1860

Some observations on the Blood and Animal Heat, &c.

David. Lyell.

Lung ?
Ca H. as Same
remarks not Constant

Fig I. A thin layer of blood dried shewing the altered form of the globules from pressure on one another See page 16.

Fig 2. Healthy Blood shewing Rouleaux. Page 16, 27

Fig 3. A specimen drawn from the same spot of the finger as the above Fig 2 but half an hour afterwards and containing many molecules Page 27

Fig 4. Blood acted on by water shewing the variety of action upon different globules. The larger globules are the white cells. Page 18.

Fig 5. Changes produced on addition of Chloride of Sodium Page 18.

Fig 6 Specimen shewing molecules & irregular formed globules in blood partly dried and from which most of the red globules have ~~been removed~~ flowed previous to being examined. Page 27

Fig 7. Some globules acted on by Tartaric acid and Bicarbonate of Potash. Page 22

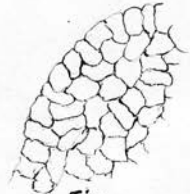


Fig I

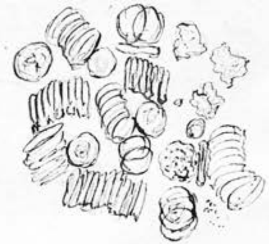


Fig 2

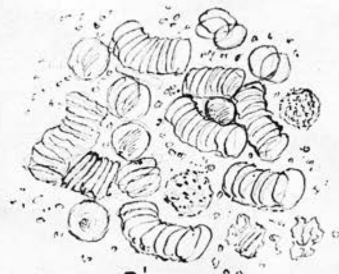


Fig 3

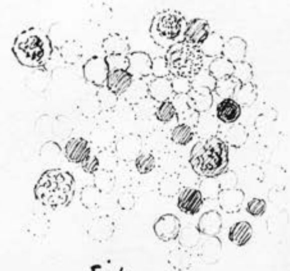


Fig 4

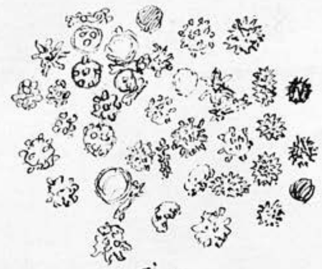


Fig 5

Fig 6

Fig 7

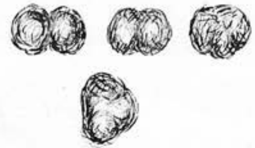
Fig 8. Appearances produced by the addition of alcohol and dilute solution of carbonate and chloride of sodium Page 24

Fig 9. Compound globules occasionally seen on the addition of water. Page 25

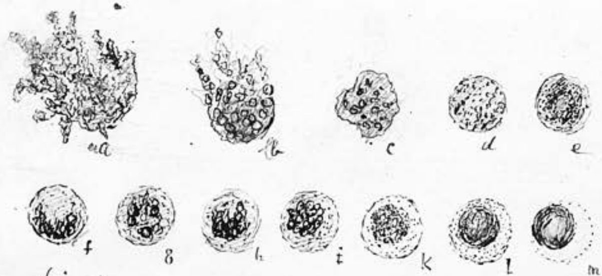
Fig 10. Different appearances which the white globules present on the addition of water. Page 26, 28, 29.

(Fig 11.) Peculiar appearance of the red globules on addition of weak acetic acid. Page 25

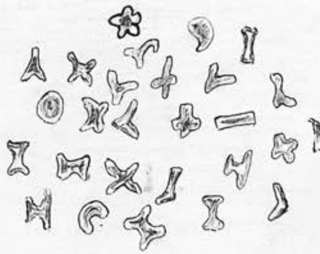
(Fig 8)



(Fig 9).



(Fig 10.)



(Fig 11.)

Importance of Blood as an animal Fluid.

Blood is the general circulating fluid of the animal body, from which all the elements required by the tissues for their growth are derived, and into which many of the effete matters of the system are poured prior to their elimination by the more special organs of excretion. The elements of the food also enter into its structure before they are capable of nourishing the tissues, or of contributing their share toward the support of the animal frame. Therefore it is that the composition of that fluid is so complex, its mechanical and chemical properties so varied and its physiological uses of so great importance. It is a fluid which has been looked upon in all ages as intimately connected with the life of the individual. Moses and the Ancient Egyptians as also many in the Greek school regarded it as the seat of life, and I may say that this is very much the public opinion held of its importance at the present time; hence we have such expressions in different languages as the "life Blood" the "living stream" and many similar terms. Although it is not the presence of this fluid in the animal body which constitutes life yet the absence of it either by slow bleeding or sudden decapitation will always produce death. Also the alterations from the healthy and normal state constituting disease of the blood must be detrimental to the health of the individual and very liable to give rise to extensive disease. The knowledge of its healthy state the changes apt to occur either in its chemical or physical properties, and the best way of treating these changes should therefore be of the greatest importance to the enlightened physician.

Humoralism & Solidism

However important the blood is now considered in the production and keeping up of disease, yet it has lost that first place which was assigned to it by the earlier doctrines of the Humoralists. By them it was considered as the cause

Solidism Pathology. and source of all disease; All changes in the solids were supposed to be due to changes on the part of this fluid. This doctrine no doubt was false, but not less far from the truth was that of solidism which followed. The disputes between the upholders of these two opposing theories were at one time fierce and bitter, and it is only within late years that a sufficient importance has been attached to either doctrine. Moreover ever and anon the balance has been oscillating more or less between them and especially within late years inclining towards the old Humoral views.

Alterations Dependent on the Solids. Most changes in the composition of the Blood must necessarily depend on changes in the solids of the body functional or organic, for these changes are produced by absorption assimilation and excretion processes carried on by solids as glands cells and vessels. If any of these solids are so altered in anatomical structure or in physiological function as to cause any change in the composition of the blood by a mal-performance of their functions then that blood so altered from its normal healthy state will inevitably be the source of various other changes more or less morbid which may arise in different parts of the animal economy. Many changes then in the blood will be directly dependent upon the actions of the solids upon that fluid and the blood once deranged will tend from its universal diffusion to excite other morbid actions general or local throughout the system. Thus when the stomach and bowels are in a diseased state, when the kidneys are unable rightly

Examples. to perform their proper excretory function, when improper aeration takes place in the lungs the blood may be so far changed as to act as a violent poison to the system.

Nutrition Essential to Health. We may even go further and say, that the excretion or elimination from the blood of those elements which go to form muscle, bone, brain, nerve, and other tissues of the animal body are necessary and essential to keep that fluid in a healthy and proper state; for if the excretion of these matters is prevented in their ordinary way that is by nutrition of the tissues as the separation of Phosphate of lime in the nutrition of bone their accumulation in the blood will alter its composition and produce disease. Nature however has a means of correcting this; safety valves exist, and the most important of these are the two kidneys. If the kidneys however are at the same time incapable of performing their function then serious results may follow. That the elimination of those substances from the blood which go to nourish the body and which are generally considered inert & harmless is necessary for preserving that fluid in a proper state is shewn by many circumstances but perhaps by none better than what occurs in the pregnant female. Immediately after delivery or on the death of the foetus-in-utero the secretion of the milk takes place by which those substances formerly devoted to the nourishment of the foetus are eliminated from the blood. If this secretion is prevented however by any circumstances whatsoever many unpleasant morbid consequences result which are well known in the lying-in-chamber. This is the safety valve by which the system rids itself of those matters formerly devoted to the nourishment of the foetus-in-utero. Again when any morbid secretion or tumor removes from the blood those elements which would have been destined had they remained for the growth of the normal tissues, the body becomes thin, ill nourished and anaemic and if this drain on the system be very great emaciation may go on to a marked degree.

Nutrition essential for Healthy Blood.

Illustrations

Conclusions.

Most of the changes in the blood then I consider are due primarily to the action of the solids. Some changes however may arise no doubt in the blood itself for it is a vital fluid containing living organised particles and as such is subject like every other vital organized structure to changes which constitute disease.

Colour of Blood in Invertebrates

Blood of the vertebrate animal is a viscous nutritive fluid of an opaque intense red colour. In the invertebrate series it is mostly transparent and colourless or milk white as in the molluscs; There are many exceptions however as that of the earth worm which is red, Helix pomatia blue, Planorbis corneus amethyst. Among insects in which it is mostly transparent ~~that of the Orthoptera~~ is greenish; silkworm yellow & beetles brown. I have examined several caterpillars in which the blood was of a yellow, orange-yellow, greenish, or brownish hue; not however being acquainted with their names I cannot now tell in what species I have observed this. The intensity varies as much as the colour itself, every shade being found from the milk white blood of the snails to the dark venous blood of man; This bears a slight proportion to the activity of the respiration and the amount of solid matter and may be estimated by the diffusive power in water. In the invertebrate animals the colour is in general faint best marked perhaps in the earth worm.

Fishes

Amongst ~~vertebrate~~ animals it is least marked in the fishes as appears from the pale colour of the flesh as compared with that of the higher vertebrates, the blood not having sufficient power to colour the tissues. The colour not only varies in different species and individuals but in different parts of the same individual consistent with health as may be well seen in Man.

Venous & Arterial &c

Thus Venous blood is much darker than arterial, arterial being of a bright intense cherry red colour, venous of a dark deep purple almost black. Whatever facilitates the absorption of Oxygen and excretion of Carbonic acid from the blood favours this change. Hence the blood of the foetus & pregnant female assumes more of a venous character for the lungs of the mother have a larger amount of tissue to supply with arterial blood than ordinary.

Colour in Anaemia & Leucocythemia

The Blood of children and females is somewhat thinner than that of man. In disease as in Anemia and chlorosis and especially in that condition termed Leucocythemia the colouring power of the blood is very slight compared with health. This in Leucocythemia is sometimes so marked that a drop held on the point of the finger transmits the light faintly and in patients suffering under it the lips cheeks and whole surface are of a sickly pale hue. The colour of the blood when drawn is a light pale pink.

Specific Gravity of Blood

The specific gravity of Blood is always higher than that of water and depends partly on the salts held in solution partly on the albumen and fibrin. The latter ingredient gives the blood a peculiar viscosity which increases after withdrawn from the body till coagulation takes place. According to Nasse the Specific gravity of human blood at 60° Fah may vary from 1050 to 1059 consistent with health, the average being 1055. Hammersmidt, Davy, & others assert that the density of arterial is lower than that of venous; This is supported by the researches of Simon on the blood of the horse but is denied by some chemists. Age sex & state of health modify the specific gravity thus it is lighter in woman & children and in patients suffering from anaemia & chronic affections than in man. The effect of bleeding is to diminish the specific gravity in a most marked degree, While in cholera it becomes increased, the blood becoming inspissated from the excessive watery discharges which pass from the patient.

Odour of Blood

The odour of fresh drawn blood is characteristic varying in different animals and so much so that a specimen from any of our domestic animals as the pig can readily be distinguished; On cooling this odour becomes faint but can again be detected even after the lapse of many days provided putrefactive changes have not far advanced on the addition of strong sulphuric acid. It is well marked in the blood of our domestic

Odour of Blood. animals as the pig and sheep but still more so in that of wild animals. I have had my hands and clothes so tainted by handling the bodies of squirrels which I have shot that it was with only after repeated washings that I could get rid of the strong unpleasant odour. Besides the squirrel the blood of the fox hare rat mouse rabbit cat & dog is also peculiar in smell. According to Barruel The odour of the blood is stated to stand in a definite relation to the odour of the cutaneous and pulmonary transpiration. The explaination of this is that the odour of the Cutaneous & pulmonary transpiration is caused by the excretion of some of the odourous matters of the blood. We do not yet know upon what this odour depends, probably to minute quantities of certain essential oils or fats, existing in the blood and tissues, becoming partly oxidated in the lungs. This supposition is supported by the fact that arterial blood is somewhat stronger in odour than venous.

Alkalinity of Blood The reaction of the blood is always alkaline. This is due not to free alkalies but chiefly to combination of Soda with carbonic and phosphoric acid and with albumen; On the other hand the juices of the tissues preponderate in acids & acid salts; The relations and reactions of these with each other, the alkali of the blood with the acid of the tissues are very interesting. It is absolutely essential that the blood be alkaline for if otherwise those numerous formations and decompositions which take place in the system & which constitute organic life cease. When the chemist wants to favour the oxidation of azote he adds lime to the Nitre beds; In the laboratory likewise he takes advantage of the same fact when he employs an alkaline solution of Gallic acid to remove the oxygen from the Nitrogen of the air. As these alkalies exert a powerful modifying influence over the union of oxygen with the other elements so also do the alkalies of the blood play a most important part in the transformations which take place in the animal system.

Temperature of Blood in Man & Mammals — The temperature of the blood of bird and mammals is considerably higher than that of the medium surrounding them except in very extraordinary circumstances. That of man is on an average about 100° Fah of children about 102° Fah. In febrile diseases it has been observed as high as 107°-108° Fah while in cholera as low as 77° F. It varies with the amount of exercise and the rapidity of the respiratory process hence during the day when the bodily functions are in more active exercise it is 1.8°-2.7° Fah higher than during sleep. In warm climates & Davy found the temperature of the blood 2°.7-3°.6 Fah warmer than in temperate climates. Arterial is somewhat warmer than

Birds — venous. That of Birds as a class is higher than that of mammals that of mammals being

Reptiles — about 100° Fah of Birds about 107° Fah. The blood of Reptiles & fishes is considerably colder and varies considerably with the temperature of the surrounding medium. In the Proteus (Tiedeman) it was 63°.5 when the air was 55°.4, 68°.25.7 when the air was 63°.5 Fah & 65 Fah

Fishes — when placed in water at 55° Fah. The temperature of Fishes corresponds still more closely with that of the water in which they swim ranging only .7-2.7 Fah higher. From many observations it appears that their temperature may be very much altered in some cases without necessarily causing death; Thus Northern voyagers have frequently seen fish frozen in masses of ice restored to complete health on being slowly thawed. Humbolt also tells us that he ~~he~~ saw fish thrown up alive from volcanoes and apparently in health although the surround-

Invertebrates — ing ~~temp~~ water was at the temperature of 210° Fah. It is difficult to ascertain the temperature of invertebrate animals but from what we know it appears probable that many of them have considerable heat producing power. On placing a thermometer in a hive of bees, or thrusting it into one of those masses in which they assemble at times the temperature is found to be higher than that of the surrounding air, in some cases 20°-30° Fah higher.

Theories of Animal Heat

Regarding the source of heat in animals several theories have been advanced. Some have supposed it was a vital property dependent on the nervous system, but Liebig and others have distinctly proved that all the heat generated in the animal system can be accounted for on chemical principles. From their researches the prevailing doctrine held is that the chemical union of the oxygen of the air with the elements of the body (Carbon & Hydrogen) is the only source of heat. The process is essentially one of combustion. The oxygen of the air combines with the Carbon and Hydrogen of the body to form Carbonic acid and water, in the same manner and with the same results, as follows the ordinary combustion of those elements in the coal which we use to warm our homes, or in the oil which we burn in our lamps. The process may be slower, and less evident to our senses, but the ultimate result is not the less certain. As by slow oxidation out of the body many intermediate substances of a complex nature & possessing interesting properties are formed, as those obtained from alcohol by the action of spongy platinum, so also in the animal system interesting analogous intermediate compounds are often produced. But whatever these intermediate changes may be the final ~~result~~ action in the healthy individual is that of full oxidation; that is the formation of Carbonic acid and water. Occasionally in diseased states we have proof of these changes as in what occurs in oxalurea; the Carbon instead of combining with the oxygen in the proportion to form Carbonic acid is arrested in its combustion and forms oxalic acid a compound of a lesser degree of oxidation. So probably in Diabetes. The sugar found in the urine in this disease is a much less oxidised compound than the Carbonic acid or oxalic acid and may be regarded as an intermediate stage in the oxidation of the fat compounds.

Imperfect Combustion

Oxalurea

Diabetes

* Some chemists hold ~~that~~ this sugar is formed from albumenous matter especially Fibrin. If this be the case what becomes of the Nitrogen of these matters? The percentage composition of dry Grape sugar ($C_{12}H_{12}O_{12}$) is C 40, H 7, O 53, of Protein C 55; H 7; N 15; O 23. Supposing half a pound (8 oz) of Glucose which is a moderate calculation be excreted by a diabetic patient per-diem then it would require $\left(55 : 40 :: 8 : \frac{64}{11}\right)$ $5\frac{9}{11}$ oz of protein & of course more of a protein compound to supply the carbon excreted in this sugar. The amount of Nitrogen set free from the Protein would be $\left(100 : 15 :: 5\frac{9}{11} \text{ oz} : \frac{192}{220} \text{ oz}\right)$ $\frac{192}{220}$ oz. As however Nitrogen is eliminated from the system chiefly if not wholly as Urea, the percentage composition of which is C 20, H 7, N 46, O 27; then ought to be found in the urine along with the 8 oz of Sugar $\left(46 : 100 :: \frac{192}{220} \text{ oz} : \frac{480}{253}\right)$ nearly 2 oz of Urea. The normal quantity of urea is about 1/2 oz.

It might be objected to this that the sugar is produced from the starch & sugar compounds of the food; but it occurs also to a very marked extent although the patient lives wholly on an animal diet which contains no other hydrocarbon compounds than fat.*

Chemical Theory of Animal Heat

Animal heat then is dependent on Chemical action. The body may be regarded as a furnace in which this process of combustion is continually going on, the materials for combustion being supplied by the food and the oxygen by the air entering the lungs; The absolute amount of heat generated by oxidation of combustible matter is constant provided the same degree of oxidation occurs. It is not altered by the formation of intermediate products nor by the particular circumstances under which that combustion takes place. Knowing then the amount of Carbon & Hydrogen consumed in the animal body and the heating power of these elements we can calculate the amount of heat produced.

Consumption of Carbon & Hydrogen

According to the experiment of Valentin & Brunner 173 grs of Carbon are exhaled as Carbonic acid by the lungs of an healthy adult per-hour. As the cutaneous exhalation of Carbonic acid is about 1/50th part that of the Pulmonary exhalation in warm blooded animals (Regnault & Reisset) it follows that 178 grs of Carbon are consumed in the system every hour, or about 8 oz per-day. The amount of Hydrogen is very much less, probably not more than 10½ grs; for as we know that 230 cubic inches or 86 grs more of oxygen is absorbed by the lungs per-hour than can be accounted for by the amount of Carbonic acid exhaled during the same period, & as this is supposed to combine with Hydrogen in the system to form water it follows that 10½ grs of Hydrogen is burned in the system per-hour. A minute quantity of Sulphur is probably oxidated in the system but this must be so small as to be of of no importance whatever as a cause of heat. Liebeg calculates the amount of Carbon consumed daily at $13\frac{1}{2}$ oz instead of 8 oz.

Heating power of Carbon & Hydrogen

According to Experiment of Liebeg (Lancet for Feb 1845) one part of carbon in combining with oxygen to form Carbonic acid is capable of raising 8558 parts of water 1° cent, or 12205 parts water 1° Fah. One part Hydrogen in like manner raise the temperature of 62626 parts water 1° Fah. Consequently 178 grs of Carbon and $10\frac{1}{2}$ grs of Hydrogen will be sufficient to raise the temperature of (2172490 + 657573) 2830063 grs

Hourly Quantity of Animal Heat

of Water 1° Fah; or in other words the amount of animal heat generated per-hour by a healthy adult supposing he consumes in that period 178 grs of Carbon & $10\frac{1}{2}$ of Hydrogen will be sufficient to raise the temperature of 404 lbs of water 1° Fah. If on the other hand we estimate the quantity of carbon consumed according to Liebeg at $13\frac{1}{2}$ lbs per-day then the heat generated per-hour will be sufficient to raise the temperature of 560 lbs of water 1° Fah.

Locality where Heat produced

Regarding the particular locality of the body where those chemical actions take place which produce animal heat different opinions have been held. The prevailing doctrine (Kirk's Physiology Page 178) is that they take place throughout the system at large: Wherever active nutrition goes on, wherever in fact arterial blood is changed into venous there and then animal heat is supposed to be generated. The lungs thus act as feeders & fanners to the flame which burns in every ~~part~~ tissue of the body. This is supposed to be proven by the fact that if these changes occured in the lungs or any other special organs the arterial blood flowing from should be much warmer than venous blood entering these organs; and also by the fact that free gases Carbonic acid & Oxygen are found dissolved in certain proportions in the blood. This however when closely examined by no means proves the point.

Temperature of Venous & Arterial Blood

Most physiologists allow that arterial blood is warmer than venous. Scudamore found it to be 1.8°. Kramer 2°.7. In animals where the facilities for more correct observation are greater Dr Davy found arterial 3°.6 warmer than venous blood. The specimens examined in these cases were probably taken from the exposed parts of the body as the limbs, where radiation is proportionably greater than in other parts, and where therefore the difference between arterial & venous would be more marked. Probably if the blood of the pulmonary artery & pulmonary vein had been examined or that from the two sides of the heart the difference would have been considerably less; suppose we estimate it as low as .5° or .°75. Knowing then that arterial blood is warmer than venous the question naturally arises why is it so? If those

Influence of the lungs in Cooling the Blood.

Changes which produce animal heat occur throughout the systems at large ~~venous~~ venous blood ought to be warmer than arterial as it comes direct from those parts the capillaries where those actions alone take place. If no actions a give rise to heat take place in the lungs then these organs ought to act as fans to cool the blood for their texture is very loose & open. The free mucus surface which they present has been estimated by Lieberkuhn to amount to 1400 square feet by others to 2800 S.F. which is far more extensive than that of the skin the only other surface from which the heat can radiate, Moreover this extensive surface is free & constantly exposed to the air by respiration whilst the skin is covered and protected by clothes to diminish radiation as much as possible. Yet the blood after thorough exposure to this extensive free surface is considerably warmer than any other part of the animal body.
The circumstance in the lungs which ought to lower the temperature of the blood passing through these organs are (1st) the entrance of cold air by respiration. The air which is normally breathed is much colder than the blood.

Pulmonary Radiation of Heat. About 400 cubic inches of this cold air is respired by an healthy adult man per-minute. And this large quantity exposed to the 1400 Sq. Feet of free Surface is raised every minute to the temperature of the blood. 2nd The amount of watery vapour exhaled is considerable, being sufficient to saturate the expired air. Probably on an average this pulmonary exhalation amounts to 350 grains per-hour. And we know that a fluid in assuming the gaseous form takes up a large quantity of heat which becomes latent. It might be argued for like reason that the absorption of Oxygen should should raise the temperature of the blood by setting free its latent heat. This may be true but we have to balance it the elimination of Carbonic acid equal in quantity. The heat thus becoming latent by the carbonic acid will exactly neutralize that set free by the oxygen.

Quantative Circulation Through the Lungs. Having determined the amount of heat generated by an adult man per-hour let us calculate how much of this is explainable on the data that we have already got viz that arterial blood is .5° - .75° Fah warmer than venous. According to Volkman (Liebegs letters on chemistry) with every stroke of the heart there is sent through the pulmonary arteries and lungs 5-6 oz of blood calculated according to the capacity of the ventricles, consequently if the pulse is 72 the quantity of 22-27 lbs circulate per-minute through the lungs. This is a high estimate. The cavity of the ventricles does not contain so large a quantity unless it is overdistended. In Kirk's Physiology it is stated to contain about 3 oz and assuming the pulse to be 69 per-minute the quantity of 13 lbs would circulate through the lungs per-minute, Magnus estimates the quantity so low as 10 lbs. If then arterial blood is .5 - .75° Fah warmer than venous and the quantity of 10-13 lbs circulate through the lungs per-minute the amount of heat thus afforded to the system would be sufficient to raise 300 - 585 lbs of blood 1° Fah per-hour.

Lungs the Source of Animal Heat.

Therefore if the amount of heat generated in the system per hour be sufficent to raise from 404–560 lbs of water one degree Fah and if the amount furnished by the lungs is sufficent to raise 300–585 lbs of Blood 1° Fah per hour and as the difference of Blood & water in their capacity for heat is not great seeing the great bulk of blood is water it follows that the lungs ~~are the~~ the great heat furnishing organs of the system. The lungs will act as furnaces in which those elements are burned the combustion of which gives rise to animal heat. The Blood passing through these organs will be warmed and afterwards carried in the course of the circulation to all parts of the system will distribute equably the heat throughout the body upon the same principle as hot water pipes are used for heating green-houses & schools. This is quite sufficent to explain the facts observed in connection with animal heat such as its local increase in inflamation &c. An increased quantity of blood circulates in the part consequently an increased warmth must be the result.

Effects of Respiration on the Blood.

Not only are the lungs the source of those changes which result in the production of heat, but I suspect of other changes as important in the composition of the blood and which are necessary in order that its properties as a nutritive fluid may remain unimpared. Heat is not an essential of organic life; it is only a circumstance which favours its proper manifestation. We see great differences in animals in the relation which they bear to this force or stimulus. The higher animals including man posses special organs the lungs to allow of the free exposure of their blood to the air. In all these animal heat is high but only a few of them as Man & his companion the Dog have the power of accomodating their bodies to great extremes of temperatures. The temperature of Reptiles & fish is little above that of the surrounding medium, while in plant life no increase is ever witnessed except in extraordinary occasions.

Importance of Respiration &c — In all these circumstances however the access of air and oxygen is necessary to the life of the individual. A short abstraction of it in the case of the higher animals although they are placed in a medium as warm as their own bodies proves very quickly fatal and surely not by the abstraction of animal heat. Reptiles may be deprived of air for a length of time without causing death, but their vital powers become lowered & a state of or similar to dormant vitality is induced. This state cannot be due to a loss of animal heat, but I rather think to an arrestment of those changes which take place in the blood during respiration, thus rendering it unfit to act as a proper nutrient and stimulus to the vital actions.

Liquor Sanguinis — Blood when examined with the microscope is seen to consist of a fluid colourless portion, the Liquor Sanguinis, and a number of slightly coloured globules, the Blood Globules. The liquor sanguinis in which these globules are suspended is not a simple fluid for on rapidly stirring blood while in the act of coagulating a quantity of a viscid stringy glutinous substance is obtained and at the same time the blood looses its power of coagulating.

Fibrin — This substance is fibrin which as it assumes the solid form enclose the blood globules in its meshes when the blood is at rest causing the phenomena of coagulation and when the blood is rapidly agitated seperating as we have seen in stringy masses.

Coagulation — This process of Coagulation can be watched taking place with the aid of a powerful & distinct microscope especially in the blood of some of the lower animals. Fine transparent molecules form which soon arrange themselves in a net-work of delicate molecular fibres. This process is somewhat similar to the formation of various Crystals under the microscope as for example Sulphate of Quina. Indeed there is no reason why we should not consider it a process of Crystallisation; for crystallisation is the seperation in a definite form of any substance previously held in solution.

the precise amount of breathing required ; in all cases it is very slight. This method although shewing well the general appearance of the blood is not to be trusted to where accurate & precise results are aimed at. Having prepared this thin layer we now examine it under the microscope for which purpose a power of 250-300 diam. is required.

Red Blood Globules — Red Blood Globules. These constituting by far the greater part of those cells found in the blood are small microscopic bodies requiring a high power to define them well. In man and all mammalia with the exception of the camelidae in which

Form — they are oval they consist of flattened circular discs of a yellowish orange tinge and having a smooth shaded aspect which appears light or dark in the centre according as they are examined in or out of focus. In well marked specimens

Elasticity — their outline is distinct and their surface & contents not granular. They are very elastic and may be made to assume various shapes by pressure on one another, especially when a thin layer of the blood is dried on a glass slide. In Fig I which represents some blood dried in this manner the globules are angular and otherwise altered

Rouleaux — in form from lateral pressure on one another. They have a great tendency to unite by their flat surfaces in masses which from their similarity to piles of shillings have been called Rouleaux. The flattened disc form can thus readily be recognised in these masses as in Fig 2. which represents a specimen of ordinary blood. The cause of the globules uniting so is I think due to the peculiar flattened disc shape and the slight motion amongst each other when the blood is drawn from the body in the same manner as coins when shaken ~~together~~ in a vessel are seen to unite in similar masses or piles. The rapid agitation of the blood in the living tissues is sufficient to overcome this tendency in the same manner as rapid agitation out of the body acts in preventing a like occurence.

Viscosity of the Globules

This tendency is also aided by the viscosity of the globules, for from repeated examination I am satisfied that their flat surfaces at least are viscid in health and in disease their margins also sometimes; for on examining blood I have frequently seen when two globules which had touched each other by their flat surfaces and were afterwards seperated by the motion of the fluid a process or tail drawn out from either globule. This process of tailing I have only seen occur in the blood of the healthy individual when part of the flat surface of both globules or the flat surface of one and the free margin of the other came in contact. In patients suffering ~~from~~ under different disease as slight Leucocythemia Anaemia &c I have however seen this phenomenon ~~th~~ take place when the globules merely touched each other and in so marked a degree, sometimes that the globules united margin to margin, formed beaded lines. In the same blood there was very generally a less tendency to form rouleaux the cause of which I think was due to an alteration in the form of the globules which were not so distinctly biconcave but rather slightly biconvex a circumstance caused by the wateriness of the blood. This view of their viscosity is supported by what we see when a thin layer of blood is dried on a slip of glass; the globules so adhere so accurately to the glass that when dried they retain their outline as completely as if each one had been seperately gummed carefully down.

Form of the Globules

The true form of the globules appears to be a biconcave disc: If they were biconvex then they could not unite to form Rouleaux whilst if they were simple discs the alterations which they present in shading according as they are examined in or out of focus provided the contents were uniform would not occur. Moreover the depression in the centre constituting the biconcavity is readily seen, when an individual globules happens to be placed on edge. The fact that they are biconcave readily explains the shaded nuclear appearance which they present. They contain no nucleus; occasionally by strong pressure one or more globules may be burst; no nucleus is seen in the extravasated content. By partial evaporation or addition of a strong saline solution curious changes occur due to endosmosis & exosmosis. In Fig 5 I have represented the change after the addition of common salt (Chloride of Sodium). The globules loose all tendency to form Rouleaux become puckered and stellate in form having very much the appearance of being composed of five or six or more smaller globules or granules. From this I think it evident that the contents are not altogether homogeneous but consisting of accumulated masses somewhat denser than the rest of the contents and representing the remains of the original development from molecules and granules. A different effect is produced by the addition of water or weak acetic acid as is seen in Fig 4 representing blood acted on by water. The globules by endosmosis become spherical & colourless diminishing at the same time slightly in their long diameter but increasing very much more in their short diameter. Some of the globules are much more difficult to act on in this way than others. The great majority of them become so transparent as to be almost invisable whilst some are dissolved altogether or burst. In none however are nuclei seen.

Change of form by Endosmosis & Exosmosis.

Many theories have been held regarding the structure of the Blood globules. Thus it was once supposed they were animalcules. This theory ~~arose~~ was propounded in those days when all free & minute organised particles discoverable by the microscope which in the slightest degree possessed the shape and appearance of cells but whose nature was otherwise unknown were supposed to be animalcules. It was therefore not at all strange that this theory arose for there are many undoubted animalcules

Theories about the Blood Globules. Animalcules

Animalcules. Which resemble closely these globules, One observer tells us that he even saw the eggs and young ones; probably some of those small molecules which occur in most specimens of blood. We however know to the contrary that they are not animalcules, They no doubt are living organised particles as much & in the same sense as the particles of our muscles; but that they are endowed with a seperate individual existence apart from the body in the sense in which this theory would necessitate is completely without foundation and contrary to all our Ideas of organised living structure.

Oil globules. Others have supposed that they were loose globules of oil floating in a fluid (Malphigii). On treating blood with ether for 24 hours a quantity of fat is obtained (Simon Chemistry Vol I page 110) but this is due partly to chemical partly to other changes and not to the fact that the globules are composed of oil. Did they consist of oil the form assumed would be a more or less perfect sphere not a flattened disc, The size also would not be so uniform, The reaction with water and acetic acid also disproves this view.

Lewenhock Theory. Lewenhock held that there were three kinds of globules. The first or primary ones were small colourless molecules; the second composed of six of the smaller ones were of a yellow colour; and the third composed of six of the yellow ones or 36 of the white were red giving the blood its peculiar colour. The doctrine arose from examining blood which had been partly or wholely dried during the process of examination. In blood partly dried the globules assume a stellate shape (Fig 5) having very much the appearance of being composed of six or so small colourless particles on allowing a drop of blood to flow over a glass slide in a thin layer and then drying it the globules sometimes accumulate in masses having the appearance of compound globules. The mind having got hold of the idea no doubt would look on the

the yellow rouleaux and individual globules in normal blood as partly broken down primary red globules especially when we consider how imperfect the instruments then were and under what disadvantages the investigations were

Doctrine of Boerhave

then carried on. The doctrine of inflamation founded on this theory by Boerhave was ingenious. Starting with the supposed fact that the globules were of three different sizes he assumed that there must be three different sets of vessels for conveighing them each set corresponding to the size of the globules which it was supposed to transmit. In this way by an error loci a globule of the larger size entering a vessel destined only to conveigh globules of a smaller size would of necessity block up that vessel and cause congestion and the other symptoms which constitute or accompany inflamation

Others Theories Nucleus

Some have supposed they were rings, a theory evidently arising from the different appearances which the globules present according as they are examined in or out of focus; others on the other hand that they were vesicles containing nuclei of different kinds; according to some the nucleus was supposed to be a loose body floating about in the cell fluid, to other that the nucleus was granular to others that it was composed of six parts to others that it contained a coiled up spiral fibre whilst others have supposed the nucleus was not free but attached to the cell wall by pole. All these theories which hold that they are vesicles containing nuclei of different kind, are disproved by the examination of normal fresh-drawn blood; by the reaction of water and acetic acid on the globules, and also by the effect of bursting and extravasation of the content. Some have supposed that they were vesicles containing air. If this was the case the clot as also the individual globules would have a much greater tendency to

Theories regarding the Blood Globules. to swim in the liquid serum than they really have. The addition of acetic acid to disolve the globules would also set free the air which is not the case. Moreover the refractive powers of air and water or blood serum are so different that these substances can with the greatest ease be detected under the microscope when mixed together.

Some others have supposed that they were solid or semi-solid fibrous bodies. Their perfect elasticity the phenomena of endosmosis and exosmosis which they present and the fact that the cell wall can occasionally be burst & the contents pressed out are strong arguments against this view.

Most if not all observers now hold that they are vesicles or cells of a biconcave discoid form and containing a semifluid viscid matter. The opinions however held regarding the chemical and physical characters of the cell wall & the cell contents and the relations which these bear to each other vary. It is a matter of dispute also whether they are to be regarded simply as cells or as the naked nuclei of cells whose cell wall has either been arrested in its development or disappeared by solution.

Size of the Blood discs. The size of the red discs in man is about 1/3000 - 1/4000 inch in diameter; on an average about 1/3300 inch diam. Their thickness is about 1/12000 inch. On the addition of water they ~~swell up~~ become spherical at the same time diminishing ~~somewhat~~ in diameter; according to my own measurements to about 1/3500 - 1/4000 inch. The colouring matter is also at the same time dissolved out.

We have already examined the several varieties of colour in the blood of different animals and the different shades of it in the arterial and venous blood of the higher animals what are the circumstances which regulate this.

Theories of About the Colour of the Blood

First then the colour resides in the cell fluid or contents not in the cell wall. This is proved by various experiments; Thus Schultz found the blood corpuscles of a salamander suffocated in Carbonic acid darker than usual; the darkness being particularly marked at certain spots giving the corpuscles a sort of chequered appearance. These spots were evidently in the cell fluid not in the cell wall. (Simon Chemistry vol II page 106). An experiment which I have performed proves

Reaction of Tartaric acid and Bicarb of Potash on Blood

this more satisfactorily. Having prepared some blood in the ordinary way I examine it with the stage of the microscope slightly inclined. To the upper edge of the specimen I add a drop of weak solution of Tartaric acid and as this spreads between the glasses and mixes with the blood the ordinary changes occur which follow the addition of a saline solution. I next add in like manner a solution of Bicarb. of potash. The blood cells now accumulate or melt into irregular masses much more intense in colour than the original globules. This is no doubt due partly to the greater accumulation of globules together but also I think to a deepening and alteration in the colouring matter, for I have seen masses comparitively colourless assume a bright red tint as the solution flowed past them, and in many of the globules washed away in the current I have frequently seen the colour very distinct indeed; so distinct is this that the change can be seen with the ~~[illegible]~~ naked eye. It is generally best marked in those globules which assume the stellate form and in these is most marked in the molecules the intermolecular spaces being comparitively clear & colourless. In many of the globules the molecules seem to be fused into different formed nuclei in which the colour is concentrated. In these the cell wall is seen to be colourless. In Fig 7 I have represented some of the more curious of those which present this nuclear appearance. I may mention that I have noticed similar nuclear appearances occasionally as in those represented after the simple addition of solution of Tartaric acid. After a time the globules loose their bright colour and become heaped in confused masses in which it is quite impossible to see distinct globules. The white corpuscles are not much altered. Crystals of Tartrate & Bitartrate of potash are formed sometimes. Those represented in fig 7 prove that the colouring matter resides in the cell contents not in the cell wall.

Colouring Matter

Again. Many Physiologists hold that the change of colour of venous blood when submitted to oxygen is due simply to a change of form of the blood discs which become brighter or arterial as they become more concave and darker or venous as they become more convex, oxygen rendering them more concave carbonic acid more convex (Lewis Physiology of Common life Page 268). This I think is quite insufficient to explain the phenomena. The power of oxygen and carbonic acid in changing the shape of the globules is very limited indeed scarcely perceptible with the microscope. The discs of venous blood are not more more convex than those of arterial; no doubt Carbonic acid may tend to make these discs more convex but the small excess of it in venous blood and the fact that venous blood is more dense therefore tending to make the globules more concave by exosmosis make it quite improbable that any alteration in form of the discs should occur. Moreover if the change in colour from venous to arterial was due to alteration in the shape of the disc it should be most marked by the addition of water & simple saline solutions which most readily alter the form of the discs by endosmosis and exosmosis. This I think no one has yet proved to be the fact. The corpuscles of venous blood contain more colouring matter than the corpuscles of arterial according to experiment of Simon on the blood of the Horse (Chemistry 2 Vol. Page 195).

Therefore from these considerations I regard the difference in colour between venous and arterial blood as due to a difference in the colouring matter held in solution in the content of the globules.

Effect of Reagents on the Blood Cells.

The effects of certain reagents on the blood cells are sometimes very strange. Thus peculiar phenomena are produced by the addition of a weak solution of common salt or carbonate of soda (say 6–8 grs to oz) containing also a little alcohol or wine (about 1/3 part or 20), The ordinary changes caused by the addition of saline solutions first take place. After a little however a granule or process may be seen attached to a few of the globules, occasionally these granules may be watched forming by a process of exudation. When they have reached a certain size varying from 1/5–1/8 the diameter of the parent globule the process of exudation still going on separates these by a kind of stalk generally also granular, These granular stalks which assume the form of tails terminated for the most part by a somewhat larger granule may extend to some length in some cases I have measured them 1/800 inch long., Sometimes there are two or three such processes ~~attac~~ attached to one globule. After a little these assume a vibratile motion so that the globules in some cases resemble somewhat spermatozoa, These tails generally break off & gradually separate into granules which present molecular movement, These changes are somewhat uncertain many globules presenting these phenomena sometimes whilst in other experiments performed seemingly in the same manner few or none of the cells will ~~present~~ ~~these~~ changes. I have represented some in Fig 8. This phenomenon is probably due to a slow process of exosmosis caused by the addition of the saline solution & the action of the weak alcohol on the exuded matter causing coagulation of it, The alcohol may also act as a stimulus to the cell wall causing slight & gradual contraction, When only weak alcohol is added the cells swell up by endosmosis;

When much salt is used the cells at once become ~~stellate~~ by exosmosis. The proportion of saline matter used is about what occurs naturally in the blood. May not this be a manifestation (~~the last~~) of vitality induced by the stimulus of the alcohol as post-mortem rigidity is the last manifestation of vitality in the dying muscle?

Effect of Acetic Acid on Blood Cells
The sudden addition of reagents modify considerably the reactions of some substances, possibly by altering and modifying the endosmotic conditions; Thus in Fig 8 I have represented an anomolous appearance caused by the sudden ~~of~~ addition of weak Acetic acid. Some curious varieties of the red globules are sometimes observed. Thus

Compound Globules
in Fig 9 I have represented some compound cells which I have occasionally seen after the addition of water to a specimen of Blood. These appear as if composed of two or more cells united, thus favouring somewhat the theory that blood cells are developed from one another by division. As however I have only seen these and that rarely after the addition of water I think they are formed by the part fusion together of two or more cells as they lie united in the rouleaux and the subsequent action of water. This explanation is supported by what has been said of the viscidity of the flat surfaces.

White Blood cells
White or Granule corpuscles of the Blood. These vary in appearance but are for the most part circular in outline and somewhat granular & refractive. They are not coloured but are more or less shaded & nebulous. Some appear smoother than others containing few granules whilst others are dark and apparently composed of agregated granules; around these latter a cell wall can sometimes be traced. They are spherical and in diameter vary from 1/2300 – 1/3300 inch. When withdrawn from the circulation many loose their spherical form by the collapsing of the cell wall and not unfrequently the cell wall bursts & scatters the contained molecules; this is a frequent source of those more or less agregated masses of molecules we so frequently see in blood examined with the microscope.

Granule Cells of the Blood.

Two varieties of the granule cell may be recognised according to Wharton Jones the coarsely and finely granular. The finely granular are often seen in a partly collapsed state shooting out irregular processes like the arms of an amoeba. On the addition of water these collapsed cells distend and the granular appearance becomes more distinct. In the coarse granule cell the granules are very dark like oil particles and frequently arranged in a peculiar manner. In these we see active molecular movements. In many cells by the addition of water distinct cellaeform nuclei are brought into view, in others I have failed to detect these. By the prolonged action of water (5-15 minutes) the cell walls burst and liberate the granules. In Fig 10 I have represented a series of these granule cells acted on by water. The reaction with weak Acetic acid is similar but I prefer that of pure water as its action is more uniform & slower affording me time to watch the changes as they occur. As Water also is the natural diluting fluid of the blood it can have no hurtful chemical properties as an acid must have however dilute it is. The granule cells are much less numerous than the red disc. The proportion varying from 1-40 to 1-2000 or 400. consistent with health; in disease they may be increased to 1 in 3 or 4. In some trials I ~~have~~ made I found them most numerous 3 or 4 hours after a full meal after which they gradually decreased in number till morning when they were reduced to a mini minimum

Free Granules

Granules & Molecules. These are small particles which occur frequently in healthy blood. In diameter they range from 1/20000 - 1/30000 inch in which respect they are similar to the granules of the white corpuscles and with which I think they are identical. The proofs for which are (1) the similarity in size and general appearance of each (2) the similarity in the reactions of either with water and acetic acid (3) The fact that both have a tendency to adhere to the glass when examined and (4) the frequent occurance of both

Free granules

in small masses as from the bursting of a granule cell, I regard them as the first stage of those materials which form the granule cells, possibly some are produced from the debris of these and other cells. These granules also are more numerous somewhat after a meal. According to some observers they occur in cases of prolonged fasting possibly from the rapid absorption of the tissues especially the adipose. I have noticed them occasionally particularly abundant in blood drawn from a spot pricked some time previous. In fig 2 & 3 I have represented some blood drawn from the same spot of the finger the latter however withdrawn 3/4 hour after the former. Probably the cause of this increase ~~of these granules~~ in this case is due to a slight degree of inflamation. On repeating this experiment I have not always got the same result. In blood partly dried and coagulated and from which most of the red coagulum has been removed they are often seen to be very numerous as I have represented in Fig 6.

Developement of the blood cells.

Developement of the blood cells. There are two different states of the blood globules in the mammalian individual that of the early embryo and that of the more fully developed adult, of the first I say nothing as I have not had the means of investigating them personally. Regarding the developement of the second set many opinions have been held. It is now however generally agreed that they have their origin in the lymphatic glandular system and in certain ductless glands especially the spleen. As supporting this view I would mention the following (a) That the lymph cells and special cells of the spleen contained in the Malpighian corpuscles are essentially similar to the white corpuscles of the blood, b that the nutritive matter of the food passes through the lymphatic system before entering the blood c that the developement of the sanguinious system is generally proportional to that of the lymphatic system and d the blood of the splenic vein is richer in white corpuscles than that of the splenic artery.

Lymph Cells — Lymph as examined with the microscope contains many molecules & granules these decrease as you ascend the thoracic duct, It also contains many lymph cells similar in all respects to the granule cells; and especially towards the termination of the thoracic duct free nuclei are found. These latter are sometimes slightly coloured. The granule corpuscles of the blood then have their origin in the lymphatic system and in those ductless glands as the spleen &c which are thus called blood glands. Possibly a few may be formed in the blood itself for we have also free molecules in that fluid.

Development of the Granule Cell. — The first stage in the process of development is the formation of molecules. This seems to take place from an alteration and deposition of albuminous matter probably around a minute oil particle a process somewhat similar to the seperation of fibrin from a fluid. These molecules however do not consist of oil at least in their more advanced stage for they have not that high refractive character which oil globules present.

The second stage is the simple granule cell. These are developed from the molecules which unite in masses around which cell walls are developed. In this stage they contain no nuclei and the cell wall is very delicate and collapses speedily when removed from the circulation. The cell wall is also very liable to rupture. In this stage many find their way into the blood. Fig 10 a & b represents two of these cells after the addition of water the delicate cell wall having burst and liberated the granules. There is no appearance of a nucleus. The further development, from this the simple non nuclear stage, to the perfect nuclear cell, can be traced in a series of globules. I have represented these in Fig 10. The cell wall becomes more defined and the granules formerly distinct and numerous disintegrate so that the cell assumes a finely molecular and hazy aspect as seen in Fig d. The cell contents again seem to rearange themselves in granules which now

Development of the Granule Cell.

however assume the form of a more or less ~~distinct~~ nucleus. This nucleus is at first coarsely and ~~[illegible]~~ irregular as if composed of more or less aggregated granules having no appearance of a ~~cell~~ limiting membrane (Figs e – i). In Fig i the nucleus is complete in form coarsely granular but apparently without a limiting membrane. As development proceeds this coarse granular stage of nucleus gradually disappears by the same process of disintegration of the granules as occurs in the earlier non nuclear stage, & the margin of the nucleus becomes more distinct apparently from the formation of the limiting membrane until as in Fig m the fully developed stage of the granule cell is reached. The nucleus is now distinctly rounded and shaded, it has lost the coarse granular aspect it presented in Fig i and the external cell wall has become delicate almost to solution. Frequently the nucleus in this stage is eccentric as represented in figure m. At this stage, the cell wall I have no doubt dissolves, and liberates the nucleus, although I have never observed this process take place. Free nuclei however are frequently observed in blood treated with water which are undistinguishable from those contained nuclei in this their perfect state. (Thus see Fig 4). It is probable I think that the free nuclei of the lymph are produced by a similar process of development. These free nuclei now undergo further changes; they clear up loose wholely their finely molecular and hazy aspect become distinctly shaded and flattened secretion in the interior of colouring matter takes place and thus gradually they assume the character of the fully developed red blood discs. These progressive changes can be traced in a series of the globules in the same manner as we have traced the development of the granule cell.

Function of the Red Blood Cell

Use of the Red globules & why flattened. The function of the blood discs seems to be that of carriers of oxygen and carbonic acid or of oxygenated materials to and fro between the lungs and the tissues of the body. This theory is supported

Function of the Red Blood Cell.

by the fact that blood globules have a greater absorbing power over Oxygen and carbonic acid than the other constituents of the blood have. Also we know that if the number of these globules be deminished as by repeated bleedings imperfect nutrition of the body follows from the inability of the remaining blood discs to carry a sufficient quantity of oxygenated material to the tissues not to an insufficiency of the other materials of the blood as these are soon restored to their normal proportions. The flattened shape of the discs would also seem to point to the same explaination as we know that rapidity of absorption is commensurate with extention of surface. Other purposes are served by this flattened disc form, more especially that of keeping the capillary vessels properly dilated and open to allow of the regular and uninterrupted passage of the blood, for although momentarily impacted in these tubes the passage of the liquor sanguinis would remain comparitively uninfluenced. From their form they will also pass readily any obstruction or contracted portion of these vessels and will also reduce the friction to a minimum.