

## Original Communications.

### RABELAIS AS A PHYSIOLOGIST; REFLECTIONS SUGGESTED BY HIS DESCRIPTION OF THE PRODUCTION AND MOVEMENTS OF THE BLOOD, IN 1546.

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IT is difficult to put oneself in a position to appreciate, with a reasonable degree of accuracy, the condition of knowledge common to scientific men of the period upon any one subject, at a time so remote as three and a half centuries; yet I have attempted to do this in respect to knowledge of the movements of the blood, in the middle of the sixteenth century. One can hardly imagine an accurate and useful knowledge of the physiology of nutrition, absorption, digestion, respiration, or secretion as existing before the discovery of the circulation by Harvey, in 1616; and this discovery was so momentous in its influence upon the science of medicine that its history anterior to the publication of the *Exercitatio anatomica de motu cordis et sanguinis* (1628) has been, perhaps, the most interesting chapter in the literature of physiology. Not only did this great discovery mark one of the most important epochs in human knowledge, but it indicated a method of observation of phenomena, and of reasoning from such observation, that has been of inestimable value to all succeeding generations. Flourens, in his history of the discovery of the circulation, says that "this little book of an hundred pages is the most beautiful book in physiology." Harvey's book was nearly contemporaneous with the *Novum organum and Advancement of Learning* of Bacon and with the immortal studies of humanity by Shakespeare. Did Harvey, as a disciple, follow the methods of inductive science founded by Bacon or did Bacon formulate a method suggested by the researches of Harvey, or were these two great minds independent of each other? These are questions that cannot be satisfactorily answered. All that can now be said is that the great investigator and discoverer illustrated the scientific method indicated by the great philosopher.

In the history of the development of the doctrine of the circulation, everything relating to the blood and its movements is of interest. Perhaps the most exhaustive and accurate account of knowledge of physiology anterior to the time of Harvey is in the encyclopedic work of Milne Edwards (*Leçons sur la physiologie*, Paris, 1858-1881), in twenty-four volumes, from which I have taken many citations.\*

It is said by a writer in the fifth century that venesection was practised by the surgeons of the army of Aga-

\*Milne Edwards, *Leçons sur la physiologie*, Paris, 1858, tome III, p. 2, et seq.

memnon in the siege of Troy. The tradition is that Troy was besieged for ten years and fell 1183 B. C. (Eratosthenes); one writer, however, fixes the date at 1335 B. C., and another at 1149 B. C. In the time of Hippocrates (460-377 B. C.) bleeding was practised from several different veins, the situations of which were well known. Aristotle (384-322 B. C.) was the first to show that the vena cava and the aorta communicated with the heart, and that the aorta carried blood. It is said, however, that the distinction between the arteries and veins was known before the time of Hippocrates and was described by Diogenes of Apollonia in the fifth century B. C.

It is somewhat difficult to ascertain exactly the notions of Aristotle in regard to the arteries. In his work, called in translation *History of Animals*, he describes the passing of air from the lungs to the heart; while in his work, *On Parts of Animals*, he describes two vessels arising from the heart, which, as well as the heart, are filled with blood. The two works referred to are generally accepted as authentic. Milne Edwards cites the following from the work, *History of Animals*, as expressing the idea of Aristotle: "Vessels arise from the heart which go to the lungs, the branches of which divide like those of the trachea. . . . These branches have no communication with these vessels, but, by reciprocal contact, the vessels which come from the heart receive the air and pass it to the heart, where their trunks open." Milne Edwards says that Hippocrates, Aristotle, Herophilus, and Erasistratus (300 B. C.) distinguished between the arteries and the veins; that on examining dead bodies the veins are generally found gorged with blood, while the arteries are almost empty; and this circumstance had led all physiologists to think that the veins were the only blood-vessels and that the arteries were designed to carry air. Aristotle considered the latter tubes as forming, with the trachea, a vast system of pneumatic conduits. Hippocrates, however, was the first to describe the pulse; Aristotle recognized that the pulse was produced by the movement of blood. Herophilus studied the pulse more closely, established its synchronism with the heart, and distinguished clearly the two kinds of vessels which "connected" the lungs with the heart. Erasistratus noted the play of the valves of the heart. This state of knowledge and conjecture, with many contradictions, remained until the time of Galen (130-200 A. D.). Galen noted that the arteries discharged blood when opened. He demonstrated experimentally the fact that the arteries carried blood by including a portion of an artery between two ligatures, opening the part of the vessel thus separated from the rest of the vascular system and finding that it contained blood only. Further observations led him to the conclusion that the liquid was not identical in the veins and arteries, although there were communications between the two systems of vessels which permitted the blood to pass easily from one to the other.



It is easy to imagine the disastrous effect upon learning of the destruction of the great libraries of the School of Alexandria, which contained about 700,000 rolls, or volumes. The library in the Bruchium is said to have been destroyed by fire in the year 47 B. C., when Cæsar burned the fleet in the harbor, the flames accidentally extending to the library. Most authorities agree that the destruction of the Serapeum, ordered by Theodosius in 391 A. D., completed the work of extinction. Following the disappearance of this, the greatest existing collection of rolls, on all subjects and in all languages, there was a long period of decline of learning. One can hardly wonder, then, that a great interval separated the work of Galen from the next important date in the history of the physiology of the circulation—namely, the description of the pulmonary circulation by Servetus, in 1553. The literature of the Middle Ages, extending from the decline of the Roman Empire to the revival of letters, or, according to Hallam, from the beginning of the sixth to the end of the fifteenth century, is very meagre; and it is easy to understand the difficulty of ascertaining the extent of common knowledge of physiology during the first half of the sixteenth century.

It is certain, however, that, with the exception of the work of Servetus, the precursors of the discovery of the general circulation were almost entirely anatomical. In 1543 the great anatomist, Vesalius, corrected the error of Galen, who supposed that there were openings in the septum between the two ventricles of the heart. The valves of the veins were described by Étienne (1545), Cannanus (1551), Eustachius (1563), Piccolomini (1586), and Fabricius (1603). Fabricius demonstrated the valves in the veins to Harvey, probably in 1601 or 1602. In a copy of Harvey's original work (1628), which I presented to the Astor Library, is the following manuscript note by a former owner: "The valves in the heart and veins, the famous Dr. Harvey told me, gave him the first hint of his grand discovery.—Boyle."

François Rabelais (1490?-1553) universally recognized as "the greatest of French humorists and one of the few great humorists of the world" (Saintsbury), in the third book of his collected works (the second book *Treating of the Heroic Deeds and Sayings of the Good Pantagruel*), gives an account in Chapter IV, in which "Panurge continueth his discourse in praise of borrowers and lenders," of the nourishment of the microcosm and its members by the blood. In the collected works of Rabelais there are but two passages in which reference is made to movements of the blood; but these are so striking, in view of the work of Servetus, published in 1553, that it has seemed to me important, in connection with the history of the discovery of the circulation, to study these passages closely and critically. The book referred to was published in 1546, seven years before the date of the *Christianismi restitutio* of the unfortunate Serve-

tus; and I find no reference to this by any writer on physiology. The remarkable passage, which I shall give in full further on, is in one of the curious discourses of Panurge, the principal character in the books relating to Pantagruel. The writings of Rabelais, as they have come down to us, are works of quaintly extravagant and humorous fiction, in language which at the present day might be regarded as gross and even obscene; but, measured by the standard of the sixteenth century, they might not be so considered. As appearing in a work of fiction, it is hardly to be expected that great care as to accuracy of scientific statement would have been exercised, as probably was the case in the serious work of Servetus; but it must be borne in mind that Rabelais was a physician, had a thorough knowledge of the Latin and Greek languages and had given public lectures in 1531 on Galen and Hippocrates. In 1532 he edited the *Aphorisms* of Hippocrates and the *Arts parva* of Galen; in 1537 he lectured on the Greek text of Hippocrates, and in 1538 he made a public anatomical demonstration. Saintsbury, who has given, probably, the best brief account of the works and character of Rabelais, writes as follows: "With an immense erudition representing almost the whole of the knowledge of his time, with an untiring faculty of invention, with the judgment of a philosopher and the common sense of a man of the world, with an observation that let no characteristic of the time pass unobserved, and with a tenfold portion of the special Gallic gift of good-humoured satire, Rabelais united a height of speculation and depth of insight and a vein of poetical imagination rarely found in any writer, but altogether portentous when taken in conjunction with his other characteristics."

The beginning of the sixteenth century was also the beginning of the revival of letters. At the period when Rabelais and Servetus wrote, the accumulated learning of the world handed down to that time was to be found in a few works written in hardly more than two languages, Latin and Greek, and this is eminently true of scientific knowledge. The description of the pulmonary circulation by Servetus, in 1553, is certainly the most important event in the progress of physiology which led to the discovery of the circulation in 1616. I have endeavored, in my study of the literature, to ascertain how far Servetus was in advance of the scientific knowledge common to the learned men of his time. Where could I find this condition of knowledge more faithfully represented than in such portions of the works of Rabelais as referred to the subject under consideration?

The following are the passages in the works of Rabelais in which reference is made to the movements of the blood. I have endeavored to present a literal translation from the original old French, and have made but little use of the well-known translation by Uirquhart and Motteux, which, though admirable and most faithful, is not so exactly word for word:



"La vie consiste en sang; sang est le siège de l'ame; pourtant un seul labour pousse ce monde, c'est forger sang continuellement. En ceste forge sont tous membres en office propre; et leur hiérarchie telle, que sans cesse l'un de l'autre emprunte, l'un à l'autre preste, l'un à l'autre est débiteur. La matière est métal, convenable pour estre en sang transmis, est baillée par nature: pain et vin. En ces deux sont comprises toutes espèces de aliments. Et de ce est dict le compagne en langue Goth. Pour icelles trouver, préparer et cuire, travaillent les mains, cheminent les pieds et portent toute ceste machine: les yeux tout conduisent. L'appétit, en l'orifice de l'estomach, moyennant de mélancholie aligrette, que lui est transmis de la ratelle, admoneste d'enfourner viande. La langue en faict l'essai; les dents la machent; l'estomach la recolt, digère, et chylifie. Les veines mésentériques en succent ce qu'est bon et idoine, delaisent les excréments, lesquels par vertus explosive sont vidés hors par exprès conduits; puis la portent au foye: il la transmue derechef, et en faict sang. Lors quelle joie pensez-vous estre entre ces officiers, quand ils ont vu ce ruisseau d'or, qui est leur seul restaurant? Plus grand n'est la joie des alchimistes quand après longs travaux, grand soing et despense, ils voient les métaux transmues dedans leurs fourneaux. Adonc chacun membre se prépare et s'estvertue de nouveau à purifier et affiner cestul trésor. Les rognons, par les veines émulgentes, en tirent l'aiguosité, que vous nommez urine et par les uretères la décollent en bas. Au bas trouve réceptacle propre: c'est la vessie, laquelle en temps opportun la vide hors. La ratelle en tire le terrestre et la lie, que vous nommez mélancholie. La bouteille du fiel en soustrait la cholère superflue. Puis est transporté en une autre officine, pour mieulx estre affiné: c'est le cœur, lequel, par ses mouvements diastoliques et systoliques, le subtilise et enflambe, tellement que par le ventricule dextre le met à perfection, et par les veines l'envoye à tous les membres. Chacun membre l'attire à soi, et s'en alimente à sa guise: pieds, mains, yeux, tout; et lors sont faicts debtors, qui paravant estoient presteurs. Par le ventricule gauche il le faict tant subtil, qu'on le dict spirituel, et l'envoye à tous les membres par ses artères, pour l'autre sang des veines eschauffer et esventer. Le poulmon ne cesse avecques ses

"Life consisteth in blood: blood is the seat of the soul; thus a single labour resteth upon this microcosm (*monde*), it is to make blood continually. In this workshop all the members are in proper function; and their hierarchy is such that incessantly the one borroweth from the other, the one lendeth to the other, the one is debtor to the other. The material is matter suitable to be converted into blood, is given by Nature: bread and wine. In these two are comprehended all kinds of aliments. And from this is said *compagne* in the Gothic tongue. To find, prepare, and cook these, the hands work, the feet walk and carry the entire machine: the eyes conduct all. The appetite, in the orifice of the stomach, by means of the sourish black humour, which is sent to it by the spleen, admonisheth it to shut in the meat. The tongue maketh the first trial of it; the teeth chew it; the stomach receiveth, digesteth and chylifieth it. The mesenteric veins suck from it that which is good and fit, leaving behind the excrements, which by expulsive faculty are emptied out by special conduits; afterward it is carried to the liver: it there changeth once again, and of it is made blood. Then what joy, think you, is amongst these officers, when they have seen this rivulet of gold which is their sole restorative? Greater is not the joy of alchemists when, after long labours, great care and expediture, they see metals transmuted in their furnaces. Then every member preparereth itself and striveth anew to purify and refine this treasure. The kidneys, by the emulgent veins, take from it the aqueosity which you call urine and by the ureters run it down. Below is found the proper receptacle: this is the bladder, which in convenient time emptieth it out. The spleen draweth from it the earthy part and the dregs, which you call black bile. The gall-bladder subtracteth from it the superfluous gall. Then is it transported to another workshop, in order to be better refined: this is the heart, which, by its diastolic and systolic movements, subtilizeth and heateth it, to such a degree that by the right ventricle it putteth it in perfection, and by the veins sendeth it to all the members. Every member attracteth it to itself and nourisheth itself from it in its own fashion: feet, hands, eyes, all; and then are made debtors, those which before were lenders. By the left ventricle it maketh it so subtle, that it is called spiritual, and sendeth it to all the

lobes et soufflets le rafraichir. En reconnaissances de ce bien, le cœur lui en départ le meilleur, par la veine artériale. Enfin, tant est affiné dedans les rets merveilleux, que, par après, en sont faicts les esprits animaux, moyennant lesquels elle imagine, discourt, juge, résout, délibère, ratiocine, et rememore."

*Œuvres de FRANÇOIS RABBLAIS*, Paris, 1857, Livre III, Chapitre iv, page 152.

"Les philosophes et médecins afferment les esprits animaux sourde, naistre et pratiquer par le sang artériel purifié et affiné à perfection dedans les rets admirable, qui gist sous les ventricules du cerveau." *Ibid.*, Chap. xiii, page 159.

members by its arteries, in order the other blood of the veins to warm and winnow. The lung ceaseth not with its lobes and bellows to refresh it. In acknowledgement of which good, the heart distributeth to it the best of it, by the arterial vein. Finally is it so much refined within the *rets mirabile*, that, thereafter, are made of it the animal spirits, by means of which it imagineth, discourses, judgeth, resolveth, deliberateth, ratiocinateth, and remembereth."

"The philosophers and physicians affirm that the animal spirits spring from, have their origin in, and operate through the arterial blood purified and refined to perfection within the *rets mirabile*, which lieth beneath the ventricles of the brain."

If it be assumed that Panurge, in this part of his discourse, represented ideas in regard to physiology that were generally accepted by learned men in the middle of the sixteenth century, it is seen that some of their notions were nearly correct.

He says that life consists in the blood and that through the blood there is a passage of material from one part of the body to another; that the material suitable to be converted into blood is food ("bread and wine; in these two are comprehended all kinds of aliments"); that the tongue tastes it, the teeth chew it, the stomach receives, digests, and chylifies it, which is a fair summary of knowledge of these processes, even up to the second quarter of the nineteenth century; that the mesenteric veins take up the nutritive constituents of the food, and that the residue is discharged from the body; that it (the food) is carried to the liver and there changes ("and of it is made blood"—the nutritive matters are actually changed in the liver, but, of course, blood is not made in the liver); that the kidneys separate the urine from the blood, which is passed by the ureters to the bladder and is discharged "in convenient time"; that the spleen takes away the earthy parts and dregs, and the gall-bladder "the superfluous gall"; that in the right ventricle the blood is "put in perfection," and by the veins the blood is sent to all the members; that every member takes the blood and "nourisheth itself from it in its own fashion"; that the left ventricle makes the blood so "subtile, that it is called spiritual, and sendeth it to all the members by its arteries, in order the other blood of the veins to warm and winnow"; that the heart distributes the best of the blood to the lungs by the pulmonary artery (the arterial vein); that out of the blood the animal spirits are made in the chorioid plexuses. (In the second passage quoted it is evident that by the "*rets mirabile*, which lieth beneath the ventricles of the brain," is meant the chorioid plexuses; Servetus speaks of the chorioid plexuses and of their producing the animal spiritus from the vital spiritus).



In brief, as regards the movements of the blood, Rabelais, in 1546, thought that the materials for the production of the blood were absorbed by the mesenteric veins from digested food and carried to the liver; that these matters were changed and made into blood in the liver; that the blood is brought to perfection in the right ventricle and is sent by the veins to all parts of the body for their nourishment; that the blood is subtilized in the left ventricle (in which part the vital spiritus is formed) and is sent by the arteries to "all the members" in order to warm and otherwise modify the blood sent to them by the veins; that the blood is sent to the lungs by the pulmonary artery; that the vital spiritus is changed into animal spiritus in the chorioid plexuses, by means of which (animal spiritus) the operations of the mind are conducted.

This was undoubtedly the condition of general knowledge of the movements of the blood up to the time of Harvey (1616). Vesalius, in 1543, three years before Rabelais, denied the existence of openings in the interventricular septum; but he made no notable physiological deductions from this most important anatomical observation. If this had been recognized in connection with the movements of the blood, knowing that the blood is carried to the lungs by the pulmonary artery, it would have been evident that the blood could reach the left side of the heart by no other way than by the pulmonary veins. Galen, in the second century, had shown that the arteries carried blood only and not air; which was well known to Rabelais and to some of the learned men of his time. As a matter of fact, the idea of the uses of the valves of the veins, which indicated the direction of the flow of blood in these vessels, was the idea which rendered it impossible to describe the movements of the heart and blood (*motus cordis et sanguinis*) in any other way than as was described by the immortal discoverer of the circulation. The correction of the ancient error which admitted openings in the interventricular septum made the passage of blood through the lungs a logical necessity; and the discovery of the valves of the veins made the general circulation an unavoidable logical sequence; yet the importance of the anatomical description of the heart by Vesalius was not thoroughly comprehended by investigators for seventy-three years (1543 to 1616); and the uses of the valves of the veins remained unknown for more than half a century.\* The writings of Servetus had absolutely no influence on the discovery of the circulation; the physiological passages in the *Christianismi restitutio* were unknown until long after the

publication of the *Exercitatio anatomica de motu cordis et sanguinis*, in 1628.

Michael Servetus (Michael Seruetus, Miguel Serveto, Michael Villanovanus, or Miguel de Villeneuve) was born in Tutella, in Navarre, in 1511, and died in 1553. The history of Servetus, with his tragic death at the stake, is too well known to call for extended repetition here. He met Calvin in Paris in 1536 and had some discussion with him on theological questions concerning which Servetus had written in 1531 and 1532 (*De Trinitatis erroribus*). He corresponded with Calvin in 1545 and 1546. In January, 1553, he published the *Christianismi restitutio*, of which but two perfect copies are known to be in existence. This book earned for Servetus the relentless enmity of Calvin. In March, 1553, he was interrogated by the inquisitor-general at Lyons, having been arrested on the charge of heresy. Early in April he escaped from his prison. In August he was arrested in Geneva. On October 26th he was convicted and sentenced to be burned alive. The sentence was carried out October 27, 1553. It is said that copies of his book were burned at the same time.

The medical history of Servetus is important as bearing upon his authority as a scientific writer. It is recorded that he studied medicine in Paris, in 1536, under Günther, Dubois,\* and Fernel. He succeeded the great anatomist Vesalius as assistant to Günther. Günther describes him as a man of high culture, specially skilled in dissection and with a profound knowledge of the works of Galen. In 1540 he entered the medical school at Montpellier. He acted as the private physician to Paulmier, archbishop of Vienna, from 1541 to 1553. He wrote a number of books on various subjects and among them a work containing six lectures on digestion and the composition and use of syrups. The first edition of this book was published in 1537, the fifth and last edition bearing the imprint: Venice, 1548. According to Alexander Gordon (*Encyclopædia Britannica*, Article, Servetus), "the passage describing the pulmonary circulation is first noticed by W. Wotton, in *Reflections upon Ancient and Modern Learning*, 1694."

I give here the original and a translation of the celebrated passage in the *Christianismi restitutio*. The original Latin was reprinted by Flourens and afterward by Milne Edwards.† I have never seen a complete trans-

\* Dubois is known in literature as Jacobus Sylvius.

† In the *Encyclopædia Britannica*, Sir William Turner, the writer of the article *Anatomy*, reprints, in the original Latin, what purports to be the entire passage from Servetus. This reprint, however, is incomplete. Nearly one fourth of the passage—the last portion, which is important—is omitted. Also, there are many important variations from the text as given by Flourens and Milne Edwards. In addition, the extraordinary error is made of crediting the passage to a work, *De Trinitate* (probably *De Trinitatis erroribus*) instead of to the *Christianismi restitutio*. These errors may be due to the fact that there are but two copies of the *Christianismi restitutio* known to be in existence, one in the National Library in Paris and the other in the Imperial Library in Vienna. I have never seen it stated that a copy is to be found in the British Museum. There is said to be an imperfect copy in Edinburgh, partly reprinted.

\*The history of the discovery of the valves of the veins is somewhat obscure. The best information in regard to it is that Étienne described valves in branches of the portal vein in 1545; Lucitanus, in 1551, published a letter from Cannanus in which he described (probably in 1547) valves in certain veins; Eustachius described valves in the coronary vein in 1563, and Piccolomini published a clear account of the valves of the veins in 1586. Fabricius published accurate descriptions and delineations of the valves in 1603.



lation into English. The translation here given I believe to be absolutely literal and accurate as regards anatomical terms. In its preparation I have been more than assisted by Mr. Montgomery Schuyler, an accomplished scholar and eminent littérateur, of New York:

"Vitalis spiritus in sinistro cordis ventriculo suam originem habet, juvantibus maximè pulmonibus ad ipsius generationem. Est spiritus tenuis, caloris vi elaboratus, flavo colore, ignea potentia, ut sit quasi ex puriori sanguine lucidus vapor, substantiam in se continens aquæ, aeris et ignis. Generata ex facta in pulmonibus mixtione inspirati aeris cum elaborato subtili sanguine, quem dexter ventriculus cordis sinistro communicat. Fit autem communicatio hæc, non per parietem cordis medium, ut vulgo creditur, sed magno artificio à dextero cordis ventriculo, longo per pulmones ductu, agitur sanguis subtilis: à pulmonibus preparatur, flavus efficitur, et à vena arteriosa in arteriam venosam transfunditur. Deinde in ipsa arteria venosa inspirato aeri miscetur et expiratione à fulgine repurgatur. Atque ita tandem à sinistro cordis ventriculo totum mixtum attrahitur, apta suppellex, ut fiat spiritus vitalis.

"Quòd ita per pulmones fiat communicatio et preparatio, docet conjunctio varia et communicatio venæ arteriosæ cum arteria venosa in pulmonibus. Confirmat hoc magnitudo insignis venæ arteriosæ, quæ nec talis, nec tanta facta esset, nec tam à cordis ipso vim purissimi sanguinis in pulmones emitteret, ob solum eorum nutrimentum, nec cor pulmonibus hac ratione serviret; cum præsertim antea in embryone solerent pulmones ipsi aliunde nutriri, ob membranas illas, seu valvas cordis, usque ad horam nativitatis nondum operatas, ut docet Galenus. Ergò ad alium usum effunditur sanguis à corde in pulmones hora ipsa nativitatis, et tam copiosus. Item, à pulmonibus ad cor non simplex aer, sed mixtus sanguine mittitur per arteriam venosam; ergò in pulmonibus fit mixtio. Flavus ille color à pulmonibus datur sanguini spirituosus, non à corde. In sinistro ventriculo non est locus capax tantæ et tam copiosæ mixtionis, nec ad flavum elaboratio illa sufficiens. Demum, paries ille medius, cum sit vasorum et facultatum experts, non est aptus ad communicationem et elaborationem illam, licet aliquid resudare possit. Eodem artificio, quo in hepate fit transfusio à vena porta ad venam cavam propter sanguinem, fit etiam

"The vital spiritus has its origin in the left ventricle of the heart, the lungs in the greatest degree aiding its generation. This spiritus is attenuated, elaborated by force of heat, of yellow color, of fiery power, so that it is, as it were, a clear vapor from the purer blood, containing in itself the essence of water, air, and fire. It is generated from an admixture made in the lungs of inspired air with elaborated subtle blood, which the right ventricle of the heart communicates to the left. Indeed this communication is not made through the middle wall of the heart, as is commonly believed, but by great ingenuity from the right ventricle of the heart, by a long passage carried through the lungs, the subtle blood is put in motion: it is prepared by the lungs, is made yellow, and is transfused from the vena arteriosa to the arteria venosa. Thereupon, in the arteria venosa itself, it is mixed with the inspired air and by expiration is purged of its dark substance. Also in this wise at least from the left ventricle of the heart the whole admixture is drawn, material is adapted, so that it makes vital spiritus.

"Since the communication and preparation is thus made through the lungs, it teaches a manifold conjunction and communication of the vena arteriosa with the arteria venosa in the lungs. The remarkable magnitude of the vena arteriosa confirms this, which would be made neither such, nor so great, nor would it thus send out from the heart itself a force of the purest blood into the lungs, for the purpose of their nourishment alone, nor would the heart for this purpose supply the lungs; especially since previously in the embryo the lungs themselves were accustomed otherwise to be nourished, on account of these little membranes, or valvules of the heart, not yet opened even to the hour of birth, as Galen teaches. Therefore for another purpose, the blood is poured out from the heart into the lungs at the very hour of birth, and in such abundance. Likewise, air not simple, but mixed with blood, is sent to the heart from the lungs through the arteria venosa: therefore the mixture is made in the lungs. This yellow color is given to the sanguis spirituosus by the lungs,

pulmone transfusio à vena arteriosa ad arteriam venosam propter spiritum. Si quis hac conferat cum illis quæ scribit Galenus, lib. vi et vii, *De usu partium*, veritatem penitus intelligat, ab ipso Galeno non animadvertens. Ille itaque spiritus vitalis à sinistro cordis ventriculo in arteriis totius corporis deinde transfunditur, ita ut qui tenuior est superiora petat, ubi magis adhuc elaboratur, præcipuè in flexu retiformi, sub basi cerebri sito, in quo ex vitali fieri incipit animalis, ad propriam rationalis animæ sedem accedens. Iterum ille fortius mentis ignea vi tenuatur, elaboratur, et perficitur, in tenuissimis vasis seu capillaribus arteriis, quæ in plexibus choroidibus sitæ sunt, et ipsissimam mentem continent. Illi plexus intima omnia cerebri penetrant, et cerebri ventriculos internè succingunt, vasa illa secum complicata et contexta servantes, usque ad nervorum origines, ut in eos sentiendi et movendi facultas inducatur.

"Vasa illa miraculo magno tenuissime contexta, tametsi arteriæ dicantur, sunt tamen fines arteriarum, tendentes ad originem nervorum, ministerio meningum. Est novum quoddam genus vasorum. Nam, sicut in transfusio à venis in arterias est in pulmone novum genus vasorum, ex vena et arteria, ita in transfusione ab arteriis in nervos est novum quoddam genus vasorum, ex arteria tunica et meninge: cum præsertim meninges ipsas suas in nervis tunicas servant."

Milne Edwards, *Leçons sur la physiologie*, Paris, 1858, tome III, p. 17.

not by the heart. In the left ventricle there is no capacious place for so great and such copious admixture, nor is there elaboration sufficient for the yellow. Indeed, that middle wall, since it lacks vessels and facilities, is not adapted to communication and that elaboration, even if it could exude anything. By the same arrangement by which transfusion is made in the liver from the vena porta to the vena cava through blood, a transfusion is also made in the lung from the vena arteriosa to the arteria venosa through spiritus. If one will compare this with that which Galen writes, lib. vi et vii, *De usu partium*, he will thoroughly understand the truth not observed by Galen himself. This vital spiritus accordingly is transfused from the left ventricle of the heart and then into the arteries of the whole body, so that what is of greater tenuity seeks the superior, where it is still more elaborated, especially in the flexus (plexus) retiformis, situated under the base of the brain, in which from the vital begins to be made the animal, approaching to the proper seat of the rational soul. Again, this is more strongly attenuated, elaborated, and perfected by the fiery power of the mind, in the thinnest vessels or capillary arteries, which are situated in the choroid plexuses, and contain the very mind itself. These plexuses penetrate all intimate parts of the brain, and gird from below inwardly the ventricles of the brain, preserving these vessels complicated and entwined with each other, as far as the origins of the nerves, in order that the faculty of feeling and of moving may be imparted to them.

"These vessels most delicately in a very miraculous manner interlaced, although they are called arteries, are nevertheless the ends of arteries extending to the origin of nerves, for the service of the meninges. It is a certain new kind of vessels. For, as in transfusion from veins to arteries there is in the lung a new kind of vessels out of vein and artery, thus in transfusion from arteries to nerves there is a certain new kind of vessels, out of the tunic of the artery and the meninx: especially as since the meninges themselves preserve their own tunics in the nerves."

In the first sentence of the extract from Servetus, he says, like Rabelais, that "the vital spiritus has its origin in the left ventricle"; Rabelais says that the left ventricle makes the blood so subtle that it (the blood) is called spiritual and the left ventricle sends it to all the mem-



bers by the arteries to warm and "winnow" the blood of the veins. Servetus says that the lungs "in the greatest degree" aid in the generation of the vital spiritus; that it (the vital spiritus) is attenuated and elaborated by force of heat, is of a yellow color (*flavo colore*) and of fiery power, and is, "as it were, a clear vapor," containing the essential parts of water, air and fire.\* "It (the vapor) is generated from an admixture, made in the lungs, of inspired air with elaborated subtile blood, which the right ventricle of the heart communicates to the left." This communication is not made through the middle wall of the heart, as is commonly believed, but from the right ventricle, "by a long passage carried through the lungs, the subtile blood is put in motion." It is prepared by the lungs, is made yellow and is passed from the pulmonary artery to the pulmonary vein.† The blood is mixed with the inspired air in the pulmonary artery "and by expiration is purged of its dark substance." In this wise the whole admixture is drawn from the left ventricle, "material is adapted, so that it makes vital spiritus."

Here is a description of the passage of dark blood through the lungs, from the right to the left side of the heart. In the lungs the blood is purged of "dark substance," which is thrown off in expiration, and is changed into vital spiritus, described as a clear vapor, of yellow color. This is the idea of the pulmonary circulation given by Servetus.

Rabelais thought that the blood was made so subtile in the left ventricle that it was called spiritual and was sent by the left ventricle to the parts to "warm and winnow" the venous blood; which latter was also sent to the parts for their nourishment, but by the right ventricle. Rabelais also spoke of the heart as distributing its best blood to the lungs by the pulmonary artery. He indeed came very near a description of the passage of blood through the lungs; and he actually did say that spiritual blood was sent by the left ventricle through the arteries "to all the members."

The arguments of Servetus to sustain his theory of the passage of blood through the lungs are most interesting. He says that since the communication and preparation of the vital spiritus is thus made through the lungs, there is a manifold conjunction and communication in the lungs of the pulmonary artery with the pulmonary vein; and that this is confirmed by the great size of the pulmonary artery, this vessel carrying too much blood to the lungs simply for their nourishment. He speaks of the lungs of the fœtus as "accustomed otherwise to be nourished," on account of valves of the heart "not yet

opened even to the hour of birth, as Galen teaches"; "the blood is poured out from the heart into the lungs at the very hour of birth, and in such abundance; the yellow color is given to the *sanguis spirituosus* by the lungs, not by the heart; the left ventricle is not sufficiently capacious for so great an admixture of air with the blood; the arrangement for the passage of blood in the lungs from the pulmonary artery to the pulmonary vein is the same as for the passage of blood in the liver from the vena porta to the vena cava. Indeed, in his argument, Servetus quite closely describes the changes in the pulmonary circulation which take place at birth. It is not germane to my purpose to follow either Servetus or Rabelais through their speculations in regard to the generation of animal spiritus from vital spiritus. Servetus speaks of the animal spiritus as elaborated and perfected in the flexus retiformis under the base of the brain and as still more strongly attenuated, elaborated and perfected in the chorioid plexuses, describing the tunics of the vessels of these plexuses as uniting with the meninges to form nerves. Rabelais speaks of the animal spirits as made in the *rete mirabile* out of the spiritual blood: "The philosophers and physicians affirm that the animal spirits spring from, have their origin in, and operate through the arterial blood purified and refined to perfection within the *rete mirabile*, which lieth beneath the ventricles of the brain."

One can hardly study closely the passages quoted from Rabelais without appreciating how near philosophers and physicians in the middle of the sixteenth century were to a knowledge of the pulmonary circulation. As regards the systemic circulation, the notion seems to have been that blood was made in the liver out of nutritive matters of food absorbed by the mesenteric veins, was transported to the heart to be further refined, and was sent to the parts by the veins; that the left ventricle sent arterial blood to the parts for some indefinite purpose. It remained to show that the blood could move in the veins in only one direction and could not pass from the right ventricle to the periphery, to give the key to knowledge of the general circulation. This was done when the great anatomist, Fabricius, demonstrated the valves in the veins to the great physiologist and philosopher, the immortal Harvey.

The work of Servetus was not a factor in the discovery of the circulation, because it was unknown, it is said, until 1694. It might be said that the cruel burning of Servetus and the practical destruction of his work, in 1553, delayed the discovery of the circulation for more than half a century; but the history of physiology shows that Realdus Columbus, of Cremona, a disciple of Vesalius, wrote, in 1559, that blood did not pass through the interventricular septum, but was carried from the right ventricle to the lungs by the pulmonary artery and then passed with air into the left ventricle by the pulmonary vein. Cæsalpinus, in 1583, wrote that the veins carried nutritive matters to the heart and that the arter-

\*Further on, Servetus calls this "*sanguis spirituosus*."

†At the time of Rabelais and Servetus the general notion was that there was but one pulmonary vein. Eustachius made his celebrated *Anatomical Engravings* in 1552; but he was unable to publish them, and they were practically buried in the papal library until 1714, when they were made public by Lancisi. In *Tab. XXVII, Fig. 13* is a very exact representation of the four pulmonary veins. (Sprengel, *Histoire de la médecine*, Paris, 1815, tome IV, p. 35.)

ies distributed these matters to the parts. He noted that when a vein was ligated, the vessel became swollen below and never above the point of ligature. He also wrote that the blood *circulated* in the lungs to pass from the right to the left side of the heart; but he had a vague idea only of the general circulation and adhered to the ancient error that there were openings in the interventricular septum through which the blood passed freely between the two sides of the heart.\* How far, then, a general knowledge of the description of the pulmonary circulation by Servetus would have hastened the discovery of the general circulation, if at all, it is impossible to determine.

The idea of this article suggested itself to me in reading the passage that I have quoted from Rabelais. After much study and bibliographical research, I have attempted to give an idea of the progress of actual knowledge in regard to the movements of the blood, up to the grand epoch in physiology marked by Harvey, and especially the knowledge that prevailed in the middle of the sixteenth century.