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A HISTORY of the DEVELOPMENT of
our KNOWLEDGE regarding the CIRCULATORY
SYSTEM.

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Edin. Univ. Union
April 1900

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A HISTORY OF THE DEVELOPMENT OF
OUR KNOWLEDGE REGARDING THE CIRCULATORY
SYSTEM.

Introduction In writing an essay on the Circulatory System as seen from a historical standpoint, one is tempted to begin by endeavouring to point out the supreme value to the medical profession of a thorough and accurate knowledge of the system which involves the blood-supply. However, as the essay promises to be a long one, we shall not burden its pages with an excess of extraneous matter, and shall at once proceed to carry out its purpose as expressed by the title, "A HISTORY OF THE DEVELOPMENT OF OUR KNOWLEDGE regarding the CIRCULATORY SYSTEM"

Hippocratic Period. 1. As one studies the subject of this essay, one marvels that prior to the age of Hippocrates knowledge regarding the Vascular System was practically nil. From the earliest records on the subject, we learn that the ancient Indian medical men, - if we may apply the term to such crude dabblers in the noblest of all professions - had a vague idea that in the body there existed definite channels, presumably with fluid contents. When we note that they considered the system as being made up by three hundred veins emanating from the navel, we realise that their theory was the outcome of lazy imaginings rather than from systematic

anatomical investigation. Ten chief vessels radiating from the heart are mentioned at a later date indicating a truer conception of the subject. The other ancients who had pretensions to medical skill - Jews, Egyptians, and Chinese - were in a similar state of ignorance; they recognised a heart and a few vessels which were apparently concerned with the blood-supply of the body. Beyond this nothing was known.

This was the state of matters which existed until the age of Hippocrates. The superstition which was rampant at that early period was responsible for the lack of anatomical knowledge; the bodies of the dead were held sacred, and mutilation of a corpse was attended by such terrible consequences to the intrepid operator that the art of dissection could make no progress.

As a more lengthy discussion of the subject as it was known prior to 500 B.C. can serve no useful purpose we shall proceed without further preamble to study the **Vascular System** as elucidated by the pioneer of anatomical research.

2. To the Greek HIPPOCRATES fell the honour of being the first great anatomist . In the fifth century before the birth of Christ he roused the Ars Anatomica from the state of coma in which it had lain for countless ages. The present age with its lore of anatomical literature cannot adequately appreciate the work of this man; surrounded by morbid superstition he dared to practise the art which even now is not

Hippocrates.

and members of this school showed some acquaintance with the details of human anatomy

without its adversaries, and gave the art of dissection that impetus which was so necessary for the ultimate perfection of the healing art. A great deal of dissection was undoubtedly practised in secret before his time, and Hippocrates, profiting by the labours of these obscure anatomists, must have suspected the existence of a great deal of what he ultimately proved regarding the human frame. We must remember too, that the anatomical knowledge of Hippocrates and his school was derived mainly from the dissection of animals, sacrifices, and surgical operations. Although the bodies of animals and savages, being beyond the pale of religious ordinances, were available for dissection, such opportunities of investigating human anatomy were not too abundant.

With regard to the vascular system Hippocrates was guilty of many inaccuracies, and the determination of the starting-point of the blood confused him very much.

This is evident when we note that in "De Morbo Sacro" he mentions the brain as the starting-point of the pneumatized blood, while in "De Corde" he recognises the heart as such. The Aorta and Vena Cava are also mentioned in the same connection. As the result of this confusion it is rather difficult to decide what were the ultimate views of Hippocrates regarding the vascular system, but we may summarize his conclusions fairly accurately in a few sentences.

In his "De Natura Hominis" we find that Hippocrates

doctrine of
Hippocrates

the latter is
generally
attributed to
Hippocrates
but not of his
school.

regarded the blood as being concerned in the heating of the body. His well-known humoral pathology teaches us that the blood, as one of the four primary fluids of the body, represented the "warm-moist" quality, and came from the heart as such. This humour- the blood - was the material which built up and maintained the body. Formed in the spleen it travelled to the heart, and in the left ventricle, which was the seat of the inherent warmth of the body -- the fundamental principle of life -- it attained the requisite temperature. From thence the blood was conveyed throughout the body by "veins". The left ventricle and arteries contained "Pneuma", the aërial vital spirit, with probably a small quantity of blood. The structure of the heart was well-known to Hippocrates and he describes the Pericardium, two Auricles, two Ventricles, an interventricular septum, *Semilunar* Valves, and *Chordae Tendinae*. The physiological functions of the parts were not understood, and he erroneously states that the ventricles communicate directly in spite of the septum, the left being nourished by the best blood from the right. The larger and more superficial vessels were fairly well-known, but the arteries were understood to contain pneuma while the veins carried the blood.

Hippocrates stands as the commencement of a renaissance in the medical world, and it is a tribute to his splendid work that his medical memoirs served as a standard for many centuries after his demise.

3. As the existence of Pneuma was so firmly believed in by Hippocrates and the physicians of many succeeding centuries, it will not be out of place at this point to mention how the conception arose. These early anatomists, in the course of their dissection, found that in the corpse the left ventricle contained no blood. It was also noted that section of an artery was accompanied by a sound suggesting an escape of air. Ever seeking for the fountain of life, this invisible yet apparently existant aërial spirit seemed to satisfy the requirements of the anatomists, and was unhesitatingly styled the "vital spirit" or "pneuma". The conception is a pretty one but was responsible for a large proportion of the fantastic theories which became prevalent regarding medical matters.

4. During the declining years of Hippocrates, an anatomical school of considerable importance came into prominence. The adherents of this school were known as the Dogmatists, and two of them - DIOCLES and PROXACORAS of COS - made important additions to existing knowledge of the Vascular System.

DIOCLES devoted most of his attention to Anatomy, and from his book on the subject we shall select those points with which this essay is concerned. Although his dissections were almost entirely confined to the animal world, the consequent discoveries are equally applicable to human anatomy.

Diocles believed that the heart was the source of the

Origin of
the term
"Pneuma".

o Dogmatists

Diocles and
his Works.

blood, and knew that from the heart arose two large vessels, the Aorta and the Vena Cava, the former stated to supply the kidney and bladder. These trunks ramified to form "veins". The blood was prepared in the liver and made capable of performing the function of nourishing the body.

Proxagoras
of Cos.

^APROXAGORAS of COS (400-20 B.C.) was a contemporary of Diocles, and ultimately assumed the leadership of the Dogmatists. He elucidated the work of his contemporary in many respects. A decided step forward was made when he distinguished between arteries and veins - a distinction which Diocles had allowed to lapse. The former were understood to contain pneuma alone, while the latter held blood. Proxagoras for the first time traced the nerves to the heart, but, as he designates that organ as the seat of mental diseases, he probably thought that the nerves originated there. The importance of the pulse in diagnosis also owes its recognition to Proxagoras.

their
Disciples

In leaving these two dogmatists, we may mention that among their more prominent disciples were Xenophon of Cos, Pleistonicos, Philetomes, and Dieuches of Athens, but their work was merely of a subsidiary character.

Aristotle

5. We pass from the work of Diocles and Proxagoras rapidly in order to study that of their more brilliant contemporary. I refer to ARISTOTLE. (384 -322 B.C.) Under his scalpel minuter details of the vascular system were

exposed with unerring accuracy, and in Aristotle we recognise the most thorough anatomist of these ages. Most of his observations were the result of dissections practised on animals and this accounts for some curious errors in his conclusions.

The heart was carefully studied but somewhat erroneously described by Aristotle. Its position is defined in the following words. "It lies about the centre of the body but more to the front than behind, and higher than the middle of the body. In man it inclines towards the left. It is a hollow receptacle for blood, and its thick walls are well supplied with 'sinews'; presumably the Chordae Tendinae. He erroneously believed the heart to be three-chambered, apparently disregarding the interventricular septum. Professor Huxley has pointed out that the blunder is only apparent, being really due to a mistaken view of the function of the right ventricular cavity, Aristotle regarding it as a venous sinus - part of the combined Inferior and Superior Venae Cavae. These two venous trunks seem to have been taken together as 'the great vein', in which case Professor Huxley's suggestion is quite a correct one. Again, Aristotle makes no mention of the valves of the heart, although it is hard to believe that such a careful dissector should have overlooked these. A rather curious observation that there is no bone in the human heart is the outcome of his zoological researches, the cruciform bone of the ox suggesting that the absence of one in Man was abnormal.

Aristotle's
views on
the Vascular
System.

Aristotle studied the Pulmonary System, and describes its anatomy quite accurately; and it is in this connection that we have evidence of the painstaking accuracy with which his dissections were made. Here, as elsewhere, no distinction is made between arteries and veins, the Pulmonary Arteries and Veins being indiscriminately referred to as 'canals' by which blood passes between the heart and the lungs. In the lungs these canals are correctly stated to ramify exactly as the bronchi do, the branches of bronchi and canals accompanying each other closely. The large systemic vessels are carefully portrayed, the Vena Cava, Aorta, and their main branches, being well-known but somewhat inaccurately described. He believed that branches from the Aorta terminated in the cerebral membranes. The Spermatic Arteries are also mentioned by Aristotle, but he makes the curious statement that they contain no blood but merely water and pneuma.

The changes in the colour of the blood are recorded, but, being totally ignorant of the physiology of respiration, he can give no explanation of the phenomenon. Aristotle explains the absorption of food by stating that it is absorbed by the intestinal walls, and thence reaches the mesenteric vessels, being then conducted to the heart as 'chyle' by the larger blood channels.

Embryology, a hitherto neglected subject, received a great deal of attention from Aristotle, and many notable facts were revealed by him in connection with it.

He recognises that the heart is the first organ to be fully formed in the embryo, and considers that its importance as the seat of life is thereby proved. This leads him to conclude that the blood is vitalised by the pneuma and inherent warmth of the heart and thus forms the necessary bond between body and soul. Kept fluid by this imparted warmth the blood passes into the vessels and, pulsating in time with the heart, it found its way to the tissues and 'watered' there as a brook might do - a more appropriate simile being that of a stream losing itself in a sandy soil.

6. By his work Aristotle elucidated the anatomy of the Vascular System very considerably, particularly in many minuter details, but the fact that he made no distinction between arteries and veins detracts from the merit of his observations. It was but fitting that such a preeminent anatomist should be responsible, although indirectly, for the establishment of that school of medicine whose adherents did so much towards the ultimate perfection of the healing art - the MEDICAL SCHOOL of ALEXANDRIA. Alexander the Great was an ardent pupil of Aristotle, and he made his capital the locus of that medical school, which bears the distinction of having been the most notable institution of its kind. The school became notable about 300 B.C. and maintained its preeminence for many centuries most of the great anatomists of the age being numbered amongst its alumni. As a school of Anatomy it excelled, as, under

Medical
School of
Alexandria.

the favour of the Ptolomies, this subject received that unprejudiced recognition which was essential to its progress; it is even recorded that the kings themselves took part in the dissections.

7. The names of two great anatomists are associated with the earlier glory of the school - those of HEROPHILUS and ERASISTRATOS.

HEROPHILUS of CHALCEDON (300 B.C.) was a pupil of Proxagoras. An even more accurate dissector than Aristotle, the results of his labours are freer from error and the relations of structures are more accurately determined.

Amongst the more important advances made by him with reference to the Circulatory System we would draw attention to the following.

With regard to the blood supply of the brain Herophilus describes the blood sinuses and Choroid Plexus. As we have seen the former had apparently been remarked by Aristotle, but were not fully investigated by him. Herophilus, and also his contemporary Erasistratos, thoroughly examined and understood the structure and function of the cardiac valves. A distinction between blood-conducting veins and arteries with blood and pneuma is clearly drawn - the latter being noted to rise from the heart. The arterial coats are stated to be six times as strong as those of the veins. The coarser relations of the Vascular System as he knew it, are much more carefully

no
Alexandrians

erophilus
and his
work.

set forth than they had been by any of his predecessors. Herophilus also states that the Pulmonary Arteries are peculiar in structure, and he terms them *πλὴν ἐρρηπίωσσης*. In the mesenteric veins passing into the portal fissure, he distinguishes the Lacteals, and thus paves the way for a more accurate explanation of food-absorption than Aristotle had given. The importance of the pulse in facilitating an accurate diagnosis is emphasised.

In passing from Herophilus and his works it is interesting to note that Agnodice, the first lady medical, was one of his pupils.

ERASISTRATOS of JULIS (330-240 B.C.).

Erastrotatos
Julis

This contemporary of Herophilus may be regarded as his equal as a pioneer, but he surpassed him in attention to anatomical details. The value of his work is ^{undoubted} ~~understood~~, but it is marred by the fact that that tone of certainty which is characteristic of his statements dominates his errors as conclusively as it does his facts.

Erasistratos brings the description of the heart with its concomitant valves and Chordae Tendinae, to perfection. He adheres to the belief that blood is formed in the liver, and then carried to the heart by the Venae Cavae. During the phase of cardiac systole, the Semilunar Valves open and allow blood to escape from the cavities of the heart, while the

simultaneous closure of the Tricuspid Valves prevents regurgitation.

The blood for the right ventricle is carried to the lungs by the Pulmonary Artery, the valvular action of which regulates the supply of blood. The Lacteals are also described by Erasistratos, but he believes them to be arteries filled with milk, and fails to recognise their significance as part of the absorptive mechanism. The current belief that blood was carried to the body by veins, and that arteries contained pneuma are not improved upon, neither does a statement that no blood is supplied to such fibrous structures as the stomach, intestines, ^{bladder} and uterus, find favour at the present day.

Erasistratos seems to have noted that section of an artery caused an amount of bleeding which was not warranted by the pneumatic theory according to its general acceptation, and the explanation given by him is evidence of the unquestioning faith which vested the pneumatic doctrine at that period. Instead of drawing the inference that the arteries must contain a large volume of blood, he endeavours to prove that the fluid is drawn from the veins by way of 'synanastomoses', these being terminal communications between the arteries and veins. Normally closed by valves, they allowed blood to pass into the arteries to replace an escape of pneuma such as might be occasioned by wounding an artery. Although the theory is obviously absurd, it is suggestive of an existant communication between the two sets of vessels which is not without interest

in view of Malpighi's discovery no less than two thousand years later.

In spite of many blemishes the work of these two Alexandrians, Herophilus and Erasistratos, revealed many important facts of the Vascular System and also perfected much pre-existing knowledge of the subject. Separate Schools were founded by their adherents with a view to continuing their work, but without noteworthy success in either case.

8. Anatomy now enters on a long period of obscurity, a period which lasted for over four hundred years. The prominence of a new sect, the Empirics, is mainly responsible for the lapse. These men relegated Anatomy to a position of minor importance, and devoted all their attention to clinical diagnosis. The lurking prejudice against human dissection which had proved so formidable a barrier to progress in earlier times were revived, and men turned their thoughts to the less repugnant practice of Medicine. Many new schools rose and fell, but, although Medicine and Surgery made considerable progress, the period was a barren one so far as this essay is concerned. A brighter era dawned at last about the beginning of the second century A.D.

9. In 130 A.D. GALEN was born at Pergamos, and he it was who was destined to emulate Hippocrates in a lesser degree by resuscitating the practice of Anatomy. While it is not the intention of the writer to record the life-history of/

lescent
period.
Obs. - 180 A.D.)

Galen.

of Galen, it is interesting to note that only a providential dream of his Father's preserved Galen to the medical profession, as, interpreted as an inspiration from Aesclepius, it turned his thoughts from Philosophy to Medicine. The records of his work are based on the dissection of animals, mainly apes, and as he considers these results equally applicable to human anatomy his statements are erroneous at times. Human corpses for dissection could seldom be procured at that time and it is probable that only on two occasions did he have the opportunity of dissecting the human body.

Galen's contributions to the subject of our study are of the greatest importance, and we shall devote the following paragraph to a consideration of these.

Once again we find the heart regarded as the seat of inherent warmth and the home of the vital pneuma. Its walls are essentially muscular, but its fibres, running longitudinally and transversely, are different in character from those of ordinary muscle. The organ is quite an independent one and has no nerve supply. The right and left ventricles move simultaneously, diastole being regarded as the dynamic phase of the cardiac rhythm. During this phase the following effects are produced. - those affecting the "vital spirit" being considered first. Blood carrying air is "sucked" into the left ventricle from the lungs by way of the Pulmonary Veins, the air being then transformed into pneuma, which in turn is nourished and vitalised by pure blood from the right ventricle (the requisite amount of blood filtering through the porous interventricular/

only
officially
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probably
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not

Galen's
Doctrine.

interventricular septum.) By the "collapse" of the cardiac walls during systole the pneuma escapes into the arteries.

In order to make the course of the blood more clear, we shall make a slight digression to consider how the blood originates and then trace it to its ultimate destination. Galen describes correctly the union of the mesenteric veins into a common Vena Porta which conveys the "chyle" to the liver to be transformed into blood. The newly-formed blood then accumulates in the Vena Cava, and, in diastole, the heart draws it into the right ventricle and allows it to escape by the venous trunks to the lungs and tissues. The communication between the ramifications of the Vena Porta and the true veins of the liver is, in default of a more satisfactory explanation, stated to be by anastomosing pores. It is noteworthy that the significance of the Lacteals is again mistaken - Galen believing them to be veins for the nourishment of the intestinal glands.

The larger arterial trunks are well known, and Galen makes a considerable advance when he states that these contain a relatively large volume of blood, this being withdrawn from the heart by the rhythmic dilations of the vessels. He also suggests the existence of anastomoses between the more minute arteries and veins and places these mainly at their vascular terminations. He considers these anastomoses analagous to the pores of the cardiac septum. How nearly Galen approaches

Origin of
the Blood.

the Vessels.

approaches the discovery made by Harvey ! If he had only carried his theory of anastomoses a little further and endeavoured to find a satisfactory explanation of their necessity, it is not improbable that, taken in conjunction with the fact that the arteries were by no means bloodless, some glimmerings of the truth might have led to an earlier discovery of the great secret.

On the contrary however, Galen states that the arterial contents merely oscillate . He studied closely the action of the heart, and made it clear that the arterial pulsation is not due to an inherent property, but to power transmitted from the heart. He proves this statement by recording the effect of ligatures applied to the Femoral Artery - the effect of applying two ligatures being to stop the pulsation of the enclosed section of the artery, the movement being resumed on removal of the ligatures. If, on the other hand, a third ligature had been previously applied at a point nearer to the heart, the pulsation was not restored by removing the two lower ligatures.

Galen on
Respiration.

With regard to the physiology of respiration, Galen realises, or at least suggests, that the blood rids itself of 'Euliginous matter' during its passage through the lungs. Here we have another great advance although Galen cannot explain correctly how the interchange takes place, the explanation given by him being that in diastole the pure air is drawn into the mouths of the arteries while in systole

the combustion products were forced out.

We have now recorded the most prominent features of Galen's work, and realise that much of it is ^{of} practical as well as of purely historical interest.

10. As one might have expected, the death of Galen marked the commencement of another long period of inactivity in the anatomical and physiological worlds - Physiology being unable to make any notable advance until reliable apparatus was available.

It almost appears that Galen had discovered so much that the barren period of fourteen centuries which ensued was but Nature's method of restoring the balance of things. The real cause of this quiescent period was the attitude adopted by the Church towards the means whereby knowledge should be acquired. Insights into spiritual truths could only be gained by the study of established facts, and this system was applied indiscriminately to all branches of learning. With regard to medical matters it was taught that inspiration not only should but must be sought, not by original research, but by close study of the doctrines set up by Hippocrates and Galen. The Church represented that human dissection was sacrilege, and in an age when she held the reins of popular feeling, this was virtually a death-blow to Anatomy. Consequently we find that until the sixteenth century the authority of Galen

other
quiescent
period.
(10-1500.)

remained unquestioned. The spread of culture seemed to assist the Church in exterminating, or at least keeping in check, the so-called coarser passions which were evidenced by a love of human dissection - "callous desecration of the image of God". In 1315, an intrepid anatomist, MUNDINUS of BOLOGNA, dissected and publicly exhibited three human bodies, and thereby raised such a scandal that he never again emerged from the oblivion into which he found it discrete to retire. Not until the early years of the sixteenth century did any-one again practice Anatomy openly, and then JACOBUS BERENGARIUS of CARPI came into prominence. He was more successful than Mundinus had been, and is stated to have dissected at least one hundred bodies. Like that of his fore-runner, his career was a brief one, the antagonism of the Church fanning the flame of popular prejudice so vigorously that he was forced to become an exile. While such a spirit prevailed Anatomy could make no progress unless in the hands of a man to whom dissection was a sine-qua-non.

II. Such an one was VESALIUS. Born at Brussels in 1514, he early gave promise of being the great anatomist he so soon became. His enthusiasm for Anatomy is proverbial, and the pupils who gathered round him were so fired by his ardour that, as resurrectionists, they kept his table constantly supplied with subjects for dissection. At the age of 22 he was appointed Professor of Anatomy at Padua, and it is characteristic of the man that only three years

Mundinus.

total a
known
professor till
his death.

Berengarius.

Vesalius.

later he dared to challenge the accuracy of Galen's anatomical teaching. His position as critic of Galen was an unenviable one, and in order to establish his unique claims he set himself to find definite proofs in support of his own theories. In 1546, his views were published in "De Humani Corporis Fabrica", and, in spite of the storm of indignation which was aroused among uncompromising Galenists such as his own teacher Sylvius, Vesalius gradually forced men to adopt his views. From this book we derive our knowledge of the Vascular System as set forth by Vesalius.

Vesalius verifies the observations of a comparatively obscure anatomist, Etienne, with reference to the existence of valvular structures at the entrance of each Hepatic Vein into the Inferior Vena Cava. The Vena Azygos is accurately described, and similarly the Foetal Ductus Venosus passing between the Umbilical Vein and the Inferior Vena Cava. He agrees with Aristotle that the heart is a source of heat, and that its active phase is diastole, but denies that nerves pass from it.

He recognises that valve-like projections exist in the veins, but denies that they perform the function of valves - probably because they would thus have prevented the retro movement which was firmly believed to dominate the blood supply.

As his views on the physiology of the Vascular System are merely repetitions of Galenical teaching on the subject, we need not give further details. Even Galen's doctrine of a porous interventricular septum is undisturbed by Vesalius, although he is doubtful of its veracity.

FALLOPIUS. a pupil of Vesalius, extended his master's work in several directions, to the intense disgust of the latter, who, in order to maintain his own pre-eminence, wrote, "Examen Observationum Fallopii". Instead of minimising the value of the work of Fallopius, the book serves rather as a recognition of the industry of that Anatomist.

SYLVIUS. During the life-time of Vesalius, his former teacher, SYLVIUS, conclusively established the existence of valves in the veins in the shape of the useless "projections" of his more famous pupil, but, though they were still more fully studied by Fabricius at a later date, the significance of this important fact remained unrecognised for many years.

Vesalius the last of the re-Harveian school. Vesalius may be regarded as the last of the earlier anatomists and physiologists for the purpose of this essay. Within a few years the theories regarding the physiology of the Vascular System which had existed almost unchanged since the age of Hippocrates were to be revolutionised and the stupendous facts of the Circulation of the Blood established in their stead.

re intermediate physiologists. 12. The work of three other physiologists, SERVETUS, CESALPINUS,

and FABRICUS - calls for recognition. These men cannot be classed with the older school, nor can they be included in the later school which was initiated by Harvey. Their works seem to foreshadow the great change which was soon to be made, and thus we may regard them as links intermediate between the alumni of what we may roughly term the pre-Harveian and Harveian Schools.

Servetus. SERVETUS was born in 1511. Like many of the older anatomists he combined the study of Anatomy with that of Theology, as the title of a book which he published in 1553 might suggest - "Restitutio Christianismi". This book was the cause of his death at the stake in the same year at the hands of the Calvinists - but that is by-the-way.

Describes the Pulmonary Circuit. In his "Restitutio" the course of the Pulmonary Circuit is accurately described, and, although the discovery is in itself insignificant when compared with the later discovery by Harvey, its suggestive value cannot be entirely disregarded. In recording the conclusions of Servetus on this matter, our purpose can be best served by adhering closely to the original text and may be summarized as follows. "The blood cannot pass directly from the right to the left ventricle, but passes indirectly by way of the lungs. Leaving the right ventricle by the Pulmonary Artery, the blood is 'agitated' in a lengthened course through these organs. During its passage it is freed from fuliginous matter, and, mingled with inspired air, it returns to the left ventricle

via the Pulmonary Vein under the 'attractive' influence of diastole". It is important to note that he denies the suggested porosity of the cardiac septum and in this goes beyond the hinted scepticism of Vasalius. With reference to the Systemic Circulation he has no original statement to make, and we shall conclude our discussion of Servetus by referring to his closest rival to the title of discoverer of the Pulmonary Circuit.

Columbus. This is REALDUS COLUMBUS, born in 1516. In his book "De Re Anatomica", published posthumously in 1559, the Pulmonary Circulation is correctly described - a repetition of Servetus in fact. It is possible that he may have derived his ideas from Servetus before the latter published his theory, but this is merely an assumption. The vanity and almost proverbial jealousy of the man, which causes Columbus' book to be a patent imitation of that of his former master Vesalius, lends colour to the suspicion however, therefore we are probably justified in dismissing his claim entirely, and shall now turn to consider the second of the three intermediate physiologists - Cesalpinus. As we shall see his work is important in that it ^{seems to} anticipate Harvey's discovery.

Cesalpinus. ANDREAS CESALPINUS was born at Arezzo in 1519. A man of profound, almost superfluous, knowledge, he is a theoriser rather than a worker. His views on the physiology of the blood-supply are embodied in two books - "Quaestiones

Peripateticae" (1571) and "Quaestiones Medicae" (1593).

According to the former work, Cesalpinus appears to believe that the heart, in systole, sends blood into the Aorta and Pulmonary Artery, and that during diastole it is replenished by blood from the Vena Cava and Pulmonary Vein. In his "Quaestiones Medicae" he notes that the veins of a ligatured arm swell on the distal side of the ligature, and deduces that the blood flows towards the heart through the veins. Finally he states, "Thus there seems to be a sort of perpetual movement from the Vena Cava through the heart and lungs into the Aortic Artery, as I have emphasised in my "Quaestiones Peripateticae".

He seems therefore to initiate the theory of a Systemic as well as a Pulmonary Circulation, but when we consider how he arrives at this conclusion our admiration tends to diminish. We know that Cesalpinus did little or no original research, and, knowing the character of the man as a theorist, we are forced to conclude that his words were spoken with a view to raising controversy by casting aspersion on accepted doctrines, and our conclusion is strengthened by the fact that his physiological teaching was not considered worthy of serious consideration by his contemporaries.

FABRICIUS of AQUAFENDENTE, a contemporary of Cesalpinus, now falls to be mentioned. He was born in 1537, and was afterwards a pupil of Fallopius. He is of importance to us at this point by reason of his pursuance of Sylvius' discovery of the

valves in the veins. In his book "De Venarum Ostioliis," published in 1574, he records his erroneous views with regard to their function.

The resultant knotting of a vein on running the finger downwards along its length, is attributed to the action of the valves in preventing too rapid a flow of blood to the extremities. His words with regard to their function are, " ... In order therefore that the blood should be everywhere distributed in a certain just measure and admirable proportion for maintaining the nourishment of the several parts, these valves of the veins are formed"

In other respects Fabricius is a staunch Galenist and therefore we need not discuss his views further.

Pre-Harveian
Physiology.

13. Having disposed of these three sixteenth century physiologists we are now free to study the work of William Harvey, but before passing to review the facts of his great discovery a brief resumé of the pre-existing doctrines will enable us to appreciate more fully the inestimable value of the truth which Harvey revealed; as Servetus belongs to the later age morally, if not chronologically, we shall neglect his discovery in making our review of relevant physiology as it was understood at the close of the sixteenth century.

The summary may be given conveniently in tabular form as follows :-

1. The blood was not stagnant but its motion was of an ebb and flow character.
2. The greater volume of blood passed from the liver to the right ventricle and thence to the system by veins, while a specialised form of blood was also supplied to the system - a pneumatized form which passed from the left ventricle by way of the arteries.
3. A porous interventricular septum admitted blood from the right to the left side of the heart.
4. The function of the heart as a source of motive power was unheard-of, its only dynamic action being to suck in blood during diastole.
5. In spite of Galen's words, the heart was probably not muscular, its pulsations being attributed to rhythmic expansion of the pneuma for the due admixture of blood and spirit.

William
Harvey.

14. WILLIAM HARVEY was born in Kent in 1578. His medical studies were prosecuted mainly at Padua, where Fabricius was the most notable of his teachers. Harvey's

views on the Circulation of the Blood were published in 1628, when his book "De Motu Cordis et Sanguinis" was given to the world, and in 1636 he gave a public demonstration on the subject at Nuremburg. In corroborating his suspicions of the circulation of the blood, Harvey proceeded with most commendable exactitude to establish unimpeachable proofs. Realising that the pneumatic theory would be unsupportable should his suspicions prove to be correct, he did not hesitate to reject that relic of untutored imagining, and, unencumbered by any misleading fallacies, he set himself to his task.

The action of the heart in the living animal was studied minutely, and he records that in systole the organ is constricted in all directions and becomes hard and tense. His inferences are :-

(a) That the contraction of the heart substance is essentially the same as that of voluntary muscle, i.e. it is shortened and becomes harder in contraction.

(b) And that, as the result of the systolic contraction and consequent diminution of the cardiac cavity, a considerable volume of the consumed blood is expelled.

The conclusion is that systole, and not diastole, is the intrinsic phase of the heart-action; and this is Harvey's first momentous step.

A more systematic study of the venous valves than had been devoted to these by Fabricius reveals the fact that their position precludes any possibility of the veins being

Action of
Heart.

Arteries as
outlets of
Blood from
Heart

the outlet for the blood expelled in systole. Only the arterial trunks remain, and, as the position of the valves of the heart at their origins cannot be a barrier to the passage of blood into these vessels, these are undoubtedly the outlets sought after. The fact that so much energy is expended by the heart leads Harvey to ask himself whether some of that energy might not be responsible for the rhythmic distension of the arteries by driving into their channels the comparatively large volume of blood ~~which is~~ expelled in systole. According to the pre-existing theory that the arteries, by an inherent property of distension, sucked in blood, section of an artery should not have caused the escaping blood to spurt as it did.

Harvey, therefore, concludes that the distension is due to the blood being forcibly injected into the arteries by the heart. While he is quite right in denying the arteries to have any inherent pulsific power, he is in error when he states that their walls merely collapse after each pulsation, and disregards their elasticity. Knowing nothing of the histology of the arterial walls, he is ignorant of their muscular coats, and consequently does not know that their elasticity is supplemented by tonic contractility of their walls - the former converting the intermittent supply of blood from the heart into an equable stream in the veins, and the latter, influenced by the Vaso-motor System, regulating the supply of blood to particular parts in response to

Arterial
Pulsation
explained.

specific requirements.

To ~~resume~~^{return} to the action of the heart :- Two consecutive motions are seen, the first being an auricular and the second a ventricular contraction. Again referring to the position of the cardiac valves, Harvey shows conclusively that the auricular contraction drives the blood into the ventricles, which, contracting in turn, force the blood contained in the right ventricle into the Pulmonary Artery, while the left ventricle pours its contents into the Aorta.

These facts, particularly the latter ones, suggest to Harvey the probability of the Vascular System being a circulatory one. He realises that the validity of his supposition depends on the establishment of three facts which we shall study in detail. The corroboration of two of these is intended to disprove the accepted doctrine that food, when absorbed, is converted into blood, the resultant excess of that fluid being removed from the blood vessels by a corresponding volume of blood being absorbed by the tissues from the vascular terminations. The following are the three facts which Harvey now sets himself to establish.

1. The volume of blood which is incessantly supplied to the heart by the Vena Cava and thence to the arteries is relatively so great that it cannot be supplied from the ingesta, and that the whole mass of blood must pass through the heart at comparatively

Harvey's
Three
Propositions.

brief intervals; consequently, the blood must have some channel by which it returns to its starting-point.

2. The blood is impelled by way of the arteries in an incessant and equable stream throughout every part of the body.
3. The veins are the conduits by which the blood is returned incessantly to the heart from all parts of the body.

The first proposition is met by the following deduction by its author, "If the heart ejects but two drachms of blood at each contraction, the average amount emitted in thirty minutes will be about twenty pounds. Obviously such a quantity cannot be derived from the ingesta consumed in that time". He, therefore, concludes that the same blood must pass through that organ at comparatively short intervals - a theory which is dependent on a circulatory Vascular System.

The second proposition is proved by the results of the following experiments. If a ligature be tightly applied to the upper part of the arm, the brachial arteries cease to pulsate, but for a considerable time at least the normal appearance of the arm is retained. On slackening the ligature the arterial pulse is resumed, the arm becomes flushed at once, and the superficial veins appear knotted and distended. The second result is the more important one; in this case the looser ligature does not compress the deeper and firmer-walled arteries, while the passages of the

more compliant veins are still closed. Consequently, the excess of blood must have reached the arm through the arteries.

Only the third proposition now remains, - to prove that the veins are the channels by which the blood is returned to the heart. The position of the venous valves is such that the contents of the vessels may pass in one direction only, i.e. towards the heart by the main venous trunks. The experiment which proves this is the very simple one of running one's finger downwards along a vein, the result being that the blood is forced back on the valves, and, as it cannot pass these, knots appear on the proximal side of the valves and remain until the finger is removed from the vein, (this last clause embodies the fact which Fabricius overlooked)

The position of the valves of the heart supply additional corroborative evidence of the facts enunciated in Harvey's three propositions; and, as these form the backbone of Harvey's discovery, the writer of this essay makes no apology for giving the details so fully.

When William Harvey published and conclusively proved the facts of the Circulation of the Blood, he was ridiculed for a brief period only, for soon the simplicity of the new theory made its irresistible appeal to men's intelligence. Even then, reluctant to submit to the purely

Reception
of Harvey's
Theory.

visionary indignity of a complete capitulation, physiologists endeavoured to prove that the theory was not a new one at all but had been propounded by Servetus or Cesalpinus, while some actually attributed the discovery to Galen or even Hippocrates. We have already dealt with the only serious rival of Harvey - Cesalpinus - and his claims as discoverer of the Circulation of the Blood, and, while unwilling to detract from what merit his works may have had, we must unhesitatingly relegate that honour to William Harvey.

Sarpi. Among his contemporary rivals we may mention PAULAS SARPI, another pupil of Fabricius, but in his case the suspicion of moral theft is well founded and may be regarded as proved by Ent in his "Apologia". Some have endeavoured to prove that Harvey merely elaborated the idea of others, but according to his own words the theory was entirely original and we have no grounds for doubting the veracity of his statement.

Effects of
his Discovery. Perhaps the greatest merits of the discovery lies in the fact that it made possible an accurate appreciation of the physiology of the organs and tissues of the body. As he had expected, Harvey's demonstration dealt the death-blow of the well-worn pneumatic theory, and although the term "vital spirit" remained in use, it lacked that semi-supernatural note which had been associated with it since its inception. The weak point in Harvey's work is that he knew nothing of the capillary communication between the arteries

and veins as, the microscope being unknown, he was unable to trace these minute channels. A remark which he made in another connection is equally applicable with reference to this matter; his words are, "Many things, now hidden in the well of Democritus, will by and by be drawn up into the light of day by the ceaseless energy of the coming age."

15. The discovery of the capillaries - they only part of the system involving the blood-supply yet to be studied - now demands our attention.

Malpighi In 1628, the same year in which "De Motu Cordis et Sanguinis" was published, MALPIGHI was born at Bologna. As botanist, as naturalist, as embryologist, and as pathologist, he has left his mark, but it is Malpighi as the first histologist we shall consider. Before going on to study Malpighi's contributions to histological lore, we must make a brief digression in order to note on what his success depended.

Microscope
invented. Prior to the seventeenth century, the magnifying-glass had been widely used, but not until the year 1600 was the combination of lenses to form a microscope attempted, or at least successful. The new instrument was first applied for anatomical purposes by Stelluti in 1625. Consequently, Malpighi possessed an invaluable instrument which had not been available to his aforementioned predecessors.

Discovery of Capillaries.

In 1661 Malpighi published his first volume, "De Pulmonibus Observationes Anatomicae". Nothing had previously been known regarding the minute structure of the lungs, the prevalent conception being that they were fleshy masses of a somewhat porous substance, likened to "tow" by Fabricius. At first, Malpighi merely states that a ^{fine} ~~finest~~ reticulum of blood-vessels exists in the lungs winding over the air vesicles, but is uncertain whether the blood escapes freely from the arterial ramifications before entering the venous tributaries. His doubts are removed when, on examining the simple lung of a frog, he remarks the minute but clearly defined ring-like channels forming communications between the two sets of larger vessels. These are the long-sought capillaries.

Malpighi's discovery was followed by a fuller study of the capillary network made by ANTON of ^{var} ~~LECUWENHOEK~~ ^E in 1668.

16. Our study of the anatomy of that part of the Vascular System which involves the blood-supply being now completed, we shall study from a historical standpoint, that part which is apt to be regarded by the uninitiated as merely of secondary importance. I refer to the Lymphatic System, which for convenience we shall consider as made up of two sets of vessels - the Lacteals, carrying lymph and chyle, and the purely lymph-conducting vessels. Although the latter set forms the basis of the entire system, the former will be considered first as its discovery claims priority in this essay

Anton.Lymphatic System.

on chronological grounds. As the systematic study of the Lymphatic System began while Harvey was building up his theory, it is peculiarly appropriate that we should give it our attention at this juncture.

It had long been understood, or at least surmised, that the food which was absorbed during its passage through the alimentary canal found its way into the blood-stream by some means. It was part of the Galenical doctrine that the food was taken from the intestines by the Vena Porta and carried to the liver, where it was transformed into blood.

Erasistrates noted that certain mesenteric vessels of a kid which had just been suckled contained milk, presumably absorbed from the intestinal wall; and, as we have already noted, the lacteals had been noticed by still earlier anatomists. Their function, however, was misunderstood, and it may be said that prior to the seventeenth century anatomists were cognisant of one set of vessels only - the blood-vessels, omitting, of course, the capillaries.

In 1622, GASPAR ASELLI discovered the Lacteals as such. Like so many facts of supreme importance, their discovery was accidental. While dissecting the mesentery of a dog with a view to displaying the nerves, Aselli noticed innumerable fine white strands. At first he concluded that these were the nerves he sought, but on cutting through some of them the exudation of a milky fluid revealed the fact that

Aselli
discovers
Lacteals

they were vessels. A closer examination led to the discovery of intravascular valves which directed the fluid away from the intestinal walls.

Aselli did not pursue the matter further however and did not trace the subsequent course of the Lacteals. He imagined them to terminate in the liver, and the explosion of this fallacy serves to bring another name before us - that of Jean Pecquet.

Pecquet. PECQUET of DIEPPE, as he is usually referred to, published a book in 1651 entitled "Experimenta Nova Anatomica". Therein, Pecquet states that, many years before, he had recognised the existence of a sac - the Receptaculum Chyli of subsequent years. He then completes the unfinished work of Aselli by tracing the chylé in its course from the intestinal wall to the mesenteric glands, and thence to the Receptaculum Chyli. Continuing, he states that from there the fluid travels by a slender conduit, the Thoracic Duct, which pours its contents into the venous blood at the junction of the *left* Subclavian with the Internal Jugular Veins.

Eustachius. Another observer, EUSTACHIUS, had already discovered the Thoracic Duct in the horse, but thought it peculiar to that animal. Harvey had known of the existence of the Lacteals but could not reconcile himself to believe that they contained chyli. Knowing that the gastric veins were largely absorptive, the relatively slender Thoracic Duct seemed to him quite superfluous as an absorptive agent. While

unconvinced of the fact himself, in the absence of any other explanation he does not deny its probability.

The anatomy of the purely lymphatic vessels alone remains to be considered.

Rudbeck. In 1653, OLAUS RUDBECK, a professor of Botany and Anatomy at Upsala, published a volume entitled "Nova Exercitatio Anatomica". In this work he refers to a set of vessels which he describes under the title of "Ductus Aquosi" or "Serosi". These are mentioned as being like the Lacteals in structure but containing a clear watery fluid - lymph - vice the milky contents of the Lacteals. Rudbeck first noticed the "Ductus Serosi" in the liver and intestine, and from these he traced them to the Thoracic Duct (which he states became known to him in 1650)

Jolive. Like the majority of the great men of this period, Rudbeck has a rival, JOLIVE of GLISSON, who in 1652 wrote a thesis in which he described correctly the lymphatic ducts. As their claims are almost equal in merit, we may bracket the two names Rudbeck and Jolive as joint-discoverers of the lymphatic vessels.

Hunter. Both observers seem to have regarded the lymphatic vessels as merely specialised veins, and it was not until Dr. HUNTER (1718-1783) showed that the vessels were quite distinct in character, that this was refuted.

The revelation of the Lymphatic System helped to foster belief in the Circulation of the Blood, while the

avidity with which the two discoveries were accepted shows how profoundly the physiological world has been revolutionised since the memorable year 1628.

17. We have now considered the most noteworthy points of the anatomical aspect of the entire Circulatory System as seen from a historical standpoint, and the remainder of Physiology of Respiration this essay will be occupied with a review of its physiological aspect. The Physiology of Respiration, in so far as it concerns the Vascular System, will be dealt with first.

We have already mentioned the most notable conjectures which has been accepted in the early days regarding the changes produced in the blood by respiration - the term "respiration" being applied to its restricted sense, that is to say, as applied to the gaseous interchange which takes place in the lungs. Therefore, rather than bore the reader with a resumé which tends to gratify an interest born of curiosity rather than profitable study, we shall only deal with additions to the subject made during and subsequent to the seventeenth century. We must, however, recognise that prior to this the Galenical doctrine of pneuma held sway, and we must admit that the general principles of that theory was quite correct, that is to say in recognising that the blood received a "vital spirit" from the air and gave up "~~fuliginous matter~~ Vapour" during its passage through the lungs. Substitute "oxygen" for "vital spirit" and "carbon dioxide" for "~~fuliginous matter~~", and we see that the essential function of respiration was formulated in Galen's doctrine. Until the

Earlier
Doctrines.

science of Chemistry was elaborated, these statements could not be improved upon, and it is virtually the discovery and development of the chemistry of oxygen and carbon dioxide which we shall unfold.

Van Helmont. VAN HELMONT, a prominent chemist who flourished during the earlier years of the seventeenth century, believed that the blood underwent a process of fermentation in the lungs; while BOYLE, a later observer, showed that air which had been repeatedly inspired lost its power of sustaining life, and thereby corroborated Galen's view that a portion necessary to life was extracted from the air.

Hooke. The next step of importance was made by HOOKE in 1667, when he demonstrated that mere contact of the lungs with fresh air was sufficient to fulfil the function of respiration (movement of the chest-wall, or at least of the lungs, had hitherto been regarded as essential to the performance of the respiratory function). He proved his point by opening the thorax of a live dog and passing a steady current of air through the lungs. Contrary to general expectation, the vitality of the animal was unimpaired by this arbitrary respiration. It was thus established that the movements were merely subsidiary and not in themselves vital.

Borelli. BORELLI, in 1680, stated that although it influenced the blood in some way, the air as such did not enter the blood channels. Uncertain of the means by which the air reached the blood, he could only suggest that minute particles

entered the blood by diffusing through the walls of the vessels. Although of no momentous importance at this stage of the subject, he made a retrograde statement when he said that the air as a whole, and not any specific portion of it, was absorbed during inspiration.

Lower. LOWER, a contemporary English physiologist of lesser note, held the same views as Borelli on this point.

Mayow. At the same time, 1668, a prominent English chemist, JOHN MAYOW, showed that the air was not a simple substance, but made up of at least two gases - one of these being essential to life. He indentified "burning" and breathing, showing that the same portion of the air was involved in both cases by the following experiment. He allowed a candle to burn in a closed vessel until the flame was extinguished, and then quickly introduced a living animal into the vessel, the aperture being again sealed up. The result was that the animal immediately showed signs of suffocation and died in a very short time. Mayow rightly concluded that the portion of the air which had been necessary for combustion of the candle^{is} was identical with that fraction which was essential to life.

Stahl. In the eighteenth century, STAHL showed that the blood absorbed the vital portion of the atmosphere during its passage through the capillaries.

Black. In 1757, JOSEPH BLACK discovered carbon-dioxide,

Priestly.

calling it "fixed air", and demonstrated its presence in considerable volume in expired air, while shortly afterwards oxygen was isolated by PRIESTLY.

Black and Priestly failed to realise the significance of their respective discoveries and an honour which might have been theirs falls to another - LAVOISIER.

Lavoisier.

Like several of the men of whom mention has been made in these last pages, Lavoisier was ^{primarily} ~~previously~~ a chemist and not a physiologist, and although he analysed correctly both oxygen and carbon-dioxide (1771-1780) and explained fully the process of combustion, he did not apply his results in bringing about a clearer understanding of the respiratory process. Although many historians credit Lavoisier with the latter work, they are inaccurate in so doing, and to LAGRANGE (1736-1813) belongs the honour of revealing the facts of respiration as we know them at the present day.

Lagrange.

Making use of Lavoisier's datum that combustion is a process of oxidation, the products being water and carbon-dioxide, Lagrange showed that, as oxygen was consumed in respiration and carbon-dioxide produced (being present in comparatively large amount in expired air), respiration supplied the necessary oxygen for a process of oxidation which was carried on within the body.

The nature of this internal combustion - what we now term Tissue Respiration - was unknown to him, and he presumed that

during its course through the body the inspired oxygen gradually combined with the carbon and hydrogen of the blood to form water and carbon-dioxide, these products being ultimately liberated during expiration.

Magnus. It was apparently assumed by these later physiologists that no carbon-dioxide was present in arterial blood, nor oxygen in venous blood. This fallacy was refuted in 1837 by GUSTAV MAGNUS. By means of a gas pump invented by himself, Magnus showed that carbon-dioxide and oxygen were present in both arterial and venous blood, but in the latter the proportion of carbon-dioxide was increased while that of oxygen was diminished relatively to the quantities present in the former.

Liebig. The conditions of the gases in the blood was unknown, and they were believed to exist in a state of simple solution. A doubt on this point led to a reconsideration of the results of Magnus' quantitative analyses by LIEBIG. The results of Liebig's investigations led to the discovery that the gases are held, to a considerable extent at least, in chemical combination. The question then arises - With what are the gases combined? In order to understand the answer to that question we must refer to a discovery made in the seventeenth century, and which we omitted when considering that period as having no direct bearing on what was occupying the attention of physiologists in the intervening period.

Discovery of
Blood Corpuscles.

41.

18. In 1658, JOHANNES SWAMMERDAM, while applying the microscope to the examination of the blood of a frog Swammerdam noticed "an immense number of rounded particles possessing the shape of a ^{flat} ~~glad~~ oval, but nevertheless wholly regular". His words obviously refer to the blood corpuscles, and his is the first recorded description of these.

Malpighi. His Italian contemporary, MALPIGHI, corroborated the existence of solid particles in the blood, but he misunderstood their formation and mistook them for fat globules. The subject attracted the attention of ^{Anton van Leeuwenhoek} ANTON of LECUWENBOEK, and he recognised and described the "globules" as corpuscles.

Anton. We are now in a position to resume the subject of the chemical combination of the gases in the blood, as it was this discovery which men turned to in seeking to solve the above question, the corpuscles being suspected of being the agents sought for.

Stokes
Hoppe-Seyler. The query was finally solved by STOKES and HOPPE-SEYLER, who found that one of the gases - oxygen - was combined with a substance, Haemoglobin, which was present in the red blood-corpuscles. With reference to carbon dioxide the question has not yet been answered, and although many suggestions have been made on the subject, conclusive proofs are not forthcoming.

19. We have now recorded the history of the most important discoveries made with reference to the Circulatory

Recent Advances in Physiology. System, - of those discoveries which we may regard as the foundation of modern Physiology. The purpose of this essay is therefore, virtually fulfilled. But, although it is impossible to give even a tolerably complete summary of the facts which have been recently brought to light, it may be advisable to give some indication of how modern Physiology has been evolved from the comparatively primitive discoveries which have been already mentioned. As physiological research of the last half-century has not yet been systematically recorded by historians, the following remarks may seem to touch on isolated rather than connected investigations, but the reader will recognise that this is unavoidable. Nevertheless, their avowed purpose of indicating how modern physiologists have prosecuted the labours of their predecessors, may be fulfilled.

Chemistry of Blood. The known chemistry of the corpuscles and plasma of the blood owes its elaboration to such men as **ABDERHALDEN**, **MICHEL**, **SCHMIEDEBERG**, **HAMMARSTEN** and **FAUST**, whose investigations were made about 1897-98. **PASUCCI** estimated quantitatively the amount of **Cholestrin** and **Lecithin** which exists in the corpuscles, while the study of **Haemoglobin** occupied the attention of **GAMGEE**, **KÜSTER** and **PREYER**.

Leucocytes. The leucocytes of the blood were classified by **EHRlich** in 1898, and his classification is the most generally accepted one at the present day. The fact that the leucocytes, particularly the **Phagocytes**, ingest bacteria, owes its

revelation to METCHNIKOFF; this phenomenon was shown by WRIGHT to be dependent on the presence of "opsonins" in the plasma.

Blood-plates. The blood-plates were first noticed by HAYEM. Subsequently, WRIGHT demonstrated their relationship to the megalokaryocytes, while DEETJEN emphasised their amoeboid character.

Hemolysis. The phenomenon of Hemolysis has attracted a great deal of attention. Specific hemolysins which may be produced by immunization have been studied by physiologists, including EHRlich and BORDEN^{r.}. The latter also showed that hemolysins may be artificially generated in the blood.

Coagulation of Blood. Coagulation of blood has been the subject of much study, ^{and} considerable advance has been made within recent years. It was originally shown by HEWSON to be a characteristic of the plasma. Among the physiologists who subsequently gave the subject their attention with conspicuous success were BUCHANAN, DEWIS, and BRUCKE. Until ALEX. SCHMIDT propounded his discoveries in 1861, little progress was made. Schmidt demonstrated that the clotting was due to formation of insoluble Fibrin derived from Fibrinogen. As the phenomenon has not yet been conclusively explained we need not detail its later history, but may mention HAMMARSTEN, DELEZENNE and MORAWITZ as being among its most zealous investigators.

Blood generally.

With regard to the physiology of the blood as a whole, many physiologists have taken part in contributing to our knowledge of the subject. Important data with reference to the total volume of blood in the body and methods of compensating for excessive haemorrhage have resulted from the works of GRÉHANT (1882), FREDERICS (1885), DAWSON, and HALDANE and SMITH (1900) - Dawson's exposition of the "posthaemorrhagic fall" being particularly well known to us.

Blood pressure etc.

The extremely important data concerning such matters as blood pressure, heart-beat, and arterial pulsation, which are so abundant at the present day, owe their compilation more especially to modern physiologists ^{and Physicians} such as LUDWIG, MAREY, DUDGEON, SCHÄFER, MACKENZIE, and HURTHLE. (The initial discovery on which these records depend, was made by STEPHEN HALES in 1732, when he demonstrated that the intravascular blood was under considerable pressure, and recorded the facts of his discovery in "Haemostatics". The most notable of the earlier physiologists after Hales who pursued the subject further, was VON BASCH (1887), the inventor of the sphygmomanometer.)

Physiology of Lymphatic System.

A brief reference to recent research into the physiology of the Lymphatic System shall conclude our review of the modern aspect of the Circulatory System. As the subject is practically in its infancy and a great deal remains

to be revealed, the following review must leave the subject in a very ~~important~~ ^{imperfect} state of development.

For many years it was unknown whether the lymph actually came into contact with the tissues or was confined in a closed system. The fact that the Lymphatic System is a closed one was conclusively proved by both MacCALLUM and SABIN about ten years ago, by demonstrating that, although minute lymph channels ramify in the tissues, the lymph is not free to enter the intercellular spaces or the larger serous cavities of the body. HEIDENHAIN has done much to elucidate the physiology of this system, but the subject is yet in such an undeveloped state that it would be unprofitable for us to pursue its history further.

conclusion.

20. With this brief indication of the present state of Physiology with reference to the Circulatory System and the lines along which further research is being conducted, this essay may conclude. Although the subject is such a large one and ^{many} discoveries of lesser note have been omitted, we have endeavoured to ^{bring} ~~bring~~ before the reader the mode by which the pre-eminent facts on which modern Physiology depends have been revealed to us. When one studies modern Anatomy and Physiology one is tempted to believe that little remains to be made known, but, although recent research has unfolded innumerable facts which were undreamt-of fifty years ago, there is yet reason to believe that when the

twentieth century has drawn to a close the modern complexion of Physiology, at least, will have undergone a very appreciable change. With regard to the Circulatory System, particularly from a physiological aspect, we realise that it is still in an incomplete state of development, but we confidently affirm that the fundamental facts have already been permanently established by the illustrious names to which allusion has been made in the pages of this essay.

Jas. S. Rankin,
"Fernlea",
HELENSBURGH.



Jas. Simpson Rankin
Edinbrough Univ. Union
April 1912