs of contraction longer than the ventricle does. The right ventricle ceases next. As the blood is gradually accumulating in the veins, and making its way to the right side of the heart, the right auricle is observed to palpitate longest; and, from the full and distended state of the venæ cavæ, a degree of this palpitating motion is communicated to them. Hence Galen called the right auricle "ultimum moriens."

There is evidently a strict connection and a mutual dependance between the functions of respiration and circulation, though the circulation of a dark-coloured blood will be carried on for some time after respiration has been stopt, by a division of the spinal chord high in the neck.*

When

* Cruickshank's Phil. Trans. London, 1795.

When the sternum and cartilaginous ends of the ribs of a living dog are cut, and raised, the lungs suddenly collapse; soon after, the circulation of the blood and motion of the heart cease, and the right side of the heart and vena cava are in a short time observed to be distended and gorged, as if ready to burst.* It was experiments like these, made on living animals, and the empty state of the left side of the heart and arteries often observed after death, which deceived the ancient physicians, and made them believe that blood was contained only in the veins and right side of the heart, and animal spirits in the left side of the heart, and arteries.

The motion of the blood, and the actions by which it is carried on in a circle, are thus accounted for. The contractile power of the heart throws the blood into the

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* Parisian Dissections, p. 261.

the arteries with a very strong impulse; but not sufficient to send it to the most distant parts of the body, circulating with due force; though at every beat of the heart, at the same time, we perceive the pulse in the most distant parts. The great and peculiar power of the arteries seconds the action of the heart. When, by the stroke of the heart, the *systole*, or contraction of the left ventricle, the aorta is distended, it contracts in its turn, being excited by this distension and fulness, and sends the blood forwards with great additional velocity. *At the same moment* every part of the arterial system must be distended and excited to contraction, because it is completely full of a fluid, moving with great velocity, and the pulse is one of the best proofs of its fulness. If the arterial system, or if both arteries and veins, were not full, a quantity of blood thrown in, even with great force, would produce little protrusion or tension of the arteries, such as makes the

pulse;

pulse ; because resistance would be wanting, and a space being ready to receive the additional quantity of blood, that already contained in the arteries would be merely moved forward, filling the vacant space, and giving way to the new blood. But as the arteries, and the continuous vessels the veins, are already full, any additional quantity of blood forced in must distend and stretch the whole arterial system, and communicate the impetus impressed to the most remote parts of it ; and thus move, at the same instant, the most distant part of the fluid, because it is incompressible, and in this respect the same as a solid body. In a perfectly rigid tube, this motion would be simultaneous, in the part of the fluid most distant from the impinging force : if very dilatable, the motion would be communicated to the remote parts in a slower and more progressive manner : if strong, dense, and not easily dilatable, the difference *would be almost imperceptible between this*

and

and the first case of a rigid tube; for only some particles of the fluid would pass by the side of the column, owing to the slight dilatation; the rest would force forwards the column contained in the tube, and the motion would be communicated to the most distant part of the fluid, at the same moment, as in the case of a solid body.

The pulse of the arteries all over the body being synchronous with the beat of the heart, is simply and amply explained by a well known law of physics, viz. the *communication of motion or collision.* When a moving power has imparted motion to any inert matter, this motion is also communicated by the body thus moved, to all those which are within the sphere of its action. Thus the earth, in its various motions, carries along with it all the loose substances on its surface. When both the impinging bodies are in motion, either in the same or in contrary directions, the term collision

is

is applied. They are relatively at rest, if they both move the same way, with equal velocities. If two non-elastic bodies move in the same direction, their velocities, after the stroke, are equal, and they move forward in one mass. In these cases the velocity and momentum of each of the bodies may be determined *a priori*, and proved afterwards by experiment. If one moving body overtake another body in motion; after the stroke, the common velocity will be equal to half the sum of the velocities before it. The following very simple illustration of the communication of motion is commonly given. If a number of ivory balls are so hung by cords as to form a row, touching each other—if the ball at one end is struck, at the same instant of time the ball at the other extremity, however long the series may be, flies off.

The experiment which I tried, to prove that this instantaneous communication of motion

motion is the cause of the pulse, and, at the same time, of making it synchronous with the beat of the heart, appears to me decisive on the point, and I think it will also appear so to every candid person. I took a piece of the intestine of a small animal, of about two feet in length, and it was about the same caliber as the femoral artery in a full grown man, evidently more dilatable, and endowed with less elasticity; but, upon the whole, very much the same as a large blood-vessel. I tied one end, and filled it with water at the other, which I then also tied. I then laid it out straight on a table, and, by pressing on one end, so as to force the fluid out of that part, and along the canal of the intestine, and, at the same time, resting the finger on the other end, I produced exactly the phenomena of the pulse, which was synchronous with the pressure made at the other end of the gut. The moment that we grasp or press one end flat, the whole gut becomes tense and

dilated, and starts upwards, and a simultaneous beat or pulse is produced at the farther end. By alternately grasping and relaxing the end of the gut, an alternate dilatation and relaxation takes place; and the pulse, as of an artery, perfectly synchronous with the contraction of the heart which causes it, is thus produced. That I might make the experiment more resemble the heart and arteries, I attached a bladder filled with water to one end of the gut, and, by forcing the fluid out of the bladder into the gut, I found the beat at the other extremity of the gut exactly synchronous with the contraction of the bladder.

These two modes of trying the experiment are, in reality, the same in effect; for in both, a portion of fluid in one end of the gut has an impetus given to it, so that it propels the column below, and produces a distension and starting of the tube, and a pulsatory motion, which is felt at every

part

part of it exactly at the same point of time; or a beat synchronous with the contraction which gave the impetus, like the pulse at the wrist, which is synchronous with the beat of the heart, caused by the contraction of the left ventricle. When the bladder is used, an additional quantity of fluid is thrown into the tube, and, by producing a distension and pulsation of the whole at the same moment, we have an exact imitation of the pulse. The length of the intestine used was two feet, which is as satisfactory with regard to the result as if it had been four, or more; for it was not far short of the length of the radial artery from the heart in the left side. Here there is not such a progressive motion as Mr. KERR has described, and which, he says, makes it impossible that the pulse can be synchronous with the beat of the heart, if caused by its contraction forcing a quantity of blood into the arteries at each stroke.

Supposing the circulation to begin, and the heart constantly supplied with blood, as soon as the arterial system became full, the pulse at the wrist would, necessarily, from the nature of things, and the common laws of physics, be synchronous with the beat of the heart. The contraction of the left ventricle of the heart forces, with great velocity, an additional quantity of blood into the arteries, these being already full. This impetus cannot be exerted with much effect laterally, on account of the very small degree of dilatation of which they are capable, though it is a fluid exerting its force equally in all directions; it must therefore, because it is incompressible, press forward the whole column of blood in the arterial system, at the same instant. Its force being concentrated in one direction by the resistance of the sides of the tube in which it moves, the impetus on

one

one end must instantly be felt at the other, just as if it were a solid column.*

The experiment which I have mentioned is decisive and incontrovertible with regard to the manner in which the pulse is caused, and explains it in the clearest and simplest manner. Nor need we seek an explanation of it by any hidden, undefinable,

 occult

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* " Quoique la vitesse avec laquelle le sang cpule dans l' aorte, n' ait été estimée qu' à huit pouces environ par seconde, le mouvement pulsatif se fait sentir, dans toutes les artères d' un certain calibre, au même instant que les ventricules se contractent. Si les battemens du cœur nous paroissent isochrones à ceux des artères, c'est que les colonnes du sang qui remplit ces vaisseaux, sont toutes ébranlées à la fois par celui qui sort des ventricules, et que cet ébranlement se transmet dans un moment indivisible, semblable á celui que ressent la main placée à l' extrémité d' une longue poutre, lorsqu' on frappe avec un marteau son extrémité opposée."

Richerand, Physiologie, vol. i. *p.* 323.

occult power, as elemental fire, when we clearly see that it can be simply explained on common principles. It is no objection to the experiment that the tube was close at the end; for, by doubling it, and pressing on the middle of the curve, leaving only a small space pervious, in imitation of the communication of the arteries and veins, the same phenomena are produced.

When, at every contraction of the left ventricle, from two to three ounces of blood are propelled into the aorta, with astonishing force, unless the coats of the aorta dilated so as to hold easily this additional quantity of blood, it must press forward instantaneously the whole column of blood in the arteries, which, being full before, become tense by this additional impulse, and impinging on parts more or less hard or elastic, start from their place, and form the pulse, which must be synchronous over the body with the beat of the heart, as already

ready shewn. The arteries are strong and dense, and not easily dilated; and, therefore, the impetus is exerted longitudinally along the tube of the artery. Indeed, experiments which have been lately made seem to shew that the circumference of the artery in *diastole* is scarcely perceptibly increased.* But this impetus is only momentary, and the artery, from the distension, is excited to contract and recoil, and the *systole* is produced, which is accompanied with a propulsion of the blood onwards, and part of the blood being delivered into the veins, leaves the arteries as before the first contraction of the heart, ready to receive a new quantity of blood, with a new impulse from the heart. These actions are repeated every moment, but when the order of succession is explained, they are easily understood. The

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* Parry on the Arterial Pulse.

When this sheet was going to the press, I was favoured with this very excellent Treatise, lately published by Dr. Parry of Bath. Had I seen it before, I might have more fully availed myself of his very interesting experiments.

The arteries act in a manner precisely similar to the heart; for, whenever the auricle or ventricle is filled and distended with blood, they are thus stimulated and excited to act with great force. It is easy to see how this alternate action going on in the arteries will produce the pulse, without much sensible change in their circumference. But, as may be supposed, the velocity of the blood is greater and the pulse stronger near the heart, and less and weaker in the extreme parts.

What is properly the pulse, or tense and distended state of the artery, called *diastole*, is entirely and solely caused by the contraction of the left ventricle of the heart, as already explained, and is quite independent of the muscular power of the artery; but the subsequent constriction of the artery depends upon the muscular and elastic power of the coats of the artery, which is favoured by the succeeding re-

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laxed state of the ventricle of the heart, and the rapid transit of the blood from the arteries into the veins. This muscular action of the arteries succeeding upon the stroke of the heart, is of the greatest use in propelling forward the blood, and preserving the impetus originally given to the blood by the heart, but which it is constantly losing in its course, from various causes, explained elsewhere.

Bichat has proved that the *pulse* is produced by the blood causing a dilatation of the coats of the artery, by a very simple experiment. He transfused blood from an *artery* of a living animal into the *humeral artery* of a *dead body*, and by that he produced exactly the common appearance of the *pulse*. And Vesalius, by his experiments, has completely proved, that the pulse is owing to the dilatation, or *diastole*, and not to the *contraction* of the coats of the arteries.* The

* Vesal. de Corp. Human. Fabr. lib. vii.

The action of the arteries, seconding the contraction of the heart, and the necessity of their possessing this power, is clearly proved by the diminution of heat and pulse in a paralytic limb, by partial actions, which we every day see, in inflammation, or in the suffusion of the face, called blushing, or *in erectione penis virilis*, or in the secretion of the milk in the breasts of the mother after the birth of a child, or in any other increased secretion, or in active hemorrhage. We see it in a moment, by applying any stimuli to the eye; we see it in the growth of tumors, or from particular causes, affecting the circulation of the brain, as insolation, which, by exciting an increased action in the vessels of the cerebrum, produces phrenitis, or a state similar to apoplexy.* And we have here another strong

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* " C'est ainsi que l' artère radial offre cent pulsations par minute, dans un panaris des doigts tandis que

strong proof of the circulation, and communication between the extreme arteries and veins, viz. that the arteries are never for any considerable time excited to increased action, but the veins of the part also become distended and varicose, from the great quantity of blood poured into them, with great increased velocity; being more than they are able easily to rid themselves of, and thus producing a state of the vessels like what medical authors call congestion. The veins becoming from permanent distension actually larger in diameter, the valves are no longer of use to support the column of blood, and the evil becomes more and more aggravated. The most experienced Surgeons tell us, " that, whenever, in any external and surgical disease, they observe a dilated state of the veins, they

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celle du coté sain n' en présente que soixante-dix, perfaitment isochrones aux battemens du cœur."

Richerand, Physiologie, p. 346.

they look upon it as a sure sign of high and irritated action of the corresponding arteries."

The action of the arteries is also proved by their contraction stopping hemorrhage; by the circulation being carried on, or continued, when the heart is wanting, in cases of monsters; and from gangrene of a limb being produced by ossification of its principal arteries, a case which has not unfrequently happened in the lower extremities.

The arteries have demonstratively a muscular coat, and muscular fibres are endowed with contractility, as is proved by surer marks than by experiments with *oil of vitriol*, as it is called; and all that Haller, justly styled great and learned, has said on this subject, is false and unfounded. For arteries most certainly, and by every candid experimentalist, have been found to contract, on the application of *mechanical stimuli.*

muli. But we cannot, in the same way, trust to *chemical stimuli.* Do not these change the nature and constitution of the matter on which they operate; as the vessels and contained blood? Experiments, then, with sulphuric acid, are here, I conceive, out of the question, and Haller might have been supposed to have known that.

Besides, the blood-vessels are much more sensible and irritable, on their internal surface, like the cavities of the heart, and to their own peculiar stimulus, (the blood), than on the external surface, or to other matters, not their natural stimuli, especially chemical ones, which change the nature of the substances on which they act. The blood is the only proper and true stimulus to the heart and arteries, as urine is to the bladder, or food to the stomach. The heart and arteries are, too, as we have said, more sensible on their internal than external surface; hence a bubble of air blown into the

heart excites contractions in it at once, when strong acrid stimuli, applied externally, do not affect it in this way. Haller equally denies irritability to the excretory ducts, as the ureters and gall-ducts. Calculi often stick in these from spasm, or this accident is accompanied with spasm; and opium, warm bath, and bleeding, favour their descent. Dr. Monro found, by touching the ureter of a pig, half strangled, that it contracted strongly; and when he moved the point of his finger along the surface of the ureter, a successive contraction of this canal was produced from above downwards. The irritability of the iris can never be denied; but Haller, a sceptical writer, as we must now call him, found no contraction to be produced by the point of a knife.* In operations on the eye, contraction of the iris is almost universally found to take place, from such causes as Haller here mentions;

* Act. Gotting. vol. ii. p. 142.

tions; though here we might adduce the same argument as formerly, and say that light is the proper and natural stimulus to the iris; and it has nothing to do contracting, on the application of any other, more than "a horse should drink ardent spirits, because he drinks the pure stream."* It is but too plain that Haller's opinion of the want of irritability of the iris, the arteries, and excretory ducts, rests on the same false foundation—some strange mistake or inaccuracy in his experiments, or reasoning, or observation. It is also well known, that, though the external surface of the arteries may not have shewn much sign of irritability or contractility, when stimuli were applied there, the internal surface of the vessel, if equally stimulated, would so

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* See Kerr's Essay, p. 40.

"It seems almost as extravagant as it would be to assume, that, because a horse had rejected ardent spirits, he, therefore, would not drink of the pure stream."

affect the vessel, that strong marks of contractility would be seen; and the vessel is so constituted for the carrying on its natural function, viz. that the internal surface chiefly should be calculated to convey the impression of the stimulus of the blood; and it is evident that this is necessary in the circulation of the blood, always going on. In animals, whose breasts have been opened, that are dying, or are newly dead, if a little warm water or air is injected into the ventricles of the heart, this gentle stimulus so affects it as to produce successive contractions and dilatations. But these contractions and dilatations are comparatively very slight, when even the most acrid liquors are applied to the *external surface* of the heart, or if it is pricked with the point of a knife. The stimulus of blood is found also to excite a tremulous motion in this organ, when sulphuric acid applied externally has not the least of this effect. This shews how deceitful Haller's conclu-

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sions were concerning the irritability of arteries.

But that we may make our proofs of the circulation more perfect, it is necessary to shew how permanent this irritable power is, surviving the apparent life of the body; and thus, by the contractility of the heart and arteries, propelling the blood from the arteries into the veins, by a gradual impulse, or by rapid convulsive contractions, according to circumstances; and depending partly on the volume of blood in the vessels. We know that the irritability remains long after the body is dead; in the arteries, the *elastic* power particularly continues long after consciousness and nervous influence have entirely ceased.* In the lacertæ we are told that the head bites half an

* If the arteries be but filled, they will be excited, and, by their own muscular power, will propel the blood.

an hour after it is cut off. The amphibiæ often live, and shew strong marks of irritability, for days after the head is cut off, and heart cut out. A pigeon lives several hours after being deprived of its brain, and even flies from one place to another: a viper lives three days after its head is cut off; and a tortoise for three weeks after decollation, and six months, it is said, after the loss of its brain.* This shews that irritability, permanent and wonderful in all, is most tenaciously retained by some creatures, particularly the amphibiæ and cold-blooded animals. "Il cuore in tutti gli animali, e la fibra carnosa in generale di tutti gli animali di Sangue bianco, e di Sangue rosso, ma freddo, conservano più lungamente questa proprietà ('irritabilità') ancor dopo la morte."† Though I am not so credulous as to believe all marvels told on this

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* Redi Obs. circa Animal. Vivent, p. 207.

† Chiarugi La Fisica Dell' Uomo, tomo ii. p. 193.

this subject, yet we have sufficient proofs of it to know, that it remains long in force after apparent death. And when we see how great its power is, can we be in the least surprised that it continues in the vascular system after the body is sunk weak in *articulo mortis*, so as to expel the greater part of the blood from the arteries into the veins?

It must next be considered, whether, in cases of *slow death*, the veins are capable of containing, besides their own, a quantity of blood equal to that which was contained, before death, in the arteries.

This question must, in a great measure, be decided by probable reasoning; and never can, from the uncertain nature of the data, and the impossibility of mathematical admeasurement being adduced, be fairly demonstrated on either side of the argument. But from very strong probable reasoning,

soning, and the circulation of the blood, and the circumstance of both arteries and veins containing blood in the living body, being proved beyond all dispute, we have such an inference as, I think, no reasonable person can easily set aside, viz. that the veins may and do contain a very great proportion of the whole blood of the body after death; injected, as it were, into them by the contractile power of the heart and arteries, in *articulo mortis*, or during the last struggles of death: and, in some cases, owing to certain circumstances of the death of the individual, partly after death. At least, we have the undoubted evidence of our senses, that in every case during life a certain quantity of blood, more or less, according to circumstances, filling both the arteries and veins, continually circulates from the former into the latter set of vessels, and returns by the same course; and that, after death, the veins are full, and in many parts of the system, particularly in

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the viscera and internal parts of the body, gorged and distended with grumous or partly coagulated blood; while the arteries in general (at least in cases of slow death) are found comparatively empty, though never completely so, blood being found in the left side of the heart, in small quantities, and in the aorta; and more or less in other arteries over the body. These we know to be facts beyond dispute, however much investigation it may require to explain, on known and just principles, how these things may be reconciled to one another.

According to Haller, the combined area of the veins is to that of the arteries as nine to four; and this is believed, by the most accurate of the present day, to be as near the truth as the subject permits. It appears to me that, in this calculation, the coats of the vessels are included; and though the caliber or cavity of the tube

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cannot, in reality, exist without the sides or coats, yet as they do exist, an admeasurement of the one can be conceived without the other; or we may consider an external and internal diameter of a vessel. Haller, I believe, took the external in his calculation.

Allowing this; and as we know that the coats of the arteries are much thicker than those of the veins, the latter also having only two coats, (except the slight appearance of something like a middle coat in the venæ cavæ,) whereas the arteries have three; the comparative internal area of the arteries to that of the veins must be less than that of the external area spoken of by Haller. As we can understand an external and internal diameter of a blood-vessel, we may as well speak of an external and internal area, calculated from that. It is as easy to conceive that, though the external diameter or circumference of any two

tubes

tubes might be the same, the internal diameter might be very different, and the ratio of the difference will be in exact proportion to the thickness of the sides of the tube. The sides of the largest vein of the body do not exceed 1-16th part of an inch, whereas the sides of the aorta and pulmonary artery are about 1-12th part of an inch in thickness.* I think, from these considerations, it is highly probable, that the internal area of the veins, compared to that of the arteries, is as three to one. It is easy to see that a slight enlargement of the venous trunks by distension would produce a very great disproportion between the area of the veins and arteries. And when we consider the comparatively weak and lax nature of the coats of the veins, and their very small degree of elasticity, and their total want of muscular or contractile power; and at the same time advert to the

* Gordon's Anatomy, p. 54 and 65.

the very strong, elastic, and muscular nature of the coats of the arteries, we can readily explain how the arteries, acting by these powers, assisted by the very powerful contractility of the left ventricle of the heart, while there is no resistance that can be taken into the calculation, may easily throw the greater part of their blood into the venous system; while the veins, by their capacity being enlarged, will admit of a greater quantity of blood than they contain before death. Although, then, the blood were to continue the same as in life and health, I do not think it difficult to believe, that the veins, by a little more distension than what they have in a healthy person, could hold, besides their own blood, nearly that which is contained in the arteries.

In cases of slow death, which we are first to consider, the case is far otherwise from

from what has been often conceived and related.

When a person has lain long in bed, wasted and exhausted by a lingering and painful disease, as scarcely sufficient nourishment can be taken to keep alive the vital spark, to speak of keeping up the usual quantity of the fluids, and the fulness of the body, would be ridiculous. This will more fully appear if we consider that, in such cases, diarrhæa, profuse and colliquative sweats, increased discharges of urine, or hemorrhages from the nose, and other hollow passages, or artificial bleeding, or profuse suppurations, expectoration, and numberless other exhausting evacuations are going on. Indeed we often see, in a dying person, that all the secretions are poured out in profusion. Even where wine is given in typhus, or low fever, it is quite an axiom in physic, that it is impossible to nourish or sustain the fulness of

the body. On the contrary, where a bottle of wine, or even two or three, are given daily for weeks, at the end of that time, if the patient recovers, he is only a shadow of himself—a living monument of what he was.

It cannot be denied, that, in all these cases, and I conclude in all slow deaths, the fluids, and we particularly speak of the blood, are dissipated and exhausted in the most extraordinary degree. It seems to me, then, very idle to doubt that the veins, at death, are sufficiently capacious to contain the whole, or, what actually takes place, nearly the whole blood of the body; when they contained it all but a third when the body was vigorous, plump, and full of blood. I make this conclusion *a fortiori*, because in *articulo mortis* serous exudations take place, more or less, into all the cavities of the body; and in a short time after death, which generally elapses before dissection, a great deal of transudation has

taken

taken place through the coats of the vessels. Need we wonder, then, that all the veins do not, in these circumstances, appear dilated? though often many of them are distended with blood. Besides, the heart is a large receptacle itself, and the right side, at least, is found gorged with blood. In life, when the circulation was going on, only two of its cavities were filled at one point of time, therefore I conclude there was more blood in the vessels than after death, when the heart is quiescent and relaxed, and contains a considerable quantity of blood in all its cavities. The right side is particularly turgid, and crammed with coagulated grumous blood: a good deal is also often found in the left auricle, and more or less in the left ventricle, and beginning of the aorta, a fact which we learn from Mr. KERR's book itself. The lungs are often crammed with blood.

We have also to take into account another very powerful argument for the veins being able to contain what they do, viz. nearly the whole blood, in cases of lingering death. Is not the blood, like every other fluid, rarified and expanded by heat? We know that the quantity of caloric which it contains in the living body is very considerable, and at death this is given out, so that the blood coagulates, becomes grumous, and occupies a *very much diminished* space.*

The coagulation begins in the heart and large venous trunks, and finally takes place in the extreme branches. We see that blood drawn from the arm, in any vessel, when

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* Dr. Gordon has proved, beyond dispute, that blood, during its coagulation, gives out caloric. In his experiments he found the coagulating part of a quantity of blood warmer than the rest by from 6° to 12° F.*

* Thomson's Annals, iv. 139.

when cold, occupies only half the space it did when warm and fluid. No doubt a quantity of serum swims around it; but this transudes through the vessels very much in the dead body.

From all these causes, then, in cases of slow and lingering death, the volume of blood in the body must be remarkably diminished; and I am perfectly satisfied that these considerations afford proof positive of the capacity of the veins in such circumstances being sufficient to contain the volume of blood, without the appearance of distension, at least over all the body; and if there be any distension, it will take place chiefly in the internal parts, in the soft and yielding viscera, so that the face and external parts may still appear pale. If all the arteries were well-traced and slit up immediately after the death of the indi-

 vidual,

vidual, I have no doubt that blood would be found in many of them.

Jones says, "both portions of artery were opened, but no internal coagulum of blood was found; each contained a little fluid blood, but *not more* than is *commonly met with* in the *arteries immediately after death.*"* I need not mention the ample means of observation which Jones had in this way, or his accuracy; it is well known and acknowledged by the profession.

In cases of sudden death, the blood is generally much accumulated in the veins; but there is also blood in the arteries.

As to the state of the contents of the arteries and veins, in cases of sudden death, I think

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* Jones on Hemorrhage, p. 129.

I think we have a powerful and ready refutation of Mr. KERR's objections, as connected with that point.*

It is matter of common observation, that in all cases of sudden death, from strangulation, hanging, drowning, the effects of noxious gases, apoplexy, from passions, wine, opium, &c. the veins and venous sinuses over the body are turgid with blood; and, in some instances, as of drowning, the arteries are particularly observed to have blood in them. At least, there is this difference betwixt the state of the vessels in slow

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* "In this instance the assumption made by Harvey appears at once unphilosophical, and *contrary to fact*; for whether a man dies by *protracted struggles*, or is instantly killed by lightning, or the equally sudden effects of a noxious gas, still the blood is found in the *venous system*, and is never detained as *in transitu* through *the arteries*, unless the vessels have suffered injury."

Kerr's Essay, p. 17.

slow and sudden death, that in the former we seldom see much distension of the veins, particularly in the external parts of the body, though there is often a fulness of the veins of the soft and yielding viscera; in the latter case the veins are always *very much distended*; or there is *blood* in the *arteries*, or, what is not uncommon, there is blood in many of the arteries, and the greater part of the venous system is *distended* with it, though this distension is not universal over all that set of vessels.* The face

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* Allowing that, in cases of sudden death, the whole blood which the arteries contained is not arrested in them, but passes partly into the veins, it may be explained by the powers inherent in the arteries, particularly their power of tonicity. Experiments shew that the larger arteries continue to contract after separation from the heart, and for some time after death, making the blood go on, by a slow propulsion, into the veins. And as this power of tonicity varies in different individuals, so will the comparative quantity of blood be in the veins and arteries.—*Parry on the Pulse*, p. 81.

face is dark red, or purple, or livid, modified in some degree by circumstances; often full and flushed, of a damask rose colour, in those who have been drowned; but all shewing an evident surcharge and distension of the vessels, more especially of particular parts.

The evidence of an unconcerned party is always considered most valid, especially if he is trying to give a faithful description, without its being his interest or inclination to do otherwise; but, on the contrary, has a strong interest in giving a true description of nature. Let this consideration be an excuse for the following quotation from Shakespeare, who, though no anatomist or physician, is the truest describer of nature who ever appeared; and no medical writer of any age or sect could in the least be compared to him.

"See how the *blood* is *settled* in his *face!*
Oft have I seen a *timely parted* ghost,
Of *ashy semblance*, *meagre*, *pale*, and *bloodless*,
Being *all* descended to the lab'ring *heart*,
Who, in the conflict that it holds with death,
Attracts the *same* for aidence 'gainst the enemy;
Which, with the heart, *there cools*, and ne'er returneth,
To *blush* and beautify the *cheek again*.
But see his face is *black*, and *full of blood;*
His eyeballs farther out than when he lived,
Staring, full ghastly, like a strangled man;
His hair uprear'd; his nostrils stretch'd with struggling;
His hands abroad display'd, as one that grasp'd
And tugg'd for life; and was by strength subdued.
Look at the sheets; his hair you see is sticking;
His well-proportioned beard made rough and rugged,
Like to the summer's corn by tempest lodg'd.
It cannot be but he was murder'd here;
The least of all these *signs* were probable."*

It has been the opinion of many eminent physicians, that those who are hanged or drowned,

* Shakespeare.

drowned, or suffer sudden death from other causes, as the inhalation of noxious gases, die of apoplexy. But although, in all such cases, there are many symptoms exactly similar to apoplexy, and though many of the morbid appearances on dissection seem to confirm that opinion; yet no two authors almost exactly agree on this point; and it would rather appear that not one of these authors are altogether correct in their opinion of the cause of death in such cases; and that it is not one simple cause in any instance, but a combination of many concurrent causes which produces the fatal effect.

The appearances of the dead body vary, no doubt, in different cases; but we have generally more or less of the following symptoms in those who are hanged, drowned, or die from the inhalation of irrespirable gases; or those who fall down suddenly from great exertions, and violent

strains

strains on the breathing, as rope-dancers, horsemen, wrestlers, trumpeters, glass-blowers, divers, &c. there is an inflation of the face and a turgidity of the vessels, particularly of the head. In some cases, before death the arteries beat weak, and very quick, and at last cease. Struve tells us, that the body, in cases of sudden death and asphyxia, is purple all over.* The countenance is sometimes livid, black, or blue, as we are informed by Kite† and Struve.‡ Often the vessels of the eye are very turgid, or even ruptured; the tongue and lips black. In the apoplectic, both arteries and veins of the head are distended. A venous congestion is the most prominent feature in the bodies of those who have suffered a sudden death, from whatever cause. In all violent exertions, where

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* Struve on Susp. Animat. p. 337.

† Page 40. ‡ Page 57.

where there is a strain upon the breathing, and the lungs are kept in a state of compression, by long continued expiration, as in porters carrying heavy loads, there is a difficult transmission of blood through the lungs, the circulation becomes impeded, and hence there is an inflation of the face, with blood, chiefly venous.

The same phenomena may be observed in every case of impeded respiration, as from tumors of the thyroid gland, asthma, chincough, or in those accidents which happen at table, where suffocation is threatened. Here the blood, by laborious respiration, is impelled into the head, and accumulated there by an increased action of the arteries, and retarded by pressure on the veins; as may be proved by the throbbing of the temporal arteries, and the turgid state of the veins of the head and neck. On dissecting such patients after death, the brain appears like one which had been in-

jected so strongly from the arteries, as to fill the veins.* This fulness of the vessels, which takes place principally in the brain of those who have been hanged, may be observed, more or less, in the venous system over the body; and, in some degree, modified, by the cause of the sudden death, in various cases. The arteries, in these cases, also contain blood.

In sudden death, from the poison of lauro-cerasus, the veins are uniformly found distended in an extraordinary degree. Sometimes both sides of the heart are crammed with blood. It is a curious fact, that rest alone is not sufficient to produce coagulation of the blood: this is proved by its continuing fluid after the circulation has been suspended over the whole system, as in drowning, fainting, and various cases of asphyxia. In animals that have been killed

* J. Bell's Surgery, vol: ii.

led by electricity and lightning, by a blow on the stomach, by the poison of the viper, and by violent passions of the mind, it is ascertained that no coagulation of the fibrin takes place; though we are unable to give a solution of this curious fact.

It must be allowed that the arteries are not found full in every case of sudden death, but when that is not the case, the veins are always found much distended. And that the blood should be detained *in transitu*, as it were, in some cases, in the arteries, and, in other cases, be driven forwards so as to gorge the veins, needs some explanation. It seems to me, that this depends partly on the suddenness of the death, and partly on the cause; particularly its tendency to destroy irritability. When we consider this, and the much longer continuance of irritability in some cases than others, I think we come very near an explanation of these phenomena. In proof of

what is here advanced I may state, that the heart has sometimes continued to beat for more than two hours after respiration was entirely gone, by the impulse of no other stimulus than the blood.* We know that this does not happen to such an extent in all cases, but we may believe that more or less of it invariably takes place : and according to such actions, influenced by various causes, will the effects be in the vascular system. In the case of a woman who died by submersion in water, on examining the body along with a surgeon in town, I found every mark of turgescence of the vessels, externally and internally. The face was flushed and full, and suffused with blood, not only venous, but arterial; for the lips were bright purple ; the cheeks rather of a dark red, at least sufficiently indicating that the small arteries were full of blood. The veins were all found much distended with

* Coleman, p. 12.

with blood; the right side of the heart very much crammed with grumous blood; the left side was also pretty full, and all the vessels of the brain were turgid. I slit up the basiliar artery, and traced some of its branches, which I found full of blood.

In page 17th, Mr. KERR informs us, "that although the globules of blood have been distinctly seen by many, no anatomist or physiologist has yet discovered the anastomoses of the terminating arteries with incipient veins, by which these red globules should pass." I have only to say here, that this assertion of Mr. KERR's is completely refuted by what I have stated from unquestionable authority, when describing the veins and arteries; and there is no doubt that the anastomosing termination of arteries in veins has been more often and more distinctly seen than the red globules, of which he talks so confidently; for these gave rise to more mistakes and whim-

sical ideas than ever arose about any medical point.

We are next informed of a curious fact in these words: "in cold blooded animals this anastomosis is distinctly seen; but I speak of animals having lungs."* By cold blooded animals, I understand, he here means or includes the amphibiæ, many of which, as the lacertæ, frogs, newts, &c. &c. by having thin membranous transparent lungs, and a peculiar heart, generally single, have afforded us a beautiful view of the circulation going on in their lungs, and the red and dark blood passing distinctly from one set of vessels into the other by anastomoses.

Indeed, from what Mr. KERR says in another part, he leaves us no room to doubt that he included among the number of cold blooded

* Kerr's Essay, p. 18.

blooded animals, frogs, and such amphibiæ, as he opposes these to warm blooded animals in description.* The fact that frogs have no lungs is certainly one which we never learnt before.

The lungs of these animals are thin, transparent, and membranous, owing to the very few blood-vessels in them, and the smallness of these vessels. By this organization only a small quantity of the blood of the animal is oxygenated, or changed, by respiration at a time; so that respiration is in them a process of far less necessity than in other animals with a double heart and fleshy lungs. All those animals seem endowed with a wonderful degree of irritability and tenaciousness of life; so that the greatest cruelties

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* "His experiments were principally performed on fishes and *frogs*, and comparatively few on *warm blooded* animals," p. 32—also p. 36.

ties inflicted upon them will not for a long time extinguish it. They are generally of cold, inert, and languid habits, and have usually been classed among the number of cold blooded animals, as well as fishes; and indeed we know that all fishes are not cold blooded, but some of warm blood, as the whale, or cetaceous tribe.

That Mr. KERR considers these amphibiæ among the class of cold blooded animals there is no doubt; and I have as little doubt that he alludes to the experiments I have already mentioned, where the circulation is seen, in the membranous lungs of the lacertæ, and in the web foot of the frog. It is no wonder, then, that we are a little surprised when we are told that those poor animals have no longer any lungs; and that the anastomosis between arteries and veins are not seen in these amphibiæ,

when

when we know that it is best seen in them.*

The lymphatics, cellular substance, and muscles, being sometimes injected along with the arteries and veins, as Cruickshank has mentioned, to me affords not the smallest argument against the proof of arteries terminating in veins, as shewn by injection. We know that a clumsy injection, or too great force being used, or the subject becoming putrid, &c. will readily produce the effect here mentioned. But in this case there is a rupture of the vessels: it is easy to perceive it, to

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* "The direct terminations of the arterial in the venous branches are most remarkable in the extreme parts of the web,"—viz. of a frog's foot.

"The circulation of the blood, as seen in these three orders of vessels, the arteries, intervening capillary vessels, and veins, in the web of the foot of the frog, placed as has been already described, ('in a micros-

to see its cause, and to prevent it. Yet I do not see but it would be very "wonderful, that a warm injection, propelled with some considerable force, should, by *transudation*, pass into the veins."*

By transudation, the fluid in the veins, either injected or otherwise, might escape, through the coats of these vessels, into the cellular substance; but I can never see that the veins could be fairly injected, filled, and distended by this process, but by the fluid passing along from the extreme arteries into the veins, which we know to be continuous with those, and to anastomose

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cope') goes on in an uninterrupted stream."—*Thompson on Inflammation*, p. 77.

The acceleration of the blood from the impulse of the heart can be traced from the minute capillary arteries into the corresponding continuous veins, in the web foot of a frog, by a microscope, the compages entire, and without any injury done to the animal.--*Thompson*, p. 80.

* Kerr's Essay, p. 18.

mose directly. If we take a proper part of a fresh subject, and inject into its arteries gently a thin solution of size coloured, or mercury, we can perceive the artery and vein continuous, without any rupture taking place.

We must now consider the arguments which Mr. KERR has advanced against the Harveian doctrine, where he states, that obliteration of the femoral artery for aneurism, and tying it in amputation of the thigh, afford great difficulties, to be explained by the received doctrine.* I trust I shall be able to do away these difficulties, and shew, that what occurs in these cases can be explained by Harvey's doctrine.

1st. With regard to the obliteration of the femoral artery, and the manner in which the circulation can still be carried on in these cases. It is well known and generally

* Kerr's Essay, p. 18 and 19.

ly allowed by the profession, that Jones' experiments on arteries, and the various changes that take place in them by disease, are the most correct ever published. I shall here, then, quote his words, which I believe to be supreme authority on the subject, being derived from actual and fair experiment, and which evidently decide in favour of the received doctrine. "The "circulation," says this eminent and very accurate author, "appears to be carried on as perfectly and vigorously by these anastomosing branches in the limb, the *main artery* of which has been *divided*, as in that in which the artery is entire; the inferior part of the divided artery and all its branches being found *fully equal in size* to the corresponding part of the trunk and branches of the artery of the opposite limb, which has not been divided; and hence we may conclude, with the celebrated Mr. Hunter, 'that vessels have a power of increase within themselves, both in *diameter*

and

and in *length*, which is according to the necessity, whether natural or diseased.' "*

2d. With regard to the case of amputation of the thigh, and how the blood in this case is to be returned to the heart, without any obstruction to the circulation.—I shall premise a short anatomical account of the blood-vessels of the thigh, which will assist our subsequent reasoning. The femoral artery gives off high in the thigh the profunda, which at its origin is nearly equal in size to the femoral artery itself; it supplies the muscular parts of the thigh, the hip-joint, &c. with blood, by pretty large branches, which are distributed through the muscles; and which, when the main artery is tied, as in aneurism, enlarge, so as to be able to carry a sufficient quantity of blood to nourish the limb. The muscular branches of the profunda, after

* Jones on Hemorrhage.

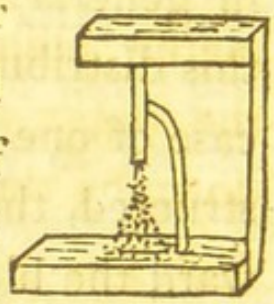
being divided and ramified to great minuteness, have their blood returned in the usual way by anastomosing veins. These uniting, form the profunda vein, which pours its blood into the femoral vein at the upper part of the thigh. The femoral artery itself only sends off some trifling branches in its descent through the thigh, after giving off the profunda, and may then more properly be considered the artery of the leg than of the thigh; while the profunda, in point of office, best deserves this latter name of femoral: for the blood of the femoral artery, after giving off the profunda, goes to nourish the leg, by the three arteries distributed through it.

We know that there are two sets of veins in all the limbs; the deep seated, which accompany the arteries, and which are generally double their number; and a superficial set under the common integuments. These veins form very numerous anastomoses

moses and plexus in many places, like a net work; not only with the veins on the same plane, but very numerous ones also with those not on the same plane, the deep-seated with the superficial. It is also to be observed, that anastomoses take place by much larger branches in the case of veins in general than in that of arteries. By this distribution and excellent provision, in case of one vein or set of veins being obstructed, the other will infallibly carry forward the blood.

Though the ancients, and even more modern authors, often erred egregiously in applying exactly the laws of hydraulics and hydrostatics to the explanation of the physiology of the human body, yet I think we can here make use of an experiment with an hydraulic machine with very good effect —I mean the experiment of Bernouilli. It consists in this: let there be two cisterns, the one placed perpendicularly above the other,

and connected by a back-board as a support; the upper one having a hole in its bottom, from which descends a small pipe two-thirds of the distance between the cisterns; and from the side of this descending tube, about the middle of its length, another tube going off with a gentle curve, and then descending into the lower cistern. If both cisterns are filled with water, and the mouth of the descending tube (or that which comes originally from the upper cistern,) is left open, the pressure of the water in this descending tube, coming from the upper cistern, is negative on its sides, and flows with great rapidity from the mouth of the descending tube into the lower cistern; but does not at all descend by the collateral tube coming off from it, or what we shall call the ascending tube; but, on the contrary, the water rises a certain height, according to circumstances, explicable by the laws of hydraulics, in the collateral



tube.

tube. But if the mouth of the descending tube be stopped up, the pressure of the water descending in it becomes positive, and descends altogether by the collateral tube; the portion of water between the obstructed extremity of the descending tube and the part where the collateral branch goes off, remains still and stagnant, merely filling that part of the vessel, while the water above that continues flowing down by the lateral tube.

It is easy to apply this experiment to the state of the arteries of the thigh, in the case of amputation. The femoral artery gives off the profunda in the same way that the descending tube gave off the collateral tube: if the femoral artery were left untied upon the stump, it would be in the situation of the descending tube when left open, and the blood would flow from it in the most impetuous manner, so as to prove fatal in a very short time. But if it were tied by a ligature, then it would be in the

same situation as the descending tube, when stopped at its lower orifice, the pressure of the blood in the femoral artery would become positive, and descend in the collateral branch or profunda, while the portion of blood contained in that part of the femoral artery between the ligature and the giving off the profunda, would stagnate, and merely fill the vessel, without any motion. If the larger branches of the profunda, cut in this case, were left untied, while the femoral artery was tied, the person would also soon suffer a fatal hemorrhage, because the blood descends with great force in these collateral branches: but these lateral branches which are cut in the operation are also tied, and the same process takes place in them; the blood only circulating along those branches by the profunda, which are distributed among the muscles of the thigh, and which have their anastomosing veins to return their blood. As the blood stagnates in this case

in the femoral artery up to the giving off the profunda, and as there is no demand of blood in it, the arterial contractions cease, the blood in it gradually coagulates, the sides of the artery fall collapsed, or are brought into contact, and adhere, so as to obliterate this part of the artery up to the first lateral branch, which, in this case, is the profunda; at last it becomes a solid cord, or can hardly be distinguished from the cellular membrane, like the umbilical vein and hypogastric arteries of the fœtus, after birth.

It is beautiful to see this, which might otherwise be only considered theory, or probable reasoning, proved and confirmed by actual experiment on the arteries of animals by the same very accurate and eminent author, whom I have already mentioned as supreme authority on these subjects: "The artery does not become unusually distended in consequence of this obstruction,

obstruction, (viz. a ligature) principally because the collateral arteries afford a passage to the blood, and partly in consequence of the effect which the obstruction to the arterial canal, and the pressure made by the ligature, have, in depriving that portion of the artery of the property of accommodating itself to the quantity of blood determined to it; a property which, it has frequently been observed, arteries are endowed with, to a certain extent, when entire and free from pressure, and which is beautifully illustrated by the almost immediate enlargement which the collateral branches have been observed to undergo, when a trunk has been tied. From these circumstances it appears, that the enlargement of a portion of the artery between the first collateral branch and its extremity is prevented; but it is obvious that there must be a small quantity of blood just within the extremity of the artery, and which is more or less completely *at rest*; it, therefore,

coagulates,

coagulates, but does not appear, in every instance, to form at once a coagulum capable of filling up the canal of the artery; for, as may be observed in many of the experiments, several hours after the artery had been tied, there was only a slender coagulum formed in its extremity." Jones is here speaking of tying an artery as in aneurism, but it illustrates what we wish to prove, the same as if it had been an artery tied on a stump; for in respect of the coagulation of the blood, and obliteration of a part of the artery, they are the same. He adds, in another part of his work, "Nor are these all the changes which the artery undergoes; for, if examined at a still later period, the *ligamentous* portion is found to be reduced to a *filamentous state*, distinguishable from the surrounding cellular membrane only by being somewhat coarser; and thus the obstruction which commenced at the extremity of the canal terminates

minates in the complete *annihilation* of the artery to the first lateral branch."*

In the dissection of stumps, years or months after the operation, anastomoses between the extreme arteries and veins can be distinctly seen, by proper injections; just as they could have been seen before the operation.

I do not at all see why there should be any commotion in the system, or why the heart and other organs should be oppressed with refluent or super-abundant blood after amputation. When a leg is cut off, its vessels are full, and that more than ordinary, on account of the application of the tourniquet; thus the usual quantity of blood at least, which filled or circulated through its vessels, or supplied it, is cut off with the leg; besides, there is generally a considerable

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* Jones.

considerable effusion more than that, before the vessels can be all secured. From this it appears that, in respect of quantity of blood, the system is exactly the same, after amputation of a leg, that it was before. And we cannot suppose that more blood would be formed, after the operation, than the necessity of the system demands; for it seems a law of the system, that the supply is proportioned to the necessity or demand, at least in cases of health: if we speak of diseased conditions, they have no bounds, and we may have all degrees of plethora, from the smallest to the greatest; but that does not apply here. Besides, we may take this into the account, that in many cases of amputation the patient has been exhausted by previous disease; and frequently artificial means of depletion have been had recourse to during the cure. If these circumstances did not occur, probably violent symptoms of inflammation would happen more often than they do. I

make

make no doubt that often, after the healing of an amputated limb, a person may grow fuller, more plethoric, and corpulent, than before; but it is because some exhausting disease is removed by the amputation.

As to the comparative velocity of the blood moving through the arteries and veins, and how the great velocity of the one is compensated by the capacity, &c. of the other, we have already given an explanation. It is very evident, also, that the whole of the blood transmitted by the arteries is not returned by the veins, but that part of it is applied to the nourishment of the body and the formation of secretions, &c. And the velocity with which venous or arterial blood flows from these vessels, when divided, gives no knowledge of the velocity with which the blood passes along in these tubes, when entire. In the first place, when a vessel is divided, much resistance is removed; and though this is

applicable

applicable to both sets of vessels, other powerful circumstances, as affecting the flow of blood, are not common to both. When a trunk of an artery is cut across, we have shewn that not only does it pour out its own blood, but all its anastomosing branches are brought into action, as long as the mouth of the cut artery is fairly open; and the blood flows rapidly from all these back into the trunk, as is explained by Bernouilli's experiment. Each anastomosing branch, then, has its own power of action, and share of propelling the blood from the divided trunk; and the velocity or force of the blood poured out from a wounded artery will not be what it was when the artery was entire; but being increased in a geometric ratio, it will be a velocity made up of the combined power of all the branches anastomosing with the trunk near the part of division, now drawn into action, as already explained. This combined action of anastomosing arteries

is felt in the throbbing of the aneurism by anastomosis. Though the same takes place with regard to blood flowing from anastomosing veins, as to *quantity*, it does not apply as to *velocity* or *force*; as, in the veins, the muscular and elastic power of arteries is wanting. This explains how, although, according to the comparative area of the arteries and veins, in the sound state, the calculation might be partly true that the velocity of the blood in arteries and veins ought to be as three to one, taking the inverse ratio of their diameters; yet, on being divided, the velocity will not continue in the same ratio, but might be, as Keill says, ten to one. We must also, to afford any satisfactory calculation with regard to the velocity of the blood in these tubes, when sound, take in a number of complicated actions and circumstances which do not admit of any precise admeasurement, therefore never affording a certain or mathematical solution of the problem. This explains

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how all the mechanical and mathematical calculations, which once rendered famous the names of Keill, Hales, Pitcairn, Borelli, and others, were fallacious, and, to speak strictly, inadmissible, when calculating the dimensions and powers of living vessels, and the velocity and motions of fluids passing through them.

Though we had exactly the comparative areas of the arteries and veins given, the flow of blood through them will not be as in rigid tubes, or where there was no propelling power at the centre, but where gravity alone acted. We must take into account the powerful action of the left ventricle of the heart, assisted by the strong muscular and elastic power of the arteries, in propelling the blood through these vessels; and at the same time remember, that the veins have their blood propelled only by a very small degree of this, a

vis a tergo continued from the arteries,* perhaps the pressure of surrounding parts, and the aid of valves.

There seems to remain little doubt that the blood moves more slowly in the small branches than in the trunks of the blood-vessels, because the combined area of the former is always larger than the latter; but as the blood contained in each of these branches is moving into a narrower tube, though the combined area is greater, I think there is room for admitting the possibility of Haller's opinion, that the blood does not move slower in the smaller arteries; for, these being very excitable, their action may be comparatively more lively than in the large branches, though several other causes may contribute to the retardation

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* Spallanzani has ascertained that the impulse which the heart gives to the blood extends to, and may be perceived in, the veins.

tion of its motion. However the general opinion is, that the blood's velocity is retarded in the branches, and accelerated in the trunks: *e. g.* it is said that the motion of the blood is much more rapid near the heart than in the remote arteries; and that its motion is retarded towards the extreme arteries by friction, by the tenacity and adhesion of the parts of the blood to the sides of the vessels, and by the diminished elasticity of the vessels; but, most of all, by the increased capacity of the area of the branches over the trunks; and that this last is the chief cause, any other being almost compensated for by the action of the arteries. In the same way, the blood moves more slowly in the extreme branches of the veins, and is accelerated a little towards the heart.*

* See this subject renewed in a subsequent page.

It certainly is true, that the blood which the left ventricle propels through the aorta was derived from the "right side" of the heart and "cava," or, to speak properly, vena cava; and not only one vena cava, but two venæ cavæ, and one vena coronaria cordis. But I am at a loss to see why these do not furnish *data* to calculate the velocity of the blood in them, according to "general and *established principles*," as far as such a calculation can be made in any similar case, which is always imperfect, from the uncertain and variable nature of the powers acting.* Not only are the diameters of the two great vessels (by which I suppose Mr. KERR means the pulmonary artery and aorta) to be taken into account, but the comparative strength of the right and left side of the heart, and the degree of velocity which they are capable of imparting to the contained fluid. The pulmonary artery and

* Kerr's Essay, p. 22.

and aorta are of exactly the same diameter at their root, viz. one inch and a quarter; and the sides of each about 1-12th of an inch in thickness.* From this the motion of the fluids, passing through each of these vessels, should be equal, as long as their caliber is equal, if the propelling power of the right and left ventricle were exactly the same; but the left ventricle is much stronger and more powerful in its action, which seems necessary to propel the blood through a much greater space, though it has the assistance of the arteries themselves. To compare the tube of the aorta with a vein of equal caliber, and to suppose the velocity of the blood in these two equal, would be inconsistent with all principle. The propelling power of the heart, and the muscular and elastic power of arteries, is wanting in carrying on the circulation in the vein, except in so far as they act as a *vis a tergo.*

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* Gordon's Anatomy.

tergo. But in order that this may be compensated for, we have, at the right side of the heart, two venæ cavæ, the superior 2-3ds of an inch in diameter, and the inferior an inch in diameter, and the vena coronaria 1-3d of an inch in diameter: the sum of the diameters is thus two inches. To oppose to this there are four pulmonary veins, each half an inch in diameter; so that the sum of their diameters is also two inches.*

We have thus the vessels of the right and left side of the heart as well balanced, in point of capacity, as the veins and arteries are in any other part of the body. There are three veins, having the sum of their diameters two inches, pouring blood into the right auricle; and four veins, having the sum of their diameters also two inches, pouring blood into the left auricle.

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* Vide Gordon's Anatomy.

In the same way we have the pulmonary artery, whose diameter is an inch and 1-4th, conveying away the blood from the right ventricle; and the aorta, whose diameter is also an inch and 1-4th, conveying away the blood of the left ventricle. We see here an exact balance between the vessels in point of caliber; and as the combined action of the ventricle and artery must propel the blood with very great velocity, and as these powers are wanting to the veins, so that the blood must move comparatively slow in them, we find that the sum of the diameters of the veins is nearly double that of the artery, in either case. And whatever difference there is between the velocity of the blood in the pulmonary artery and aorta, if there is any, must proceed from the superior strength and contractile power of the left ventricle.

I see no difficulty in explaining, upon known and established principles, and by the

the anatomical structure of the body, how the circulation is carried on, in a manner complete enough to support the life and health of the animal, after the principal vein or artery, or both, of a limb have been tied, and a portion of them obliterated; or to account for what Mr. KERR mentions to happen when a ligature is tied round an arm, as for blood-letting.* Nay, I shall prove, to the satisfaction of every person concerned, that not only may a portion of the principal vein of a limb be obliterated, but even of the principal vein of the body; and yet the circulation and life of the animal be preserved.

Mr. KERR seems to be satisfied of the way in which the blood finds a channel to return to the heart, where a ligature is put upon the arm for blood-letting. I shall first, then, explain the return of the blood when

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* Kerr's Essay, p. 23.

when a principal vein of the limb, the saphæna, is tied. It must be allowed by every person skilled in anatomy, that in every case of obstruction of a blood-vessel, there are anastomosing branches of sufficient number and size to carry on the circulation, and particularly in the case of veins, whose anastomosing branches are, in general, much larger and more numerous than those of arteries. Nor is this "begging the question;" for we have proof positive of the fact advanced. We know that there are two sets of veins, a superficial and deep-seated; and that very frequent anastomoses take place between these, by large branches. It is evident, then, when the saphæna is tied, that these anastomosing branches will carry on the circulation; and that in time they will enlarge, according to the necessity of the function, as Mr. Hunter has proved to us.* This experiment has been made by Jones, and the result

* Vide Supra, p. 11.

sult is satisfactory, and proves the truth of the explanation generally given in such cases—that the anastomosing branches carry on the circulation, and are enlarged. Jones' experiment proves the present position more completely, as it was not only the saphæna vein which he obstructed by ligature, but the femoral vein itself: he tied this vein of a dog, at the same time that he tied the femoral artery, which was no objection to the experiment, because he shews by the dissection, thirty-seven days afterwards, that the circulation was carried on as freely as ever by the anastomosing arteries, which were, as in similar cases, much enlarged, tortuous, and serpentine in their course, or forming little circles. Jones informs us, that "the vein was obliterated to a greater extent than the artery, and the superior and inferior portions communicated freely by branches, which passed from the one to the other."* This Mr.

* Jones, p. 150.

Mr. KERR will say, is not so complete a proof of the Harveian doctrine as tying the common iliac, because, to use his own words, "the ingenuity of the most zealous Harveian will scarcely succeed in discovering how, the iliac vein being tied, blood propelled by the iliac artery can possibly be returned into the cava"* It has been remarked already that the veins anastomose with one another in large branches much more frequently than arteries; and it is known that any artery being tied, the anastomosing branches will supply the place of it, and carry on the circulation, as in tying the iliac artery for aneurism. I think it cannot be doubted that the hypogastric veins in the pelvis of *opposite sides* anastomose freely; and as there are no valves in the veins, within the cavities of the body, with a few exceptions, I think it is easy to

 demonstrate

* Kerr's Essay, p. 99.

demonstrate, that when even the *common* iliac is tied, the blood will find a circuitous route, by the anastomoses between the hypogastric veins of the opposite sides in the pelvis, and with the sacral and lumbar veins, &c.

Not only may the principal vein of a limb be obstructed, and the circulation carried on by anastomosing branches, but even the principal vein of the body, the vena cava, as we find proved by a case from the highest authority, Dr. Baillie, in his Morbid Anatomy.—" A considerable portion of the vena cava inferior had become obliterated; in consequence of this, the usual vena azygos, together with an uncommon one on the left side, were the only channels through which the blood could return, by a circuitous route, to the heart; they were therefore, necessarily, from the impetus of the blood, much enlarged in size,

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and, for the same reason, likewise varicose."*

The next objection which Mr. KERR mentions is the case of aneurism, and where the main artery of a limb has been tied or obliterated at one part; as in the case of axillary aneurism, or in the subclavian artery itself, which is Dr. Barclay's case. He states, that it is inexplicable on the Harveian doctrine, how "when (as he informs us) not a drop of arterial blood can reach the hand, the veins on the back of it, and up the arm, remain turgid?" and he adds, "the veins of the arm have remained turgid for months after the artery was destroyed at the axilla, and till death, although the limb remained cold all the while."†

* Baillie's Morbid Anatomy, p. 108.

† Kerr's Essay, p. 24 and 25.

I never believed that any limb can live and be nourished, without some circulation of blood by anastomosing branches, though the supply may, in some cases, be more scanty than in the natural state of the limb. But through all parts of the body inosculations of all kinds of vessels are innumerable and perpetual; and the inosculations of arterial branches are so numerous and complete in every part, that, whatever artery in the body we tie or obliterate, from the aorta to the smallest trunk, a circulation of blood will be maintained, so as to support the life and health of every part of the system.

The anastomoses of the smaller branches of arteries promote a free circulation of the blood, and prevent any obstruction taking place from unequal and sudden pressure of neighbouring organs, or from contortion or distension. By means of these anastomoses,

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a retrograde course of the blood may sometimes takes place. Whoever wishes to understand how numerous and infinite these anastomoses between smaller branches are in some parts, let him examine plate v. of Monro's Outlines of Anatomy, which gives a beautiful representation of the great number of arteries distributed in a muscle, and their anastomoses, as seen when magnified.

We particularly find numerous and free anastomoses about the different joints of the extremities, as these are very liable to various causes of partial pressure and obstruction; and it is found perfectly safe to tie by ligature the subclavian, axillary, humeral, iliac, femoral, or popliteal arteries, the circulation being continued by the anastomosing branches. Even the very smallest anastomosing branches may, in this case, contribute to support the circulation.

When parts have been injured, or divided, or separated, the anastomoses of the arteries contribute very much to the regeneration of the parts, and the restoration of continuity. This is apparent in the growth of parts, in the healing of fractures, or wounds of the soft parts, or in the curious experiments which teach us that a nose may be supplied for a lost one,* a tooth transplanted, and that the spur of a cock, or a human tooth, may be made to grow into the comb of a fowl.†

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* "So learned Taliacotius, from
"The brawny part of porter's b——,
"Cut supplemental noses, which
"Would last as long as parent breech;
"But when the date of Nock was out,
"Off dropt the sympathetic snout."

HUDIBRAS.

† Vide Taliacotius. Du Hamel Mem. de l' Acad. des Sciences, 1746, &c.

We have now undoubted proof, that, not only may the large arteries and veins of the limbs be tied and obstructed with impunity, but that the aorta and vena cava may be completely obstructed, without any danger to life. In Desault's Journal, vol. ii. we have a case related, in which the aorta was contracted to the size of a writing quill. His words are, " qu' elle avoit tout-au-plus la grosseur d' un tuyau de plume à ecrire ;" and he adds, " La partie de cette artere qui se trouvoit au dessus du retrécissement, etoit à peine delatée, et celle qui etoit au dessous conservit son calibre ordinaire." In this case there was an enlargement and tortuous appearance of the subclavian artery, the external thoracic, the internal mammary, the lower intercostal derived from the aorta, and the epigastric arteries. The internal mammary and epigastric arteries were here the chief channel by which the blood passed from the heart to the

lower

lower extremities, instead of its usual course by the descending aorta.*

But the experiments of Mr. Cooper have demonstrated that the aorta may be fairly tied, and part of it obliterated, as in the case of aneurism of the principal artery of a limb, and yet the circulation be carried on by lateral branches, and the life and health of the animal preserved. "During the last winter," says Mr. Cooper," assisted by my friends Mr. White and Mr. Dean, two of our most promising and intelligent pupils, I repeated the experiments, (viz. of opening the abdomen of a dog and tying the aorta,) and have the honour of shewing to the Society the aorta tied and divided, the animal having survived the experiment, and maintained his usual health; the

* "The human aorta also, like arteries of a smaller size, has been found in a state of complete coalescence and imperviousness."—*Parry on the Pulse*, p. 81.

the ligatures coming away as other ligatures upon arteries, and a successful injection having been made of the body, the anastomosing vessels are beautifully seen. These were sufficiently large and numerous to allow of a *free* injection of the *femoral vessels.*" "Previous to the animal being killed, the femoral artery and vein were laid bare; the *blood in the artery was florid* as *usual*, and passed with a *motion* that was *pulsatory*, although weaker than natural."

Mr. Cooper's experiments on the arteries of the extremities shew how much the lateral anastomosing arteries enlarge, when the main trunk is obstructed or obliterated. In a case of popliteal aneurism, on which he operated, "the femoral artery, which is necessarily obliterated by the ligature, was here converted into a cord, from the origin of the arteria profunda down to the ham. The whole of the popliteal artery was also changed into a similar substance." In this

case

case the profunda and circumflex arteries supplied blood to the muscles; and the articular arteries received blood from the profunda. The profunda, which formed the new channel for the blood, was considerably enlarged in diameter. Mr. Cooper adds, "It appears, then, that it is those branches of the profunda which accompany the sciatic nerve that are the principal supporters of the new circulation. They are five in number, besides the two deep-seated arteries, which do not accompany the nerve." The coldness of the limb Mr. Cooper attributes to the languor of the circulation; and this, because the anastomosing vessels do not increase in diameter but by a slow and gradual process. He thinks active exertion very necessary for the attainment of this end.

Mr. Cooper has shewn, that not only may the aorta of an animal be tied with safety,

safety, but that the principal trunks of the arteries may be taken up, in *succession*, in the *same animal*, and thus the blood be transferred to the smaller anastomosing vessels, without hurting or changing the habits of the animal.*

Thus we see the aorta has been obstructed to the size of a crow-quill, and also completely obliterated by ligature; the vena cava quite obstructed; the carotids, and external iliac artery, have been tied; the femoral artery, and all its branches on the fore part of the thigh, quite obliterated; all the principal trunks of the arteries of an animal tied in succession; and the thoracic duct obstructed: all, in their respective cases, without danger to life, or gangrene ensuing.

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* London Medico-Chir. Transactions, vol. ii. p. 257.

How idle is it, then, to speak of "not a drop of blood circulating to the fingers," because a part of the subclavian or axillary artery has been obliterated? There are such anastomoses between the vertebral artery, the internal mammary, the thyroid, and the transversalis colli, the superior intercostal, and, above all, between the supra-scapularis, branches of the subclavian artery, and the subscapularis and circumflex arteries, given off by the axillary artery, that an aneurism can never so obliterate any part of the subclavian, but the circulation will be carried on by anastomosing branches.

When the axillary arteries have been tied, to save the arm for an after injection, a *coarse* injection thrown into the aorta has filled the arteries of the arm. The axillary artery has been tied for a wound, and the use of the arm continued entire, though the pulse was weak. We read of cases of

aneurism

aneurism of the axillary artery, where the artery below was spontaneously obliterated for two inches; and yet the inosculations carried on the circulation, as appears by the arteries being found pervious, though it is confessed that the circulation was languid, so much so that the *pulse at the wrist was gone*. But there is a great difference betwixt stopping the pulse, and *completely* stopping the flow of blood through the artery. For when only a very small quantity of blood flows through the artery, the artery is not distended or much stimulated, and scarcely any perceptible pulse is excited. We have sometimes a near approach to this in the last stage of typhus fever, where the circulation over the whole body is nearly arrested. This shews that the pulse depends entirely upon, and is caused by, the blood in the arteries; and proves, that not only is there blood in them in the healthy state, but that they are full of blood; and no minute portion, such as

might be supposed diffused in a subtile vapour, could have the effect.

In Dr. Barclay's case of aneurism, there is no doubt that the obstruction had affected that part of the subclavian artery between the part where it gives off its principal branches and the axilla; or at least, concluding from effects and consequences, which is all we have here, we must believe that the circulation had been maintained by the anastomosing branches of arteries which surround the shoulder, and which would, as in every similar case, gradually enlarge. For Dr. Barclay himself, in the conclusion of his letter, informs us of his own ideas on the subject, and which exactly concur and agree with what I have been endeavouring to enforce. Says he—" My own idea is, from a beautiful preparation in my own possession, from those which I have seen in the possession of others, and from what I have read in Scarpa, and others, *that no limb*

limb is preserved unless the circulation of *even red blood* be *continued in the lateral vessels,* which are *always* enlarged, and often rendered tortuous, from increased impetus."*

We know from very accurate experiments, by the very venerable Monro the Father, that the nerves have a very great influence on the state of the circulation of a part; that there is a mutual sympathy between these two systems, the nervous and vascular. "By throwing a ligature upon a nerve, the quantity of fluid secreted by the gland is diminished."† Nuck has proved this by an experiment. When the axillary artery has been tied, or an aneurism has existed, and the pulse ever after been very feeble, with unusual coldness and

* See part of Dr. Barclay's Letter, Kerr's Essay, p. 26.

† Monro tertius, 2d vol. Anat. p. 349.

want of proper feeling of the arm, it is to be presumed that, in some cases, some of the principal nerves have also been injured; though, in general, this is only to be ascribed to the diminished vigour of the circulation in the limb, on account of the small size of the lateral anastomosing arteries.

There is no manner of doubt, then, that red blood did circulate by the lateral branches, through the arm, in Dr. Barclay's case of aneurism; and if so, it must have been returned by the veins. How the veins were turgid is not, I think, very difficult to explain. In cases of aneurism, the canal of the artery has either been obliterated by external artificial pressure, or by a ligature, or by a clot of blood, or the pressure of the tumor itself, at last so acting on a part of the artery above or below, as to obstruct its channel; and perhaps some other accidental circumstances may produce

produce a spontaneous cure. But in any or all of those cases the tumor of the aneurism has every chance of pressing so on the neighbouring vein, or veins, as to obstruct very much the return of the blood, acting like a ligature on the vein. I have no doubt that this had happened in Dr. Barclay's case of aneurism, which makes it very easy to explain the turgid and distended state of the veins on the back of the hand, &c. We have seen how, when a principal vein is obstructed, (as the vena cava in Baillie's case,) the veins which carry on the circulation are distended and varicose, by accumulation of blood, and perhaps increased impetus, on account of the narrowness of the lateral branches, which, in that case, returned the blood. The action or muscular motion of such a limb must have been much diminished, which has considerable influence in propelling the blood through the veins. The usual propelling power from the arteries,

the *vis à tergo*, must have been much diminished, on account of the weak and languid circulation of red blood; and, most of all, the return of blood by the veins was much impeded by pressure on the principal returning vein. It is well established, that the effect of inactivity of a limb, and obstruction of its principal veins by pressure, is a varicose and distended state of these veins. From the various causes just mentioned, the motion of the blood in the veins of the arm would be slow and retarded; the veins would gradually dilate, and their valves would be of no use to sustain the column of blood, being too narrow for the enlarged caliber of the vessel, and a permanent and incurable varicose state of the veins would be the consequence. This would take place most in the superficial veins, as there is in them least resistance to the dilating power, from surrounding parts; whereas the deep-seated veins are braced down and compressed by the fascia and muscles.

I think,

I think, from these considerations, we have a fair account and explanation of the phenomena related in Dr. Barclay's case of aneurism, concording with the Harveian doctrine of the circulation.

When an arterial trunk has been obliterated for the cure of aneurism, and the blood circulates by the lateral arteries, as is demonstrated to have happened in every case, the trunks which receive the blood from the lateral arteries, after becoming capillary, terminate, as usual, in veins, &c. and thus the blood is returned in the ordinary way.*

I do not apprehend that "arterial *surculi* shoot out as new branches from a pollard,"† as Mr. KERR says, in order to carry on the circulation when a trunk has been obliterated

* Vide Kerr's Essay, p. 27.

† Kerr's Essay, ib.

obliterated for aneurism; but that the principal anastomosing arteries existed as such before, and are now only enlarged, and often become tortuous, by the chief current of blood being diverted into them, and by the increased impetus.

After the facts which have been related concerning anastomosing arteries, facts which were published to all the world, it seems surprising that a man of distinguished talents should have overlooked them in writing a book to disprove one of the best established doctrines in medicine. He informs us, "It will not be said, that, when the iliac is tied, or even the femoral artery, *any arterial blood can reach the toes!!* and yet the veins of the foot and leg contain blood, as if no obstacle had intervened in the artery."* To see the absurdity

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* Kerr's Essay, p. 27.

dity of this sentence, we have only to consider the use of anastomosing arteries.

From what Mr. KERR says with regard to Mr. Cooper's cases and engravings in the Medico-Chir. Trans. and the different appearance of the plates in vols. iv. and ii. which he mentions in a foot note, we can hardly believe that he thinks he is here bringing forward a serious and substantial argument. If vessels sufficient to carry on the circulation are seen in one case, it is enough; and whether they are seen in the plate or not, it is of no consequence. Perhaps the nature of the drawing might not permit of exhibiting the complete course of the vessels. But even although Mr. Cooper had published plates with the express purpose of shewing that the usual arteries did not reach the toes, nor were supplied with blood by the lateral arteries, in cases where the main trunk was obstructed, it would have been of no avail, because the fact is

proved

proved demonstratively beyond all dispute; and I apprehend that even he would have, by such a conduct, drawn down ridicule and contempt upon himself.

As to what Mr. KERR says with regard to the comparative velocity of the blood in the trunks and branches of the blood-vessels, and as opposed to the opinion of the great Haller,* I have only to say that this point remains in some doubt even to the present moment. For though we know that the combined area of the branches invariably exceeds that of the trunk, and that, by the laws of hydraulics, the velocity of fluids in rigid tubes is in the inverse ratio of the squares of their diameters, and that such a fluid as water, moving in metallic tubes, moves slower in wide than contracted channels; yet, perhaps, this does not happen in a set of living vessels, having a muscular

* Page 31 and 32.

a muscular and contractile power:* and though the combined area of the branches surpasses in size the area of the trunk, yet the blood in its course is really flowing from *wider* into *narrower* vessels, while in the arteries—and *vice versa* in the veins. Some circumstances, as the greater area of the branches, mechanical pressure, the angles at which the arteries come off, the friction and viscidity of the blood, would incline us to think that its motion was retarded in the smaller branches. But the experiments and conclusions of Haller and Spallanzani are quite against this. The latter author says, he did not find "that the blood, in passing out of the middle sized arteries into their branches, experienced the least retardation from any difference in the capacity of the vessels, or the numerous angles they formed with one another."† We

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* Monro's Anatomy. † Spallanzani's Experiments on the Circulation of the Blood.

We may conclude this part of the subject with the opinion of the very celebrated philosopher M. D' Alembert, that " we must not imagine that the theory of the motion of fluids in tubes, whether solid or flexible, can ever lead us to a knowledge of the mechanism of the human body, of the velocity of the blood, or of its action upon the vessels in which it circulates. To succeed in such an investigation, it would be necessary for us to know exactly to what degree the blood-vessels are capable of being dilated; in what manner, and according to what laws, they are dilated; to know precisely their figure, the degrees of their elasticity, their different anastomoses; the number, force, and disposition of their valves; the heat and tenacity of the blood, and the moving forces which impel it, or by which it is circulated. Even if each of these circumstances were perfectly known, the great number of elements which enter into a similar theory would probably lead

us to impracticable calculations. This is, indeed, one of the most complex cases of a problem, the simplest case of which is extremely difficult of solution. But since the operations of nature are too complicated and too little known to be subjected to our calculation, experience is the only guide which remains; we can rest our opinions only upon inductions deduced from a great number of facts. Such is the plan that we ought to follow in the examination of an hydraulic machine so complicated as that of the human body. It may be left to idle physicians to indulge the hope that they shall ever unveil the secret springs and hidden operations of the animal economy, by algebraical reasoning or hypothetical statements."

It is unnecessary to enter upon what Mr. KERR has said here against the fact of the pulse being caused by the blood, as it is

fully considered in another part of this Essay. It is sufficient to say here, that we have incontrovertible proof that the pulse is caused by the blood, when this dilates the coats of the artery; for Bichat made this obvious by demonstration, viz. he transfused blood from the artery of a living animal into the humeral artery of a dead body, and which, from this, acquired distinct pulsation.*

If, as Mr. KERR admits, "the experiment of applying two ligatures to an artery in the living subject, to ascertain whether blood is to be found between them, is certainly well calculated to establish the fact, whether

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* "The pulsation of the arteries is not occasioned by any power or action which is inherent in themselves, but is derived entirely from the dilatation and elongation which they experience from the blood impelled into them by the systole of the heart."

Thompson on Inflammation, p. 63.

whether blood is really contained in the arteries or not,"* the whole argument is already fairly decided against Mr. KERR, *suo judicio*, and in favour of the Harveian doctrine; for when a portion of an artery in a living animal is selected, giving off no branches, and two ligatures put under it, while the circulation is going on, and both tied at the same moment, blood is found in the intervening portion of artery. No doubt if the ligature be first tied on the upper part of the artery exposed, the blood below will escape, by the contractile power of the vessel, into the descending branches; or if the lower ligature be first tied, the blood may return, by a retrograde course, into the first anastomosing branch; but if both ligatures be quickly and dextrously drawn at the same moment, a portion of blood will be arrested between them.

* Page 35.

To put this important fact beyond the reach of doubt, I had the following experiment performed on a full grown rabbit. The necessary preparations being made, my friend Dr. Blaikie, whose abilities as a practical anatomist and a surgeon cannot be highly enough commended, and which I hope will be recognised on a better occasion, dissected into the abdomen of the animal, and laid bare the aorta, which was seen distended, and of a florid colour. A portion of the aorta was then selected, and two ligatures, put under it, including betwixt them about an inch of the artery, were tied, exactly at the same moment, by Dr. Blaikie and myself. This being done, the portion of the artery so intercepted instantly lost its red colour and fulness; becoming flaccid, and like a piece of white tape. This would have been a glorious result for an Antiharveian, or those of the school of Erasistratus; but what followed, I am afraid, would have afforded them opposite

posite reflections. On examining the portion of artery intercepted by the ligatures, we found a small lateral branch going off from it. We, therefore, included between two ligatures, as before, a small portion of the artery which gave off no branch, and found that it retained its red and full appearance. We now tied a ligature round the aorta, above the upper ligature of the last intercepted portion of artery, and cut out this piece. Upon puncturing it with a lancet, arterial blood flowed out. We repeated the experiment upon a portion of the aorta immediately above the last intercepted part, and found exactly the same result. We then allowed the divided aorta to remain untied, in order to terminate, as speedily as possible, the sufferings of the animal. These experiments were made by Dr. Blaikie, in presence of Mr. Allan and Mr. Smith, Surgeons in town, who very kindly gave us their assistance on the oc-

 casion,

casion, and who will bear evidence to the result of the experiments, as above stated.

This is an *experimentum crucis*, and leaves no room to doubt that the arteries are filled with blood in the living animal. It will also be observed, that the result of the first experiment, of intercepting a portion of the aorta between two ligatures, explains how the ancients, and also those of more modern date, have been deceived.* If a lateral branch goes off from the intercepted portion of artery, as soon as the two ligatures are tied, the part so intercepted must be immediately drained of its blood, and become flaccid, on account of the demand by the lateral branch, and the muscular and elastic power of the coats of both acting. It appears to me, that, in such a case, the lateral branch, in some degree acting like a syphon,

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* Such an experiment is mentioned by Drelincourt and Schwenke. Haller seems to explain it properly.

a syphon, may exhaust the blood from the intercepted portion. But this supposition is not necessary to the explanation of the phenomena, and Bacon objects to the adducing of more causes than are necessary. The case here alluded to certainly affords an extremely good proof of the contractile power of the arteries; that they can, in some measure, propel the blood, independently of the action of the prime mover of it, the heart; and that, in the natural state, they assist, by their own contraction, to carry forward the column of blood which they contain.

It seems very surprising how far the ancients, and those of more modern times, who subscribe to their opinions, have allowed themselves to be deceived in this simple matter. If they looked at the artery in its sound state, and saw it full or distended, and pulsating, they might at first be in some doubt between two opinions,

whether

whether blood or any aerial fluid was included, causing the phenomena. But although there is some excuse for the ancients remaining undecided, there is none for any since the time of Bacon, who laid down rules for the method of induction. "When in an investigation," says Playfair, "the understanding is placed *in equilibrio*, as it were, between two or more causes, each of which accounts equally well for the appearances, as far as they are known, nothing remains to be done but to look out for a fact which can be explained by one of these causes, and not by the other; if such a one can be found, the *uncertainty* is *removed*, and the *true* cause *determined*. Such facts perform the office of a cross, erected at the separation of two roads, to direct the traveller which he is to take, and on this account Bacon gave them the name of *instantiæ crucis*." By following out an investigation in this manner, Playfair informs us, "the doctrine of phlogiston

phlogiston was exploded, and a creature of the imagination replaced by a real existence."*

Mr.

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* See Playfair's Second Dissertation on Mathematical and Physical Science.—*Encyclopædia Brit.* vol. 2d. Part i. of Suppl. to 4th and 5th edition.

"But whence," "said Bacon, "can arise such vagueness and sterility in all the physical systems which have hitherto existed in the world? It is not certainly from any thing in nature itself; for the steadiness and regularity of the laws by which it is governed clearly mark them out as objects of clear and precise knowledge. Neither can it arise from any want of ability in those who have pursued such enquiries, many of whom have been men of the highest talents and genius of the ages in which they lived; and it can, therefore, arise from nothing else but the perverseness and insufficiency of the methods that have been pursued. Men have sought to *make* a world from their own *conceptions*, and to draw from their own minds all the materials which they employed; but if, instead of doing this, they had consulted experience and observation, they would have had *facts*, and not *opinions*, to reason about,

Mr. KERR informs us, "that all experiments made upon the living body under the influence of extreme pain, when the whole animal economy suffers from violence," "have never added any thing of real

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and might have ultimately arrived at the knowledge of the laws which govern the material world."

"As things are at present conducted," he adds, "a sudden transition is made from sensible objects and particular facts to general propositions, and round which, as round so many fixed poles, disputation and argument continually revolve. From the propositions thus hastily assumed, all things are derived, by a process compendious and precipitate, *ill suited* to *discovery*, but *wonderfully accommodated to debate*. The way that promises success is the reverse of this. It requires that we should generalize slowly, going from particular things to those that are but one step more general; from those to others of still greater extent, and so on to such as are universal. By such means we may hope to arrive at principles, not vague and obscure, but luminous and well defined, such as nature herself will not refuse to acknowledge." BACON.

real importance to medical science."* It is needless to endeavour to controvert this assertion here, though it is certainly very incorrect, as I think he has taken the trouble to do that himself, two pages over; for there he praises in the most lively terms the six hundred butcheries of living criminals, performed by his favourite ancient, Herophilus ("*lanio.*")†

I say, Mr. KERR contradicts his assertion of the total inutility of dissecting living animals, by his subsequent praise of the mode followed by Erasistratus and Herophilus, by which he says their observation or information was more correct. "Not only," says he, "did they dissect dead bodies, but those of living criminals, in great numbers; and such dissection, although

* Kerr's Essay, p. 40.

† "Herophilus ille Medicus aut *Lanio* qui *sexcentos* homines exsecuit," &c.—*Tertullian.*

though cruel in the extreme, certainly affords much better opportunity for experiments to ascertain the truth on this question, than that practised in our times."*

I certainly am least of all inclined to doubt, that Herophilus and Erasistratus, who so delicately gave names to the most delicate parts of the human body, performed dissections on living criminals; but as to the number, if we believe our most elegant Latin author Celsus, who has been always considered correct, as well as a model and standard of purity and elegance of diction, I think we have ground to doubt. Celsus says, "Necessarium ergo esse incidere corpora mortuorum, eorumque viscera atque intestina scrutari; longèque optime fecisse Herophilum et Erasistratum, qui nocentes homines, a regibus ex carcere acceptos, vivos inciderint," &c. "Neque esse

* Kerr's Essay, p. 43.

esse crudele, sicut plerique proponunt, hominum nocentium, et *horum quoque paucorum*, suppliciis remedia populis innocentibus seculorum omnium quæri."*

Though I do not approve of dissecting human bodies alive with a kind of idle curiosity, as seems to have been done by some of those mentioned, yet I think we have confirmed many most important facts in anatomy and physiology, by dissecting and making experiments on the bodies of living animals, particularly with regard to the functions of respiration and circulation, and also many with regard to digestion and absorption, and the functions of the brain and nervous system. By opening the breasts of frogs, newts, and such creatures, and of dogs, we have many beautiful proofs of the circulation, and see the effects of respiration, &c. To such experiments I

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* Celsus, p. 5.

have no objections, and think them highly useful; and there are few, I believe, of the medical profession who have not tried them more or less. I even think that occasionally, if it were permitted, some important experiments might be tried on the body of a criminal; and particularly that a mode of practice which might be useful, but apparently dangerous to life, might be first tried on a criminal condemned to die, provided he chose to take his chance of it for his life.

Nor need we fear that the false and absurd doctrine of Erasistratus, now revived by Mr. KERR, will ever gain ground, even among the most ignorant of the profession. Though it is not to be wondered at, that Erasistratus should conclude that there was no blood in the arteries, because he saw little or any after death in them; and, like the ignorant vulgar, try to explain the pulse by a supposed invisible and undefinable agent, which required to get some fine

sounding

sounding name, which makes a mouthful of nonsense always look much better. He, therefore, called *this nothing* the vital spirits, which were continually leaping about in the arteries, and so causing a pulse. What blood came out of an artery when cut had only liberty to do so after these animal spirits had chosen to take their departure. This is just what might be expected; for the vital spirits being of a more noble rank than the blood, would, according to the rules of politeness, take the precedence. It is easy to see that this is a fable of Erasistratus, and no true doctrine; for we know that, on the infliction of an wound of an artery, the flow of blood from it is simultaneous. And it shews that Erasistratus has not even attended to the common rules, viz. of making his fable *probable*. Aristotle says, "as well in the conduct of the manners, as in the constitution of the fable, we must always endea-

vour to produce what is necessary, or what is *probable*."*

It may readily be thought an unnecessary task to endeavour to prove, by grave and formal arguments, what is self-evident to all, viz. that the arteries, in the natural state, are full of blood, and that they do not contain, instead of this, any subtile aerial fluid, or indefinable existence, such as Erasistratus believed, and Mr. KERR has tried to confirm, under the name of vital spirits, elemental fire, &c. and which they conceive cause the pulse. But, as it has been urged by Mr. KERR as an incontrovertible opinion, and assumed as the basis of much of the reasoning, in supporting this ancient doctrine, I shall endeavour, by a little explanation, to shew the absurdity and falsity of

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* Χρὴ δὲ κὴ ἐν τοῖς ἤθεσιν, ὥσπερ κὴ ἐν τῇ τῶν πραγμάτων συστάσει, αει ζητεῖν, ἢ τὸ ἀναγκαῖον ἢ τὸ εἰκὸς.

Arist. Poet.

of this opinion of Erasistratus, which also runs through the whole of Mr. KERR's Essay.

The fact or experiment which we have mentioned, of Bichat's transfusing blood from the artery of a living animal into the radial artery of a dead body, and that producing exactly the phenomena of the pulse, proves, beyond all doubt, that the pulse in the living body is caused by the blood in the arteries, and that they are full of blood. But suppose Mr. KERR's position to be true,* "that there is no blood in the arteries in the sound and natural state, but that they are filled with elemental fire, which causes the pulse; and that, on the infliction of a wound, the vital spirits, or elemental fire, immediately escape, and the blood that is poured out is then derived from the heart, of course from a conside-

 rable

* Which is Erasistratus' opinion renewed.

rable distance;"* if we attempt to reason and draw conclusions from these assumed *data*, we find that we end in consequences which are most obviously inconsistent with plain matter of fact, with one another, and with the general scope of the theory founded on these *data*. It is needless to say, that it will be allowed by every one, that such a *theory* or *hypothesis*, so constituted, *must* be *false*, and *every thing* that *rests upon it*.

According to the principle assumed by Mr. KERR, and the established laws of fluids propelled through empty tubes being progressive in their course, it necessarily follows that some *time* must intervene between the infliction of a wound of an artery and the flow of blood, (allowing time also for the escape of the vital spirits). The *time* occupied in this progression of the

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* Vide Kerr's Essay, passim.

the blood, must be exactly according to the *distance* which the wounded part of the artery is from the heart, (allowing for any cause of retardation). For the sake of easy calculation we shall suppose that the blood moves along the arteries from the heart with an uniform and equable motion, at the rate of one inch every second of time. Suppose, then, an artery divided about the throat, which may be about the distance of a foot from the heart; then, (omitting the time which the vital spirits would require for their escape!!) *twelve seconds* of time will elapse before the blood spouts from the artery. And if an artery is divided on the fore part of the foot, as the tibialis anticus, this being supposed four feet distant from the heart, then *forty-eight seconds* of time, or nearly a minute, would elapse before the blood issued from the artery; and there would, consequently, be a difference of *thirty-six seconds* between the time of effusion of blood in the two cases.

But

But we know that these conclusions are altogether inconsistent with plain matter of fact, and, therefore, false and absurd; for, in both cases, the blood will spout out at the same instant, and *no difference* of time will take place between the effusion of blood from the throat and foot.

Jones has instituted more experiments on wounded arteries, with a view to stopping of hemorrhage, &c. than any other, and has had the most frequent means of observing the phenomena which took place on the infliction of a wound of an artery; and the result of his experiments produced this observation: "An *impetuous flow* of blood, a sudden and forcible retraction of the artery within its sheath, and a slight contraction in its extremity, are the *immediate* and almost *simultaneous* effects of its division."*

We

* Jones.

"There are some," says Bacon, "who, delighting in mere contemplation, are offended with our frequent

We know also, from uniform experience, that if a wound were inflicted on an artery of the throat, and one near the ankle, at the same moment, the blood would immediately flow from both arteries simultaneously; and that, instead of thirty-six seconds of difference, the *supposed* time here intervening betwixt the times when the blood flows from the two different arteries, no calculable time would intervene. When the *direct communication* of an artery with the heart is *cut off*, as by tying a ligature round the carotid artery, and then dividing it just above the ligature, a profuse hemorrhage *instantly* takes place from the upper portion of

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reference to experiments and operations to be performed by the hand, things which appear to them mean and mechanical; but these men do in fact oppose the attainment of the object they profess to pursue, since the exercise of contemplation and the construction of experiments are supported on the same principles, and perfected by the same means."

of the artery.* Here the blood could not have come directly from the heart to the wounded part, and could only come round by anastomosing branches; but some time would have been required for this, whereas we are told "a profuse hemorrhage instantly takes place:" hence it necessarily follows, that the arteries were full of blood before the infliction of the wound.

We have thus a *demonstratio ad falsum*, if we may use this term on so trivial an occasion, which proves, irresistably, the absurdity of Erasistratus' hypothesis, revived and supported by Mr. KERR. I am only afraid, that it will be thought the absurdity was so manifest that it required no such proof. But it is admitted, that, when once the principle of any theory is fairly proved to be false, consequently and necessarily every conclusion legitimately drawn from, and

* Jones.

and argument resting on, that principle, is also *false*. It is, then, clear and incontrovertible, that every part of Erasistratus' doctrine, and every argument of it connected with the supposed empty state of the arteries (their not containing blood) in the natural state, but, instead of that, vital spirits, or elemental fire, must be false and absurd.

It is of the utmost importance to have the first principles of every investigation fairly settled, and those things admitted as truths upon which we ground our subsequent arguments. As the preceding is demonstrative reasoning, and the inference necessary, it being impossible that the conclusion should not follow from the premises, an entire conviction and belief must result of the falsity of Mr. KERR's opinion of the arteries being empty of blood in the sound state; and of the truth of the opposite, that they must contain blood, for the reasons assigned.

assigned. Farther, as demonstrative reasoning has no degrees, one demonstration cannot be stronger than another. It is, therefore, superfluous to give more than one demonstration of the same truth.

We have, however, a very simple analogy, which may impress the truth on some minds, viz. the common instance of a leaden pipe going from a cistern. If, on cutting it, water *instantly* spouted out, and continued to run, no person in his sober senses would deny that the pipe had contained and conveyed the water before it was opened; or say, that the water had, at that instant, without any time allowed for its progression, come from the cistern, a distance, perhaps, of several feet or yards.

We know that the reasoning *a priori* may be applied to physics, after its first principles are established, and the evidence then rests on the same basis as mathematical demonstration.

monstration. I am afraid, that Mr. KERR, when he believed that the arteries were empty of blood, and began to reason about the cause of the pulse, as consistent with that supposition, was imitating too much the *exceptionable part* of the philosophy of his friends, the ancients; not that part of it which justly raised their names so high, and which will distinguish them to all perpetuity of time. He imitates Aristotle, when he admitted, as first principles, that the earth is at rest, that the heavenly bodies move in circles, that all bodies are composed of matter and form, &c. though these were totally devoid of evidence. I repeat, then, that it is a necessary truth, founded upon established principles of physics, by induction of the same weight as mathematical, that blood is contained in the arteries, in their sound state; and a truth shewn to be necessary from established principles may be considered as an axiom.

It was natural to enquire into the mode of reasoning and kind of logic which has been employed by Erasistratus, and adopted, approved, and boasted of, by his follower and admirer Mr. KERR, in our degenerate days. For it has been ingeniously found out, that, though Harvey and all his followers have had abundance of facts and experiments, they have been all equally unfortunate in drawing their conclusions, and in their mode of reasoning; leaving the true and safe path of philosophizing to be trod by two fortunate individuals, just mentioned. This, it is evident, must be very fortunate for them, and very unfortunate for all the world besides. But if Erasistratus and Mr. KERR be right in their mode of reasoning, and deducing conclusions from facts, or even in settling first principles; then it is as clear that Bacon, and Newton, and Boyle, and Reid, and a host of our first rate philosophers, are quite wrong.

On

On tying a frog's aorta, it has so swelled with the blood, and working of the left ventricle, that it has burst, the blood instantaneously spouting out.

If the vital spirits, or elemental fire, and not blood, cause the pulsation in the left ventricle and aortic system; I would be glad to be informed why the right ventricle and pulmonary artery pulsate, which Mr. KERR allows to be full of blood, and in their natural state to contain *no* vital spirits or elemental fire. This shews that pulsation is consistent with such vessels, as the left ventricle and arteries being full of blood; and I shall prove that pulsation is not consistent with the opposite state, or at least does not take place, when they are empty of blood, as far as uniform experience goes. When a tourniquet is made very tight about a limb, so as to suppress or prevent the flow of blood into the arteries, the pulse ceases. In this case the circulation in the limb is ar-

rested, and the blood, leaving the arteries, accumulates most in the veins. If only a small quantity of blood is allowed to enter the arteries, the pulse is weak and feeble, or perhaps gone. This goes far to prove, that there is not only blood in every part of the arteries, but that they are full in the ordinary and sound state, when the pulse has a firm and regular beat: for we see that the pulse is stronger or weaker exactly in proportion to the quantity of blood in the arteries, if there is not too much, which has the effect of oppressing the pulse.* "Upon tying the two venæ cavæ, so as to prevent the blood arriving at the heart, the heart ceases to beat: when we slacken the ligatures,

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* The circulation of the blood is seen by a microscope to go on in an uninterrupted stream, in the arteries, intervening capillary vessels, and veins, of the web of the foot of a frog.

Thompson on Inflammation, p. 77.

tures, and let in the blood again, the motion is renewed."*

Mr. KERR, in adopting Erasistratus' opinion, contradicts himself flatly, by saying that, when an artery is wounded, though it contained no blood before, it may have it, at that instant, derived from the heart. According to his own unfounded belief, there is no blood, but elemental fire, in the left side of the heart, *which alone* is continuous with the *aortic system;* and as he denies that arteries anastomose with veins, or that there is any medium of communication by which blood might circulate from the one to the other, the conclusion is inevitable, that blood cannot, when an artery is wounded, or at any other time, pass from the right side of the heart, through the pulmonary artery and veins, to the left side of the heart; and from thence along the

* J. Bell's Anatomy.

arteries, to the wounded part. Here, reasoning again from his own *data*, we end in manifest absurdity.

Mr. KERR has insinuated a very sly argument against the fact of arteries in their natural state being full of blood, by telling us that, in performing arteriotomy in the temporal artery, the first blood thrown out has the appearance of bloody vapour, for several pulsations, and that afterwards the blood becomes of a darker colour, and does not flow *per saltum*, but equally, as from veins; that an alteration soon takes place in the *size* of the jet, from *small* to *large*; and "the *moment* the artery is *full*, *pulsation* is *lost*, and the colour is changed."*

This is evidently an incorrect and coloured account of what takes place when an artery is cut; and I shall only attempt to

* Vide p. 44 and 57.

to refute it, by quoting the highest and most respectable authority with regard to the point in question. No one will deny that Jones has had far more ample experience of what takes place on the division of arteries than any other, or that he has given faithful and candid reports of his experiments. I have, therefore, already quoted him as supreme authority in this respect. He informs us, that, when an artery is cut across, the *size* of the stream, and *strength* of the jet, or *pulse*, are observed to *diminish in equal degrees;* at first a full stream, thrown out by regular jets and strong pulsations, synchronous with the beat of the heart; and, *after* some time, as the *animal languishes*, and is *exhausted*, the *stream* becomes *small*, and the pulsation and flowing *per saltum* ceases; a clot is formed at the mouth of the vessel, and if the animal lives, the blood passes on by collateral branches, the blood stagnating and coagulating between the mouth of the

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cut vessel and the first anastomosing branch; and of course there can be no pulsation in this part of the artery any longer. "Previous to the division of the great vessels, ('to kill the animal') the jet of blood, from the portion of carotid hanging out at the wound, had diminished both in size and in strength;"* *i. e.* after the vessel had bled with a full stream for some time.

"The humeral artery of a dog was divided, and the wound in the integuments left entirely open. A very *profuse hemorrhage* ensued, but the animal soon became *faint*, and the *blood ceased* to *flow*."† "A *languid state* of the circulation is necessary for the accomplishment of the natural means for stopping hemorrhage."‡

Does

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* Jones, p. 34. † Ibid. p. 53.

‡ Ibid. p. 58.

Does this account given by Jones at all correspond with that brought forward by Mr. KERR to bias our opinion against the Harveian doctrine? I shall leave it for others to conclude whether the extensive experience of Jones in this respect entitles him to confidence or not. To confirm the evidence of the *diminished flow* of blood, as the artery continues to bleed, &c. I shall add Jones' conclusions on the natural process of stopping hemorrhage.*

From

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* "They (viz. experiments) accordingly shew that the blood, the action, and even the structure of the arteries, their sheath, and cellular substance connecting them with it—in short, that all the parts concerned, or affected by hemorrhage, contribute to arrest its fatal progress, by operating, in the case of a divided artery of *moderate size*, in the following manner:—

"An *impetuous flow* of blood, a sudden and forcible retraction of the artery within its sheath, and a slight contraction in its extremity, are the immediate and almost *simultaneous* effecs of its division. The natural impulse, however, with which the blood is driven on in

From the result of Jones' experiments, we see that the ceasing of the pulse in bleeding

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some measure counteracts the retraction, and resists the contraction of the artery. The blood is effused into the cellular substance, between the artery and its sheath, and, passing through that canal of the sheath which had been formed by the retraction of the artery, flows freely externally, or is extravasated into the surrounding cellular membrane, in proportion to the open or confined state of the external wound. The retracting artery leaves the internal surface of the sheath uneven, by lacerating or stretching the cellular fibres that connected them. These fibres entangle the blood as it flows, and thus the foundation is laid for the formation of a coagulum at the mouth of the artery, and which appears to be completed by the blood, as it passes through the canal of the sheath, gradually adhering and coagulating around its internal surface till it completely fills it up, from the circumference to the centre.

" A certain degree of obstruction to the hemorrhage, which results from the effusion of blood into the surrounding cellular membrane, between the artery and its sheath, but *particularly* the *diminished force* and velocity of the circulation, occasioned by the hemorrhage, and

bleeding arteries, after a time, is not, as Mr KERR falsely reasons, from an *increased flow or stream* of blood; but from the *diametrically*

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the speedy coagulation of the blood, which is a well-known consequence of such diminished action of the vascular system, must essentially contribute to the accomplishment of this important and desirable effect.

"A coagulum, then, formed at the mouth of the artery, and within its sheath, and which I have distinguished in the experiments by the name of external coagulum, presents the first complete barrier to the effusion of blood. This coagulum, viewed externally, appears like a continuation of the artery; but, on cutting open the artery, its termination can be distinctly seen, with the coagulum completely shutting up its mouth, and inclosed in its sheath," &c.

"From this view of the subject, we can no longer consider the suppression of hemorrhage as a simple or mere mechanical effect, but as a process performed by the concurrent and successive operation of many causes. These may briefly be stated to consist in the retraction and contraction of the artery; the formation of a coagulum at its mouth; the inflammation and consolidation of its extremity, by an effusion of coagulable

metrically opposite cause, a *diminished* stream of blood, and the faintness of the person or creature, &c. as explained in the observations just quoted.

And as we do not know any thing satisfactory with regard to the colour of the blood, or how the crimson or purple colour is given or caused, we cannot, of course, draw any conclusive argument from its colour, as extravasated, against the Harveian doctrine. Many causes may change the crimson colour of the arterial blood during its

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lymph within its canal, between its tunics, and in the cellular substance surrounding it."*

"And we may conclude, that, except in some rare instances, in which the strong retraction and contraction of a divided or lacerated artery prevents hemorrhage altogether, *a languid state of the circulation* is *necessary* for the *accomplishment* of the natural means by which the *hemorrhage is stopped*."†

* Jones, p. 56. † Ibid. p. 57.

its flow from an artery, and when extravasated, to a dark purple colour, which we know nothing of. One thing at least we know, that the colour of the blood is intimately connected with the temperature; for Dr. Crawford has satisfactorily ascertained, that, in animals placed in a very high temperature, the change of arterial blood into *venous* does not go on; but the blood in the veins is of a crimson colour: and thus no addition of heat arises from this source; or the arterial blood does not evolve any of its latent caloric in a sensible or free state, some chemical change, which commonly takes place, being prevented.

I shall here quote Dr. Henry's words, in his last edition of his Chemistry, which are explicit with regard to the colouring matter of the blood:—"It appears, therefore, that the colouring principle of the blood is *an animal substance*, of a peculiar nature, susceptible, like the colouring matter from

vegetables, of uniting with bases, and admitting probably of important use in the art of dying. On examining the colouring matter distinctly from the crassamentum, Mr. Brande did not discover a greater proportion of iron than in the other principles of blood; and the theory may, therefore, be considered as completely set aside, which accounts for the red colour of the blood by the presence of iron."*

"It is, doubtless, on the red globules of the blood that the different gases act, which produce such remarkable changes in the colour of the entire fluid. Nitrogen gas blackens arterial blood, and, according to Girtanner, venous blood also. In an experiment of Dr. Priestly, it appeared that the bulk of a quantity of nitrogen gas, to which arterial blood was exposed, sustained a diminution. Blood, which has had its colour

* Henry, p. 323.

colour thus impaired, it was found by the same philosopher, may be restored to its bright florid hue, by agitation with oxygen gas; and these changes may at pleasure be repeated alternately. Oxygen gas, to which blood is exposed, is diminished in volume, and contaminated by carbonic acid. Atmospheric air undergoes the same change, in consequence of the oxygen which it contains, but in a less remarkable degree."

"Similar alterations are also constantly going on in the blood, during its circulation in the living body."*

Nitric acid is found to destroy the red colour of the blood, and convert it to a brown.

The changes which are made upon the blood by respiration, and the precise way

* Henry, p. 323.

in which these are effected has been long matter of dispute, and has given rise to much controversy. All, however, that we know satisfactorily about it is, that a certain quantity of oxygen is abstracted from respired atmospheric air, and that an equal volume of carbonic acid gas is substituted, the nitrogen gas being unchanged. But Messrs. Allen and Pepys have observed a very curious circumstance—that when herbiverous animals respire pure oxygen gas, a portion of it disappears, and a corresponding quantity of nitrogen is produced in its stead. The same takes place when a mixture of hydrogen and oxygen has been respired.

It is still matter of doubt, whether, during respiration, oxygen is absorbed through the coats of the vessels, and displaces carbonic acid, which might be considered as pre-existing in the blood; or whether the carbon

bon of the blood does not rather unite with the inspired oxygen, and form that acid; but the most intelligent chemists think the latter supposition most probable. It is proved that all the oxygen expended in respiration goes to the formation of the carbonic acid, of course no portion of it serves to form with hydrogen the halitus expired; but the latter must be rather the condensed vapour, exhaling from the cells of the lungs, where it is secreted. The experiments of Messrs. Allen and Pepys seem to establish this. One of the most important purposes which respiration serves, is to preserve an equable temperature of the animal body, independent of the changes of the surrounding atmosphere; only a few degrees of variation being observed under a cold of many degrees below the freezing point, or a temperature nearly that of boiling water. In the latter case the caloric must be absorbed, and become latent in the body; and in the former, the latent caloric

must be evolved in a free or sensible state. With regard to this point, observations have been made by Dr. Crawford, more satisfactory than by any other; though we are still unacquainted with the precise difference which makes the distinction between arterial and venous blood, or how that change is effected by respiration. He has shewn that the animal temperature is preserved by the difference of capacity for caloric which exists in the arterial and venous blood, that of the latter being to the former as 892 to 1030. It follows, that when the arterial blood is converted into venous, a quantity of latent caloric must become sensible; and as this change is constantly going on during the course of the circulation, a proper temperature of the body will be maintained.

Mr. Brodie has shewn, however, that the animal temperature is not properly produced, if the nervous influence is diminished, though the circulation go on—and this

this partly accounts for the coldness of a paralytic limb; for if the influence of the brain is cut off, no heat is generated, though respiration and circulation be kept up for some time.

It is ascertained that the skin has a function similar to the lungs; that part of the oxygen of the atmospheric air is absorbed, and carbonic acid and watery vapour exhaled.

I have entered upon this digression about the blood, and the changes it undergoes, for various reasons. It will serve as a basis for our reasoning afterwards, and prevent continual repetitions. In particular, it will shew, that the dark colour of blood, after it is poured out by an artery, or its being poured out of a darker colour after the hemorrhage has continued for some time, as Mr. Kerr alledges, can afford no decisive argument against the circulation. As we know

know that arterial crimson-coloured blood can, by various causes, be changed into dark-coloured venous blood, and as we are ignorant of the precise way in which this is produced, how can we reasonably infer that the arterial blood in this case is not changed by some chemical action going on, while it is effused? We know that nitrogen gas renders it dark, and here it is exposed to it in the atmospheric air; the temperature is diminishing, and we have seen that this has an intimate connection with the changes going on in the blood; as, when the temperature is excessively high, the change from arterial to venous blood does not go on, but the blood in the veins is as florid, and of the same crimson colour with that in the arteries. How then can this be explained on Mr. KERR's assumption, that the blood is florid when it first comes from an artery, because it is mixed with the vital spirits or elemental fire, which resides only in the left side of the heart and arteries, and

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becomes afterwards dark, when the spirits have escaped; and it is derived, as he assumes, from the right side of the heart and veins, which have no vital spirits in them, but gross animal blood, and therefore dark? Here we see a proof of the communication between the arteries and veins; the florid blood of the arteries passing into the veins unchanged, on account of the high temperature applied to the animal, and yet no vital spirits in the veins to produce this change, which makes it evident that the crimson colour of blood in arteries must depend on another cause.* It also sets aside the false account which we have received of the pulse; for if the florid colour of arterial blood and the pulse equally arose from

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* It is clear that the arteries are full of blood, and blood alone; for if air were contained in them, it would soon arrest the circulation, by collecting at the various angles and curvatures of the vessels, which we know takes place in pipes conveying water from any cistern.

from the supposed vital spirits, then in the case just mentioned we should have a pulse in the veins, as well as arteries, which is contrary to the fact.

That the lymphatics have valves, as well as the veins* is no proof at all against a circulation; or because the fluid in the lymphatics does not move round in a circle like the blood. These valves are placed in both sets of vessels, veins, and lymphatics, with the same intention, viz. to make the contained fluid move in one direction, to support the column, and prevent any retrograde movement. After death, they are also observed to perform this office accurately, supporting a column of mercury without giving way. As the valves do not exist in the lymphatics of all animals equally, perhaps they are of use chiefly where not much muscular power exists; for it is observed

* Vide p. 47.

served in some animals, particularly fishes; and where the muscular power of the lymphatics is very distinct and perfect, there are no valves. This is very perfectly seen in the sea egg, or star-fish.* The lymphatics being more narrow in their caliber at their mouth, absorb their particular fluid by capillary attraction. Afterwards it is propagated along their course by the muscular contraction of the vessels themselves, assisted by the valves, and perhaps by the contraction of neighbouring muscles, and the pulsation of arteries. The muscular contraction of the coats of the lymphatics themselves must be of great advantage, by lessening the caliber of the vessel, and of course increasing the power of capillary attraction; as a fluid rises higher in proportion to the smallness of the tube. They may also possess very different degrees of irritability, in different parts; and in general are probably much

* Monro's Anatomy, vol. ii. p. 292.

much more irritable at their orifice than at any other part. They are also more irritable, or contract more on the application of some substances than others.

It seems to me from these facts and observations, that it is of no consequence, so far as respects the use of the valves, whether they are placed in tubes forming part of a circle, or only ascending and descending in a straight direction, more than it would argue against the use of locks or flood-gates in a canal, whose course was a straight line, or winding round in a circular direction; or turnpike gates on a straight road, or a serpentine, or a perfectly circular one.

Mr. Playfair speaks very highly of the utility of analogies between natural and artificial productions as guides to discovery. "Comparative anatomy," says he, "is full of analogies of this kind, which are most instructive,

instructive, and useful guides to discovery. It was by remarking in the blood-vessels a contrivance similar to the valves used in hydraulic engines, for preventing the counter-current of a fluid, that Harvey was led to the discovery of the circulation of the blood. The analogies between natural and artificial productions are *always highly* deserving of notice."*

I have already given reasons why Harvey, or any other, might take it upon him to say that Erasistratus had been deceived by the appearance of the arteries after death.† For whether he dissected living criminals or not, which is not the question here, we know that if he had opened any of the arteries in these living criminals, he would have found them full of blood, as they would instantly have testified, by bes-

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* See Playfair's Dissertation.

† Kerr's Essay, p. 48.

nearing his face, if opposed, with that same fluid. And, at any rate, we find them full of blood now a days. If the arteries were different during his enlightened age! it must be explained by a change in the structure of the species. We can make as many experiments as we please on dogs, which are neither cold-blooded animals, nor want lungs, and we always find their arteries *full of blood.**

"Could Harvey possibly believe that the pupil of Plato, cotemporary of Euclid, the son-

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* Surely if Erasistratus was not imposed upon by some false reasoning of his own, or others, he could not believe what is notoriously false: and I think, with Harvey, it is most probable that he must have been deceived by the appearance after death; for he could not have been deceived by the appearance before death, else we would have been inclined to ask him a question, not much used by philosophers, or to philosophers, but, nevertheless, *pertinent* enough, viz.—"Whether he

son-in-law of Aristotle, and friend of Theophrastus, had, from want of accuracy, or ignorance, omitted to perform those simple experiments upon which he founds his hypothesis?"* Yes: I do think it possible, and even probable, that not only the pupil of Plato, cotemporary of Euclid, the son-in-law of Aristotle, and friend of Theophrastus, as we are magnificently informed this chimerical physiologist Erasistratus was; but even Plato himself, Aristotle, and Theophrastus, might have committed this error, and made hypotheses without just foundation, as we know they did make

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knew a hawk from a hand-saw when the wind was N. West!!"? That part of Erasistratus' doctrine which supposes the arteries of the living body empty of blood seems to me so ridiculous that I can compare it to nothing else in all the world but the craniology of Doctors Gall and Spurzheim.

* Kerr's Essay, p. 48.

many such ;* as to Euclid, I would have expected more accuracy from him. But whether

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* Plato, for example, in speaking of the matrix and its diseases, says, " the matrix is an animal which longs impatiently to conceive, and if it be long disappointed in bearing fruit, is enraged, and runs up and down the whole body, and stopping the passages of their air, it takes away respiration, and causes great uneasiness, and an infinite number of diseases."—*Le Clerc*, p. 381.

Aristotle, after attributing the most noble uses to the heart, says, " The brain was, in his opinion, but a heap of water and earth, without blood and without sense. The office of this cold lump was, says he, to refresh and moderate the heat of the heart." " And although the brain be placed immediately upon the spinal marrow, and fixed to it, yet he pretended that the substance of that marrow was quite different from that of the brain, being a sort of blood prepared for the nourishment of the bones, and consequently hot, whereas the other was cold." *Le Clerc*, p. 390.

He pretended to describe the anatomical structure of the human body, and reason on its physiology, though he never dissected it, or saw it dissected, as he tells us himself in these words: " The inward parts of men's

whether this be the case or not, it is very plain that Plato might have had many foolish scholars, and Aristotle equally foolish sons-in-law; Euclid many ignorant and fanciful cotemporaries, and Theophrastus might have many friends, who had benevolent hearts, and other good qualities,

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bodies are unknown, for we have nothing certain thereupon, but we must judge of them by the resemblance which we suppose them to have to the parts of other animals, which answer to each of them." Le Clerc adds, "I am surprised that Riolan should mention the contrary, and more that he should endeavour to prove it from passages of Aristotle, which are nothing to the purpose; *but he is not the only one whose prejudice and bigotry for the ancients has caused to make such false steps.*" p. 396.

As an example of Theophrastus' mode of reasoning, we may insert the following:—"He says, that vertigos come, when some strange spirit or superfluous moisture goes into the head, or, as he expresses it, about the head, whether this comes from any sort of food, as from wine, or from any other humour, or from turning the

without their being good anatomists or physiologists, or strictly attentive or infallible in making theories on just grounds.

"Could Harvey believe that they who gave names to the valves of the heart, which remain even to this day, had left it for him to form the first rational opinion of their use?"* &c. Yes—surely we can believe it. Many parts of the body were named and described long before their use or proper functions were justly explained or understood. Various parts of the heart, as the

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head round. For, adds he, the place about the brain, or the brain (an usual manner of expression among the Greeks) is naturally moist; when any foreign spirit gets in, it does violence after it is got in, and forces the natural moisture into the veins, causing it to turn round, so that this spirit has the same effect as if any body turned the head round, it being indifferent whether it be done inwardly or outwardly."—*Le Clerc*, p. 398.

* Kerr's Essay, p. 49.

the foramen ovale, and its valve, the coronary arteries and vein, the eustachian valve, the lungs and liver, and heart itself, the eye, and ear, and many other parts, were named and pretty well described long before their functions were accurately understood, or their *ratio* explained so well as now. Nay, the very valves of the veins were described by Fabricius, without his thoroughly understanding their use, and, as we learn from an authority which Mr. KERR, I presume, will not dispute, viz. his own, this suggested to Harvey a circulation of red blood.* Now I do not see any thing against Harvey being the fortunate person "to form the first rational opinion of the use of the valves of the heart," if it had so pleased God, more than that Sir Isaac Newton should first give a true explanation of the motions of the heavenly bodies, or Sir Humphry

* Kerr's Essay, p. 97.

Humphry Davy find out the metalloid bases of the alkalis and earths, which were known and described, accurately enough, long ago, and considered as simple substances.

After this Mr. KERR expatiates as usual on the superiority of the ancients in every thing; as if he had taken for his creed, τα ωγυγια αριστα—*antiqua sunt optima*. But it is unnecessary to enter upon any minute discussion of this here. I shall only refer to the judicious observations of Mr. Playfair.*

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* " Again," says he, " the reverence for antiquity and the authority of great names have contributed much to retard the progress of science. Indeed the notion of antiquity which men have taken up seems to be erroneous and inconsistent. It is the duration of the world, or of the human race, as reckoned from the extremity that is past, and not from the point of time

If the artery which is divided be of any considerable size,* and allowed to bleed freely, I doubt the patient will not be long in very good spirits! but rather sick and faint, as has been shewn by the accurate observations and experiments of Jones, and the action of the arterial system languid over the body.—"*Motus cordis imminutus vel aliquamdiu quiescens,*" is Cullen's definition of Syncope.†

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which is present, that constitutes the *true antiquity*, to which the advancement of science may be conceived to bear some proportion; and just as we expect more wisdom and experience in an old than in a young man, we may expect *more knowledge* of nature from the *present*, than from *any* of the ages that are *past*."

Vide Playfair's Dissertation, Encyclopædia Britannica.

* In a foot note, p. 93, Mr. Kerr tells us it must be "artery of considerable size."

† Page 56.

"In expellendo—what?"* (says our author) "not blood."—Yes, blood to be sure! what else, I would ask? not vital spirits, which I believe have no existence; and are only mentioned by such authors as Erasistratus, or Dolæus, a certain German author of eminence, with a curious theory of whom I shall end this volume. Although Harvey says, *in articulo mortis*, when the function of the lungs is ceasing a due quantity of blood does not pass through them to the left side of the heart; yet a small quantity passes, which excites some contraction in the left ventricle; and this, with what remains in the arteries, is, by the last convulsive action of the heart and arteries, partly propelled into the veins, though not altogether; for more or less blood is to be found, after death, in the left side of the heart

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* Page 60.

heart and arteries, (as has been explained already,) according to circumstances.*

I think Mr. KERR has been particularly unfortunate in adducing the case of the blue

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* "It is also certain, that in the human aorta, several hours after death, a great *diminution* of the *usual quantity of blood* is often observable; whence, on the principles already laid down, we may infer that this artery is possessed of a considerable degree of *tonic power.*"

"The facts which have been related afford a probable reason why, in the experiments of Haller, the circulation of the blood proceeded, for *a certain time,* in microscopic arteries, after ligatures on the aorta, or even the entire separation of that artery from the heart. The *larger* arteries *continuing* to *contract* by their *tonicity,* the *blood* during that period must necessarily have *gone on,* suffering slow propulsion from them into the smaller or *capillary branches* of the *same system,* or, *through that into the veins.*"

Parry, p. 81 and 82.

blue boy, as a proof of his assumed hypothesis, that no blood is naturally contained in the arteries; but is here present, from the circumstance of the *foramen ovale* being open. To me it appears that no better proof can be given of the true and natural state of the circulation and respiration than by contrasting it with this diseased state, where, instead of a full oxygenation of the blood, only a small quantity, on account of organic derangement of the heart and large vessels, passes through the lungs, to undergo the usual change which produces in it the crimson florid colour.

It is unnecessary, and it would be very tedious to enumerate the different kinds of malconformation of the heart which causes the purple or livid colour of the skin of those children alluded to. Several authentic and minute accounts of the hearts of these are to be found recorded by Baillie, Hunter, and others; but they all agree in this,

this, that either the heart sends little blood to the lungs, or the lungs cannot receive that blood; so that a very small portion of the blood circulating through the body is oxygenated, and therefore wants the usual florid crimson colour; and the child lives like an amphibious animal, having as it were a single heart, and a scanty portion of its blood oxygenated. But although this was sufficient for the existence of the *fœtus in utero*, yet, being born, this imperfect mode of circulation will not suffice; but sooner or later, though it may survive for a time, life is, by some slight accident, destroyed: for after birth, a double heart and a double circulation is required, one through the lungs, and one through the body.

In the cases alluded to, there is some fault in the organization, which prevents the proper separation of the two sides of the heart: either the *foramen ovale* remains open, or there is a hole through the *septum*

ventriculorum, as was observed by Hunter in one case, of a size to admit a goose quill, and in another case a hole through the *septum cordis*, at the basis, sufficient to admit a small thumb: and Dr. Pulteney has given a case similar to the former, (in the 3d vol. of Med. Trans.); or the pulmonic artery does not admit the blood so as to pass through the lungs, being impervious in some part; or the aorta arises from the right ventricle, so as to carry the blood past the lungs, while the pulmonary artery arises from the left ventricle;* or the aorta has been found to rise equally from both ventricles, its mouth standing over them as it were, and in this case would receive its blood from both ventricles, of course half of it oxygenated, and half of it dark coloured. The deviation from the natural formation most generally exists in the pulmonary artery. Any person in the least acquainted

* Baillie's Morbid Anatomy, p. 40.

acquainted with the structure of the heart and lungs, and their functions in the sound state, could not fail to see the true cause of the purple or livid colour of the child, in which these malconformations occur; nor in the least degree adopt the opinion offered by Mr. KERR, that the blood has an egress from the right to the left side of the heart in this case only, and *not* in the sound and natural state; and that, *therefore*, the morbid symptoms of the blue boy occur.

Even in this simple and self evident case, that I may not seem to rely too much on my own opinion, I shall shew how strongly it is supported by the highest medical authority of the present day. Dr. Baillie says:—"It is obvious that in these deviations from the natural structure, only a *small quantity* of blood can *pass* through the *lungs* to receive the benefit of respiration, and that this will be more or less, according to the degree of the deviation.

The *blood* will, *from this cause*, be of a *dark colour*, as it is well known that it receives the florid hue from the influence of the air upon it in the lungs. Hence the *colour of the skin* must be *necessarily dark*, and this will be *increased* when the blood is *accumulated more than usual in the veins.*"*

The paragraph about wounding or puncturing the left ventricle of the heart, and that producing instant death, while the same does not happen from puncturing the right ventricle; and attributing that to the escape of the vital spirits, the πνευμα εμφυτον of Hippocrates, &c. from the left ventricle, and only the gross material blood in the other case, requires a strict investigation in all its particulars.†

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* Baillie's Morbid Anatomy, p. 38.

† Vide Kerr's Essay, p. 66.

In the first place, I am not inclined to believe that there will be such a disparity betwixt the time intervening between the infliction of a wound of the left ventricle, and death, and a wound of the right ventricle and death; if the wounds are equally large, and calculated to discharge an equal quantity of blood in a given time. This does not at all seem to have been suspected by Dr. Baillie, who has had the most extensive experience, and the greatest opportunities of investigating morbid appearances after death. When speaking of the heart being sometimes burst, he says, "it sometimes happens, and I believe chiefly in those who are advanced in life, that the heart, *at some part*, becomes thinner, and, upon any great exertion, bursts. The blood escapes into the cavity of the pericardium, and the person is *instantly* destroyed."*

* Baillie's Morbid Anatomy, p. 34.

Dr. Baillie does not even hint at any difference between the right and left ventricle being burst, as modifying the *instantaneous* death; but speaks of this event being equally certain and sudden, whatever part of the heart bursts. He seems not to have suspected any such circumstance as Mr. KERR confidently speaks of, else he would have said, when this weakness and bursting of the heart takes place in the left ventricle, life is *instantly* extinguished, "*quasi fulmine ictus;*" but, on the contrary, when it takes place in the right ventricle, "the person may live for days, and even use considerable muscular exertion." But Dr. Baillie mentions no such circumstance, and I conclude from that, that he was not in the belief of such; and his opportunities for observation have been more extensive than those of any other.

However, admitting that a person will die instantly of a considerable wound of the

the left ventricle, which, I think, is very likely to happen from a like wound of the right ventricle, I think we may explain any slight difference in the circumstances thus: We know, that when the proper quantum of blood which supports the energy of the brain is, by any means, suddenly abstracted from, or diminished, in the arteries of the brain, the person instantly faints, as in tapping the abdomen, for ascites, when a very large quantity of fluid has been allowed to escape suddenly, without a proper bandage to support the viscera of the abdomen; for then a column of blood in the descending aorta, and in the large veins of the abdomen, is not supported; the blood accumulates in these vessels; the abdominal muscles, diaphram, and membranes about the heart, are relaxed; and the heart acts feebly and flutters—so that little or no blood is sent to the brain to support its due energy and stimulus, and the person faints. We know, that when such ascitic water is

allowed

allowed only to flow in a very small stream from a small opening, or if only a part of the accumulated fluid is abstracted at a time, or a proper bandage is put round the patient's abdomen, and tightened during the operation, no fainting or sinking takes place, because the change on the vessels is produced gradually, and they contract equally over the system, and accommodate themselves to the change, without any deficiency or collapse being felt in the heart. The same takes place in bleeding; for the system will bear an infinitely greater loss of blood, as to quantity, by a slow oozing from a number of small vessels, bursting out occasionally, than from an artery or vein of a large size; for in this case a few ounces from the aorta, or iliac, or femoral artery, will so exhaust the heart, and affect the brain in such a manner, that the person will immediately faint, and, perhaps, never revive. And, to shew clearly, and we may say demonstratively, that it is not in this

case

case the loss of that imaginary principle, vital spirits, elemental fire, aerial acid, phlogiston, æther, πυρ εμφυτον, or whatever mystical and undefined existence our author supposes to fill the arteries, to cause life, and which he will now be ready to come forward and say produces sudden death, by its escape from the arteries; it is found by actual experience, which nothing can set aside, no suppositions or conjectures, or negative proofs, however numerous, being at all to be put in competition with a positive fact, that the same sudden sinking, and instant death, is produced by the bursting or wounding of a varicose vein in the thigh. In this case the valves have lost their power, along the course of the vessel, being too narrow for its distended state, and in a moment the column of blood which should supply the heart and brain descends, and thus the person instantly expires, as without this supply we know there is no life, in whatever way that

principle

principle may be communicated or supported. The energy of the brain, which is supported by the due fulness of its vessels, is instantly destroyed. And it is thus, I conceive, that we are to explain the death being more sudden from a wound of a large artery than from that of a vein, in general, (*i. e.* when the latter is sound and undilated, its valves acting as guards to support the column of blood,) and also the difference betwixt an oozing of blood from a number of small vessels, and a sudden gush from a large trunk; between a wound of the right ventricle and left ventricle of the heart. We have not, therefore, to seek an explanation of this phenomena in the mystical and exploded doctrine of the *vital spirits* being evacuated: for if this doctrine be true, how will Mr. KERR explain to me the equally sudden sinking and death, from the bursting of a large varicose vein of the thigh, which he confesses contains no vital spirits or *elemental fire*, but only blood? or

how

how the same should happen from removing, suddenly, the pressure of any fluid, as ascitic water, without either artery or vein being opened, or any wound, whereby the vital spirits may escape? It is evident that the principle is the same in both cases; the column of blood descends instantly, for want of its usual support, leaving the heart empty and collapsed, and the vessels of the brain without their supply of blood.

Here, perhaps, it will be alleged, that a part of the hypothesis is, that the blood of the right side of the heart and veins, and the vital spirits of the left side of the heart and arteries, mutually balance each other; "and each forces forward to supply the place of the other, when withdrawn."* But we are informed, that when the vital spirits mix with the blood, it immediately becomes of a light florid crimson colour, as in the case

* Vide Kerr's Essay, p. 56.

case of arteries; and a proof of this is offered which to me appears very absurd. Where large bleedings have been instituted, as for pneumonia, it is said, the blood at last becomes pale, like washings of beef, "*lotura carnis;*"* and Mr. Kerr alleges it is from the mixture of refluent vital spirits. But we know, on the contrary, that this appearance arises only from the system being impoverished, by the great evacuations, and the abstraction of the usual nourishment, by what is called antiphlogistic regimen. In such cases, the *crassamentum* is always greatly diminished, while the serous part abounds; so that there is a thin watery state of the blood, something like washings of flesh; and this always arises from inanition. Of the colour of the blood we know little, but we know that it is attached to, or depends upon, the red globules; and that the crassamentum, (including

* Vide Kerr's Essay, p. 73.

cluding the fibrine and red globules) is much accumulated by rich and high feeding, and in high health; and diminished wonderfully in debility and disease, and by all kinds of inanition: so that the colour of the blood is the index of health. It is a fluid which varies every day, and is either poorer or richer according to the state of the system, and many fortuitous causes.*

Nor does this opinion, and what I have said against the existence of animal spirits,

* I conclude, from a very high authority, viz. the experiment of Mr. Cruickshank, that all Mr. Kerr's assumptions and reasonings about the *arteries*, the *pulse*, the *vital spirits*, and *elemental fire*, the latter causing the *pulse*, and, with an equal certainty, the *light* and *florid colour* of the *arterial blood*; and his conclusion, that the *arteries* do *not* naturally contain *blood*, and that the *pulse* is *inconsistent* with their containing blood, are false and absurd. He remarked, that when an animal had its spinal marrow divided in the upper part of the neck, respiration ceased; but the action of the heart conti-

lead to that mean and contracted view which some have espoused, that "the life consists in the blood."* This is materialism.

"I can most easily imagine," says Mr. J. Bell,† "how the system, having, by successive

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nued, and circulated a *dark coloured* blood, the blood not having undergone the usual change in the lungs. This circulation continued for ten or fifteen minutes.* There can be nothing more explicit than this in shewing the absurdity of the assumptions which have been mentioned about the arteries, the pulse, and elemental fire, or vital spirits. The blood was here equally dark in the arteries and in the veins. Where then could be the escape of the vital spirits? or how, in this case, does Mr. Kerr explain the fact of the blood circulating through the arteries, and the *dark* colour of the blood, without the loss of vital spirits; and at the same time the *pulse*, without the usual index of the presence of these spirits, viz. the florid colour of the blood?

* Hunter. † Vide Anatomy, vol. i. p. 456.

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* Phil. Trans. Lond. 1795.

cessive operations, converted the food into chyle, the chyle into blood, and fashioned the nutritious part of the blood into various solids; these new solids may partake of the vitality of all the parts to which they are applied, and to which they have been assimilated by so peculiar and so slow a process." "Shall we have the blood communicating life to all the body? or the body only alive, and the blood, like various other excitements, acting upon it with those powers which it is continually acquiring, without acquiring along with them any share of life?"*

It is clear, then, from what the light colour of the blood arises, in cases of repeated large bleeding, as in pneumonia. But when a varicose vein suddenly bursts, or a large vein is accidentally ruptured, or cut, even this light colour does not appear,

 and

* Bell's Anatomy, p. 457.

and we have a conclusion, *a fortiori*, against the opinion alleged by Mr. KERR. For an impetuous flow of dark coloured blood takes place, and the person instantly dies; and surgeons distinguish venous from arterial hemorrhage always by the distinct colour of the blood, which is different in the two cases.

If this πυρ εμφυτον, or elemental fire, be so subtile as to escape our senses, why does it not make good its retreat equally fast, and produce equally sudden death, from the wound of a small artery, as from that of a large; or at least much sooner than by a wound of a large vein, which contains no vital spirits, which, we are told, reside only in the left ventricle and arteries? I think this goes far to set aside the doctrine of vital spirits residing in the left side of the heart and arteries, and blood in the right side and veins only; or, in our author's own juridical language, goes far to prove

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an *alibi* of the vital spirits, and decide the question without farther discussion.* It also goes far to prove, that there is *not*, in reality, such a difference between the suddenly fatal effects said to arise from a wound of the left and right ventricle of the heart. This sudden death would always take place from the bursting of a large vein, the same as in the case of an artery, if it were not for the valves, which, in their sound state, prevent that sudden descent of the column of blood, which takes place when they become dilated and varicose, and, therefore, no longer guarded by their valves. I apprehend from this, and I think it is no hasty conclusion, that a fair open wound in the right ventricle, so as to let the blood escape rapidly, in great quantity, will

 produce

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* The whole story of the vital spirits derived from arteries reminds me much of what Hudibras says:

"He extracts numbers out of matter,
"And keeps them in a glass like water."

produce equally sudden death as a similar wound of the left ventricle. At same time I can conceive, that an exceedingly long, narrow, and slanting wound might be so critically made into the right ventricle, that the person would not die instantly. In this case the small flap inwards would act as a kind of valve, and the blood in the ventricle would force it down, and shut the cavity every time it was full. Only a small quantity of blood could, therefore, escape at a time; and perhaps several hours, more or less, according to circumstances, might elapse before the person died; either from the pericardium being filled or distended, so as to oppress the heart; or if it escaped into the chest, till a sufficient quantity collected to oppress the lungs, and cause suffocation. But in this case the functions of the heart and brain would be, in some degree, supported for the time, and there would be no sudden sinking. It remains, however, to be proved, that upon firing a

pistol

pistol bullet fairly through the right ventricle, or if the ventricle be fairly slit up with a scalpel, the person will not instantly expire, just as he would do if the same were done to the left ventricle. From the fact of the sudden death from bursting of a varicose vein, I think I am entitled to draw the conclusion, that he would die in the one case as soon as in the other.

I also contend, that a long, narrow, and oblique puncture might be made into the left ventricle, as well as into the right, without instant death being the consequence. At same time, I think that the discharge of a less quantity of blood will cause death from the left than from the right ventricle, for the cavity of the former is rather smaller; and if the wound were such as let its whole contents rush out, the person would instantly drop down dead, from the want of the supply of blood through the aorta to the brain and other parts, the functions

tions of which are essential to life. This being the case, we can easily see that very little blood would pass round from the right side, to be effused into the chest from the left side of the heart; but a coagulum would be formed in the heart, so as to prevent further effusion. I conceive this accounts for the less effusion of blood being observed in some cases, where death has been suddenly caused by a wound of the left ventricle, than in the case of the right. For, suppose a small puncture made into the right ventricle, blood would be effused into the cavity of the chest, but still some might pass round to the left ventricle, which, being entire, would propel the blood thus transmitted to it, with its usual force, and so support the functions of the brain, and other parts necessary to life, for a time, so that sudden death would not happen; but the blood would be gradually accumulating in the chest, till at last it produced oppression on the lungs and heart,

suffo-

suffocation, and death. Here, as some time has intervened between the infliction of the wound and death, we can easily see how there will be a much greater effusion of blood than when a wound has been inflicted in the left ventricle. But suppose a large wound of the right ventricle, by which the person will be suddenly destroyed: in this case all the blood of the body is moving upwards, behind the right ventricle, in the veins and sinuses, and must be effused in a much greater quantity, if it were only during the struggles of death, than when the left ventricle is wounded, and its blood escapes; for here the brain being no longer supplied with blood, the person instantly dies; and there is no considerable quantity of blood can pass through the lungs, and be effused from the left ventricle, as in the case of the right.

I think I have explained pretty sufficiently how a large wound, either in the right

right or left ventricle, will produce sudden death; how in the one case there is a chance for greater effusion of blood than in the other; and how it is possible that an extremely narrow and oblique puncture might be made into either ventricle, without producing instant death. I have also shewn, that the case has been unfairly stated, if it is said that a *wound of exactly the same kind* will produce instant death, without almost any effusion of blood, in the case of the left ventricle; and only death, after some days of languor and lingering, with a great effusion of blood, in the case of the right ventricle. Dr. Baillie, as we have seen, says, that instant death will be produced by the bursting of any part of the heart; by which, I understand, he means the right as well as left ventricle. When the relaxation and collapse of the heart is not produced suddenly, from an instantaneous effusion of its blood from a large wound, I conceive the case will be in

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some degree the same, as when the fluid is drawn from the abdomen in ascites; though no doubt the case must be taken with a great many grains of allowance.

I mean only to affirm, that fainting and death will more quickly follow a large evacuation of blood, suddenly made, than a slow and scanty oozing; a large than a small wound in the heart; a wound of a large than of a small vessel; or a wound in veins deprived of the use of their valves, as in varicose cases, than in undilated veins, which have the use of their valves.

We are informed* that it is surprising that Harvey's doctrine, when it came out, was not more severely criticised than it was. I do not know to what sort of criticism Mr. KERR thinks it should have been subjected; but I always learned that Harvey's

* Kerr's Essay, p. 72.

vey's doctrine was violently opposed; and every method tried to subvert it. Yet so unchangeable and firm is truth, that, on this account, the beauty and certainty of the theory appeared more evident. And Friend, who was an accomplished physician and elegant scholar, well acquainted with the ancient as well as modern doctrines and learning of the profession, speaks in the following words:—"*Nova hæc* de circulatione *Doctrina* licet *firmissimis* rationibus *extra dubium* posita, *vehementer* a *multis impugnata* est; ejusque inventor *adversantium plurimorum* impetum sustinuit: quorum responsiones pleræque magis contradicendi studio, quam argumenti vi refertæ sunt."*

I shall here take the liberty to quote a paragraph from a very excellent Thesis, published (by a fellow graduate of my own)

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* Friend. Hist. Med.

own) at the University of Edinburgh, *an.* 1815, as most applicable to the present occasion; and conveying the most accurate information about Harvey's discovery of the circulation.

" Plurimæ enim inventiones, quæ in lucem nuper prodierint, hanc scientiam promoventes et patriam nostram ornantes, *medicis antiquis omnino ignotæ* fuerunt. Talis fuit circulatio sanguinis major, primum perspicuè descripta et in lucem edita Doctore Gulielmo Harveio, anno Domini millesimo sexcentesimo et vigesimo octavo. Observationes tamen Vassei, Columbi, Cæsalpini, et Vesalii doctrinam quam Harveius celeberrimus postea confirmavit, proculdubio suggerere contulerunt.

* * * * * * * * *

" Harveius immortalis, etsi *invidiæ eorum* qui eodem tempore artem Medicinæ exercebant, novitate ejus opinionum *sese objiciebat,*

ciebat, tamen *veritatem laudi inhoneste acquisitæ præponens, omnes convitias* æquo animo tulit. *Malignitatem inimicorum igitur spernens*, expositionem circulationis reddidit, *quæ semper immota manebit.*"*

Nothing could give a better account than Dr. Murray has here done of the opposition which Harvey's doctrine met with by his cotemporaries, and of the manly way in which he supported the truth against all cavil and enmity.

These controversies terminated in so complete a demonstration of Harvey's doctrine, as to shew the weakness and absurdity of all attempts to subvert it. Unless, indeed, ages of darkness shall again overcloud the world, and learning and science be erased from the memory of man, it must remain unshaken

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* Vide Dr. Murray's Thesis "De Circul. Sang. in Fœtu," anno 1815.

unshaken to the end of time. Even if the dark ages of barbarism and ignorance should return, and men should be left, as formerly, to grope their way through mists of doubt and error; the idle theories which they might form, like those dreams and reveries which preceded Harvey's true doctrine, would vanish before the growing light of truth, till the knowledge of the circulation of the blood would again be firmly established, as it is in our times.

"Had the flow of blood," says our author, "from a wounded artery afforded any proof of the circulation, that circulation must have been known from all antiquity; for arteriotomy was practised as a remedy from the earliest times; and the effects of the wounds of arteries in battle must have been observed from the time that battles were fought, as well as from numerous accidents occurring in civil life. Neither the *structure* of the parts, nor the

flow of blood, had escaped the observation of the ancients; but they reasoned *very differently* from Harvey concerning these appearances, and, in *my opinion*, *more correctly*."*

Though "the *flow* of *blood* from a *wounded artery*" must have been familiar to the ancients, as well as to the moderns, from the causes assigned, and though it certainly does afford evidence and concurrent proof of the circulation, it does not appear to me at all to follow, that "that circulation *must* have been *known* from *all antiquity*." For it might as well be asserted, that the true or Newtonian theory of gravitation, and of the motions of the heavenly bodies "must have been known from all antiquity;" because, in the earliest ages, men had an opportunity of contemplating the

* Kerr's Essay, p. 84.

the sun, and the moon, and the stars, every day of their lives.

Nor did the ancients accurately observe or fully comprehend the structure of the various parts of the circulating system. Though they knew some parts, many important ones escaped their observation; and they were frequently mistaken in ascribing uses to parts, the structure of which they did observe and describe.

It was not one single and insulated fact which could prove the circulation of the blood; but one striking phenomenon, or a curious structure of parts, seemingly adapted to a particular and useful end, might point out a track of investigation, which would end in the true explanation of the whole. In this manner, any one of the proofs of the circulation, singly, might have been observed, and, by tracing its connection with

other circumstances, the whole theory might have been established. It is, however, merely accidental that any person should make the proper use of such a fact; and thousands might see it every day, without drawing any such conclusion, or without any farther investigation. At last, by some fortunate train of thinking, one individual has first imagined what were the true uses of certain structures, and, by following out the enquiry, has happily been enabled to explain the whole phenomena. It was just in this way that the circulation was discovered. It was by following a path which our greatest philosopher, Bacon, seems to reject as useless, viz. the investigation of final causes. Mr. KERR asserts, that, even in the present instance, the mode of investigation and reasoning alluded to *misled* Harvey; saying, "that the presence of valves in the veins ('which first suggested to Harvey a circulation of red blood')

blood') affords *no proof* of a circulation, *nor renders it in any degree probable.*"*

In refutation of this statement of Mr. KERR's, I shall only adduce the observations of the eminent Professor Robison.

"Speculative men have of late years shewn a wonderful hostility to final causes. Lord Bacon had said, more wittily than justly, that all use of final causes should be banished from philosophy, because, like vestals, they produce nothing. This is not historically true; for much has been discovered by researches conducted *entirely* by notions of final causes. What other evidence have we for all that we know concerning the nature of man? Is not this a part of the book of nature, and some of its most beautiful pages? We know, then, only by the appearances of design, that is, by

* Kerr's Essay, p. 97.

by the adaptation of things in evident subserviency to certain results. Are there no such adaptations to be seen, except in the works of man? Nature is crowded with them on every hand, and some of her most important operations have been ascertained by attending to them. Dr. Harvey discovered the circulation of the blood in this very way.*

"He saw," says Professor Robison, "that the valves in the arteries and veins were constructed precisely like those of a *double forcing pump*, and that the muscles of

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* I remember," says Mr. Boyle, "that when I asked our famous Harvey, what were the things that induced him to think of a circulation of the blood? He answered me, that when he took notice that the valves in the veins in so many parts of the body, were so placed that they gave a free passage of the blood towards the heart, but opposed the passage of the venal blood the contrary way, he was invited to imagine that so provident a

of the heart were also fitted up for an alternate systole and diastole, so corresponding to the structure of those valves, that the whole was fit for performing such an office. With boldness, therefore, he asserted, that the beating of the heart were the strokes of the pump; and laying the heart of a living animal open to the view, he had the pleasure of seeing the alternate expansion and contraction of its auricle and ventricle, exactly as he had expected. Here was a discovery as curious, as great, as important, as universal gravitation. In precisely the same way have all the discoveries of anatomy and physiology been made. A new object is seen.—The discoverer immediately examines its structure—Why? To see

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cause as Nature, had not placed so many valves without design; and no design seemed more probable than that, since the blood could not well, because of the interposing valves, be sent by the veins to the limbs, it should be sent through the arteries, and return through the veins, whose valves did not oppose its course that way."

see what it can perform; and if he sees a number of co-adaptations to a particular purpose, he does not hesitate to say, 'that is *its* purpose.' He has often been mistaken; but the mistakes have been gradually corrected. How? By discovering what is the real structure, and what the thing is really fit for performing. The anatomist never imagines that what he has discovered is of no use."

"So far from banishing the consideration of final causes from our discussions, it would look more like philosophy, more like the love of true wisdom, and it would taste less of an idle curiosity, were we to multiply our researches in those departments of nature where final causes are the chief objects of our attention—the structure and economy of organised bodies in the animal and vegetable kingdoms."* The

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* Elements of Mechanical Philosophy, by Professor J. Robison, vol. i. p. 680.

The ancients could not understand the circulation of the blood, though they had known all the facts in the living body on which that theory is founded, as they were totally unacquainted with that branch of physics, viz. hydraulics, some knowledge of the laws of which is necessary to suggest and explain such a theory, from a view of the structure of the organs of the circulation. It is true that the two leading principles of hydrostatics were known and established, at an early date, by Archimedes and Stevinus; but hydraulics, or the motion of fluids, were not equally understood. Toricelli made the first step in that branch of physics, which has been elucidated by later philosophers.

So late were mankind of finding out and adopting the true method of philosophizing, that, even "in the end of the sixteenth century, it might still be affirmed, that the situation of the great avenue to knowledge

was

was *understood* by *none*, and that its *existence*, to the *bulk* of philosophers, was *utterly unknown*."*

It would be very difficult to ascertain whether Harvey's calculation be exactly true, that the whole blood of the body circulates through the heart about twenty times in an hour, or four hundred and eighty times in a day; but it is probably as near the truth as any calculation made on that subject.† Nor is it so astonishing, when we consider what happens in some of the larger animals, as the whale. "The aorta of a whale," says Paley, "is larger in the bore than the main pipe of the water-works at London Bridge; and the water, roaring in its passage through that pipe, is inferior, in impetus and velocity, to the blood

* Vide Playfair's Dissertation, Encyclop. Britannica.

† Kerr's Essay, p. 21 and 86.

blood gushing from the whale's heart."* Dr. Hunter gives the following account of the dissection of a whale:—"The aorta measured a foot diameter. *Ten* or *fifteen gallons* of blood are thrown out of the heart at a stroke, with *immense velocity*, through a tube of a *foot diameter*. The whole idea fills the mind with wonder."†

It does not follow that Harvey's doctrine, because true, should have improved every part of medical practice.‡ Many of our best pieces of practice, and most important reme-

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* Natural Theology, p. 154.

† Dr. Hunter's Account of the Dissection of a Whale, *(Phil. Trans.)*

‡ "Though these two things are in their nature so closely united, that the *same truth* which is a *principle* in *science* becomes a *rule* in *art*, yet there was at that time hardly any practical improvement which had arisen from a theoretical discovery."

Playfair's Dissertation on Ancient Physics.

Kerr's Essay, p. 76.

remedies, have been introduced, and used accidentally, as empiric medicines, without reference to any theory, good, bad, or indifferent; and have been continued, as being found successful, independent of any theory or explanation of their *modus operandi*, which, with regard to some of them, may never be made out. Many examples of this kind might easily be mentioned, but a few will suffice. All our class of medicines called specifics are of this nature; and many of them have been introduced into practice by quacks and empirics, boldly despising and disclaiming all theory. Of this kind is cinchona, arsenic, mercury; and somewhat on the same footing, though more explicable, the cold bath, Dover's powder, James' powder, &c. I conceive that Harvey's theory, however true, had no right, and could not be expected, to produce a change in practices, which were found to succeed so well. At whatever æra they were found out, as being successful,

ful, they should remain unchanged by any theory, unless that theory, from its nature, suggested something better. But surely they were more independent of the chimerical theory of vital spirits, than of the circulation of the blood, which actually served to explain, in a complete and satisfactory manner, the *modus operandi* of many medicines, and the true theory of many diseases. As examples of this, we may mention the hemorrhagiæ, the phlegmasiæ, the comata, &c. and the practices of bleeding, blistering, and purging, the true operations of which were but imperfectly understood by the practitioners who used them before the circulation of the blood was understood. Many medicines and useful pieces of practice have been accidentally found out, by experiments to prove a false theory, and have been afterwards explained.

That no complete theory of medicine or physiology has hitherto been made, is true,

though that is not altogether to be despaired of, if science advances. At all events, it has an infinitely greater chance of being correct, if founded on the Harveian doctrine of the circulation, than on any of the false, exploded, and mystical doctrines of Erasistratus, or those of any of the ancients, about humours, and spirits, and fires, and acids, and oils, and æthers. For we may apply the Greek adage—κακὸς κοράκος, κακὸν ὠόν.

Every one must approve of the qualifications given by Galen, as essential to a true theory: Πρῶτον μὲν ἀληθὲς εἶναι δεῖ—εἶτα χρήσιμον—εἶτα ἀκωλύθον ταῖς ὑποτεθείσαις ἀρχαῖς. 1st. It must be true—2d. It must be useful—3d. It must be founded upon established principles.*

I have,

* Kerr's Essay, p. 73.

I have, in the preceding pages, stated my reasons, which I think incontrovertible, why I firmly believe the Harveian doctrine *true*—it is matter of notoriety that it *has* proved *useful;* by explaining satisfactorily many important parts of physiology, and by thus rendering our theory more perfect and respectable; preventing, discountenancing, and discouraging quackery. I have also proved that it is founded on established principles, and in every respect consistent with them; whereas it is notorious that *Erasistratus' hypothesis* is altogether *inconsistent* with established principles—that it is totally *useless* in point of theory and practice—and that it prevailed in the times when quackery was most rife. The conclusion is, therefore, inevitable, that it must be *false.*

The reader will instantly recognise the striking similarity and family likeness between Erasistratus' theory and that of a

certain German author of eminence, which I shall here quote. Dolæus is the name of this German author, who has written, as he styles it, an Encyclopædia!! of all Physic!! in order to *instruct* us! in the *right notion* of each distemper!! "Palpitation," says our learned author, "is a disease, wherein *Cardimelech*, the king, *it seems*, who keeps his residence in the *ferment* of the heart!! *finding* himself *attacked* and opposed by a *civil war*, raised by a disaffected party, among his subjects, exerts himself all he can to drive out the enemy; and calling unto his aid his *ancient! good ally*, *Microcosmeter*, Governor of the animal spirits!!!! he gives *battle* to the disturbers of his rest!!"

It is now full time to take our leave of Mr. KERR, and his doctrine. His talents, ingenuity, and learning, require that we do so in respectful terms. But we must say, that his present publication has left little

favour-

favourable impression on our mind, or in the least convinced us that any part of Harvey's doctrine is untrue. We, therefore, heartily wish him better success in his future enterprise* than we can pretend to say, with candour, we think he has had in the present. We, perhaps, cannot say positively what impressions his future and intended publication may make on our mind in favour of the Kerrenean doctrine; but we rather think, that if he convince us of the falsity of Harvey's theory, it will be a *little* against our inclination: and it is an established maxim, that, in these cases, the person retains his original belief.

"*He that's convinc'd against his will*
"*Is of the same opinion still.*"

The

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* "The only apology I have to offer you, and the public, is, that I send the present publication abroad merely as a *prodromus* of something in a more finished form," &c.

See Kerr's Essay, Preface, p. xx.

The remaining part of Mr. KERR's Essay being only "repetitions of assumptions and conjectures"* about the probability of the visionary hypothesis of Erasistratus, and the occult and fanciful ideas of some of the ancient sages, the meaning of which nobody understands, and it is doubtful whether they understood it themselves, requires no commentary, animadversion, or refutation from me, farther than a reference to what has been said in the preceding pages.

Upon the whole, after considering the structure of the heart and blood-vessels attentively, we become impressed with the belief that it is one of the noblest works of the creation; nor can any part of nature, animate or inanimate, impress us with a more lively conviction of the wisdom, power, and beneficence of the Creator, than the wonderful contrivance of the heart and blood-vessels, and the admirable manner in which these parts are designed and fitted to carry

* Kerr's Essay, Preface, p. iv.

carry on the circulation of the blood. The contrivance and adaptation of the parts is complete and astonishing; and the design, or final cause, evident.

"The wisdom of the Creator," saith Hamburgher, "is in nothing seen more gloriously than in the heart." Notwithstanding the complex nature of its structure, and its many delicate parts, which, if altered or destroyed, even in a slight degree, would impede or suspend its function; yet, wonderful to conceive, it will beat at the rate of a hundred thousand strokes every twenty-four hours, propelling the blood against considerable resistance, for eighty years, without being wearied, or even without one alarming pause.

Whatever sceptics may say, no one can study, deeply, the structure and functions of these organs, and understand them, but must join in the enthusiastic and fervid ex-

clamation

clamation of Bellini, which the study of these subjects so naturally excited, and is so well calculated to inspire :—

" Quæ equidem omnia si a rudi intelligentia hominis tantum consilii, tantum ratiocinii, tantum peritiæ mille rerum, tantum scientiarum exigunt, ad hoc, ut inveniantur, seu ad hoc, ut percipiantur postquam facta sunt; illum cujus opera fabrefacta sunt hæc singula, tam vani erimus atque inanes, ut existimemus esse consilii impotem, rationis expertem, imperitum, aut ignarum omnium rerum? Quantum ad me attinet, nolim esse rationis compos, si tantum insudandum mihi esset ad consequendum intelligentiam earum rerum, quas fabrefaceret nescio quæ vis, quæ nihil intelligeret eorum quæ fabrefaceret; mihi etenim viderer esse vile quiddam, atque ridiculum, qui vellem totam ætatem meam, sanitatem, et quicquid humanum est deterere, nihil curare quicquid est jucunditatum, quicquid

læti-

lætitiarum, quicquid commodorum ; non divitias, non dignitates : non pœnas etiam, et vitam ipsam, ut glorairi possem postremo invenisse unum, aut alterum, et fortasse me invenisse quidem ex iis innumeris, quæ produxisset ; nescio quis ille, qui sine labore, sine cura, nihil cogitans, nihil cognoscens, non unam aut alteram rem, neque dubie, sed certo produxisset innumeras innumerabilitates rerum in hoc tam immenso spatio corporum, ex quibus totus mundus compingitur. Ah Deum immortalem ! Video præsens numen tuum in hisce tam prodigiosis generationis initiis, et in altissima eorum contemplatione defixus, nescio quo œstro admirationis conciter, et quasi divinè furens cohibere me minimè possum quin exclamen.

Magnus Dominus ! Magnus fabricator hominum Deus ! Magnus atque admirabilis conditor rerum Deus, quam Magnus es !"

Bellini de Motu Cordis.

FINIS.

D. Chalmers & Co. Printers,
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