VII.—*Miscellaneous Observations on Blood and Milk.* By JOHN DAVY, M.D.,
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1. *On the State of Combination of the Alkali in the Blood.*

The condition of the alkali in the blood—of that portion on which its alkaline reaction depends—has been the subject of much speculation, and of many experiments. ENDERLING is one of the latest inquirers who has given it his attention. After having made an analysis of the ashes of the blood, he has come to the conclusion, that the alkali in it is in combination with phosphoric acid, the former predominating in the form of the tribasic phosphate of soda.*

Granting the accuracy of ENDERLING's analytical results on the ashes, does it follow that his inference must be correct relative to the condition of the alkali in the liquid blood? It appeared to me doubtful *a priori*; and the doubt I entertained was confirmed by experiment. The doubt arose from considering the tendency of the alkaline carbonates, when strongly heated with charcoal, to be reduced; and when heated with phosphate of lime in excess, to exchange their carbonic acid for a portion of the phosphoric—the acid gas of course escaping, and compounds of lime and alkali remaining, each with excess of base. In accordance with this, when I have added carbonated alkali to the coal obtained from blood, and have reduced the coal to ashes, I have not been able to detect in the lixivium obtained from them any trace of carbonic acid. Moreover, I find that the carbonate of soda is liable to loss when heated strongly, exposed to the air; and, consequently, when it exists in a small quantity in a bulky coal, the whole of it may be dissipated—carried over much in the same manner as boracic acid is in combination with water as a hydrate, when it is subjected to heat.

If ENDERLING's view were correct, the blood, after having been acted on by the air-pump, ought not in its fresh state to yield any carbonic acid on the addition of an acid. This is the experiment alluded to, which confirmed my doubt. I find that blood or its serum, after having been so acted on until perfectly tranquil, has effervesced strongly, when mixed either with dilute sulphuric or muriatic acid purged of air, or with a solution of cream of tartar. And, in accordance with this, I have also found that serum, after having been subjected to the air-pump, gives on coagulation, by immersion in boiling water, a different result, whether

* See Mr PAGER's Report on the Progress of Human Anatomy and Physiology, in the British and Foreign Medical Review for January 1845.

immersed unmixed, or after admixture with a little acid. In the one instance no air bubbles are disengaged ; in the other very many.

Some years ago, when engaged in experiments on the blood, especially in relation to the present question—the condition of the alkali in it—I noticed the effect of cream of tartar in expelling carbonic acid, and that both from venous and arterial blood, and from serum ; an effect which, with other considerations, induced me then to conclude, that the soda in the blood exists in the form of the sesqui-carbonate ; an inference which appears to me still to be most in harmony with the facts.*

In opposition to this view, perhaps, it may be said, that farther proof of its correctness ought to be afforded by the effect of a solution of muriate of lime on the serum,—that, if the latter contain the alkali as stated, a precipitate of carbonate of lime ought to be the result. This experiment I have tried, with the aid of the air-pump, sometimes with a doubtful result, sometimes with a negative one, especially in the instance of serum from venous blood. But in these instances I have also found the result the same, even on the addition of a portion of sesqui-carbonate of soda, as much as $\cdot 2$ of a grain to 316 grs. of serum—a quantity of the alkali, which, when dissolved in the same bulk of water, is more than sufficient to give a precipitate with muriate of lime. Would not this seem to indicate that in the blood and its serum the carbonated alkali is in a peculiar state of combination with the animal matter ; and the same remark is applicable to the phosphates or their elements.

The trials referred to have been made on the blood and serum of the ox and sheep, at a favourable time of the year, during the winter season, when the temperature of the air has been little above the freezing point.

2. *On the Viscid Quality of the Blood Corpuscles.*

That the corpuscles of the venous blood of the mammalia, when quite fresh, and in the act of coagulating, collect together in piles, as it were by a kind of attraction, is well known. The viscid, adhesive quality, I am about to notice, is distinct from this, and, indeed, is best seen when the aggregation in piles ceases to be witnessed, as in cruor, procured by breaking up the crassamentum, and separating the fibrin by straining through linen.

The cruor thus obtained is essentially a semifluid, the particles loosely adhering forming a mass in some respects not unlike honey or molasses. I shall notice some appearances connected with and indicating the condition referred to.

When poured into a fluid, such as water or serum, it rapidly falls to the bot-

* Physiological and Anatomical Researches, ii. p. 152.

tom ; and, in the instance of serum, if not agitated, remains as a connected mass. If now a glass rod be put into it, and withdrawn through the supernatant serum, it will come out not sensibly coloured by the red particles ; the surface of the cruor round the rod will be seen to be raised a little in the act from adhering to it, and then to return to its former level, shewing that the corpuscles adhered to each other in the mass more strongly than to the glass : and, if the serum through which the rod has been drawn is examined with the microscope, a small number only of blood corpuscles will be detected in it.

If, instead of allowing the cruor to remain undisturbed, it be broken up by agitation with the serum, it will be found to be divided into clusters of corpuscles and detached particles. When one of these clusters is placed under the microscope, between two plates of glass, the adhering corpuscles forming the group are seen to be attached, not by their broad or concave surfaces, as in the instance of aggregation by piles, but by their narrow rims. Now, if graduated pressure be employed, so as to break up the cluster, just before separating, the adhering corpuscles will be seen to be elongated, as if drawn out almost to a fibre, and yet when detached, the adhesion being overcome, recovering, and that suddenly, their circular form : and, on relaxing the pressure, many of them will be seen to reunite, sticking to each other even when in motion.

This adhesive quality of the blood corpuscles is exercised, not only on each other, but also on other substances, though, perhaps, in a less degree. Proof of this is afforded when cruor has been allowed to remain, even but a short time, in a glass tube, or any other vessel. The portion in contact with the bottom of the tube is found to adhere to it, and is not easily detached ; whilst any that may adhere to the sides commonly appears in streaks, the blood corpuscles being attached to each other, and so producing a linear arrangement.

This viscid property of the blood corpuscles must, I apprehend, be considered as specially belonging to them, quite distinct from the fibrin, which appears to be viscid only in its transition state, in the act of coagulating,—previously even more liquid than serum attenuating the blood, and subsequently, as soon as coagulated, constituting the firmest and the cementing part of the crassamentum. The blood corpuscles, as regards this quality of viscosity, are far more constant ; it belongs to them when fresh, probably when circulating in the vessels,—it is exhibited in them long after removal from the living body, and is not even lost with incipient putrefaction, and, connected with that, the change of the particles to a globular form.

3. *On the Tendency of Fibrin in Coagulating to a certain arrangement of its Particles.*

Amongst the many remarkable properties of coagulable lymph, I am not aware that a tendency of its particles to arrange themselves in a certain manner out of the body, representing, as it were, what takes place in the body in the process of growth and of reparation, has hitherto come under observation, or, at least, has been the subject of commentary.

A striking instance of the kind I have witnessed in the buffy coat. When the buffy coat is well marked, as in cases of acute rheumatism, when it is thick and cupped, the blood abstracted having been slow in coagulating, it is easily detached from the soft crassamentum; and this is best done under water. Thus separated, it may be described as a fibrous mass loaded with serum, enveloped in a pellicle or membrane, performing the part of a sac. This pellicle, or containing membrane, is very thin, yet of considerable strength, and with care may be dissected off, especially after maceration in water for two or three days, at a low temperature. It is very like a serous membrane, both as seen with the naked eye, and under the microscope. Under the latter, it bears a strong resemblance to the arachnoid, appears as a tissue of extreme delicacy; hyoloid, without any visible pores or fibres, with a few particles like blood corpuscles, or their remains (according to the method used of separating it), scattered through it. When a force is applied to it, it breaks less readily in one direction than another; and exhibits, when drawn in one direction, more elasticity than in the opposite. When the blood, as is usual, has been received in a circular vessel, and the buffy coat, of course, is of the same form, tearing the membrane with a forceps towards the margin, shreds of it, several lines in length, are easily detached in a line from the centre to the circumference, but not in a line at right angles to this; and in the same direction small portions of the membrane exhibit considerable elasticity, which they do not in the opposite direction.

I may mention another example, also well marked. If the blood, in the act of coagulating, is stirred with a glass rod, or a wooden skewer, or the like, the fibrin, as it is well known, will adhere, with which blood corpuscles will be mixed. The adhering clot, consisting of the two, the fibrin in excess, when pulled off, which it easily is, exhibits a canal with a smooth inner surface. If it be well washed to deprive it of colouring matter, and slit open, it will be found to bear a close resemblance to an artery, especially to its middle coat, being composed of fibres arranged seemingly transversely, that is, at right angles to the axis of the tube. This is to be inferred from the effect of a force applied. If applied in that direction, transverse shreds pretty readily separate; but if in the opposite direction, using a forceps, only small bits. And, in the one, the transverse direction,

the tube is far more elastic than the other, after the manner of the middle arterial coat.

Other instances might be given, tending to shew the same disposition on the part of coagulable lymph to a certain regular arrangement of its parts, as it were, of a *nisus formativus*, in the act of coagulation. In examining the buffy coat, or the fibrinous masses which are so commonly met with after death in the right cavities of the heart, it is not uncommon to find in them, when divided, cavities containing serum resembling cysts. And in the ventricles of the heart, and the aorta and the principal veins, especially the iliac and femoral, fibrinous concretions, as it is well known, are often found after death from lingering diseases, in which a puriloid matter is contained, as in a sac,—a matter which has been imitated by Mr GULLIVER, by the coction of lymph, at about the temperature of the human body, and which, previous to his experiments, had been considered as pus, and, erroneously, as the product of inflammation.

I would ask in conclusion, is not this disposition of coagulable lymph called into play in other occasions during life, and may it not serve to explain certain appearances which are commonly accounted for in a different manner, such as the cysts which so rapidly form in the instance of aneurisms, the consequence of wounds, and the lining membrane of the sacs of false aneurisms, which is hardly in appearance distinguishable from the inner coat of the artery with which it is continuous?

4. *On the Effect of Serum in promoting the Coagulation of Milk.*

There is a marked difference, as is well known, between the albuminous part of the serum of the blood and that of milk,—ordinary cow's milk,—viz., that, whilst the former is coagulated by a temperature below the boiling point of water, the latter, in its fresh state, is not so affected, even by ebullition, but, on the contrary, has its natural tendency to coagulate, connected with the absorption of oxygen and the formation of an acid, retarded. *A priori*, perhaps, it would hardly be expected, as regards the property of coagulation, that the one fluid mixed with the other would have any material effect. But that it is not so, I have found on trial. Milk, I find, when mixed with serum in certain proportions, is coagulated by heat. I shall notice some results obtained, using mixtures of the serum of the blood of the sheep, which coagulated at about 170° Fah., and cow's milk.

Equal parts of the two remained liquid at 170°, and coagulated about 175°. The coagulum was of an opaque white, very little softer than the coagulum of the serum alone. Mixed with water it did not render it milky; and the watery infusion was not rendered turbid by acetic acid, and only in a very slight degree by the nitric acid.

One part of serum and three parts of milk in mixture, coagulated at about 190°, forming a soft tremulous mass, which, by boiling, was rendered firmer. Broken up and mixed with water and filtered, the fluid had the properties of weak whey, and was not rendered turbid by acetic acid.

A mixture of 1 part of serum and 4 of milk did not coagulate after several minutes boiling; but, keeping it on the fire, in about a quarter of an hour the effect was produced. The coagulum formed was very soft. Mixed with water, it rendered the water turbid at first; but after a while, the finer particles subsiding, left the water clear, and it was not affected by acetic acid.

A mixture of 1 part of serum and 5 of milk, immersed in boiling water, at least an hour, was found coagulated. The coagulum was of the consistence of very soft custard. A like result was obtained, using a mixture of 1 of serum and 7 parts of milk.

Lastly, a mixture of 1 part of serum and 10 of milk was liquid after more than an hour's boiling; but after about three hours' boiling, when a portion of its water was expelled, it was found coagulated.

As in these instances, the serum promotes the coagulation of the milk, so also the latter may be considered as favouring the coagulation of the former; that is, viewing the milk as a diluent of the serum, having the effect of removing further apart its albuminous particles, and comparing it as a diluent with water; two parts of which, I find, with one of serum, prevent the coagulation of the latter, even at the boiling point, and thus heated, for many minutes.

The property exhibited in the foregoing experiments is to be witnessed in many other instances; it may be, probably, in every instance in which liquid casein and albumen are heated together in certain proportions. Mixtures of white of egg and milk exhibit it even more strongly than serum and milk. With equal parts of milk and white of egg, a firm coagulum is formed on boiling, the fluid exuding from which is almost transparent, and is not sensibly affected either by acetic acid or by the nitric acid. With 1 of white of egg and 5 of milk a coagulum is formed of moderate consistence; and with 1 of the former and 10 of the latter a very soft coagulum, after immersion in boiling water for about a quarter of an hour. I give these results, because, in no work on chemistry, with which I am acquainted, have I met with any account of the effect of white of egg on milk, even in culinary processes. Using the yolk of the egg in place of the white, the effect on milk has been, as might be expected, very similar; the chief difference in the coagulum being, that it has been somewhat softer.

From similarity of composition, it might be inferred that the roe of fish, mixed and boiled with milk, would have the effect of coagulating it; and this, I find, is the case. The only other animal substance I have tried has been muscle; it, triturated and boiled with milk, did not coagulate it; the muscular fibres, it may be noticed, were found collected together in a mass in a singular manner.

Extending the analogy to vegetable substances, it seemed likely that all those which contain albuminous matter, similar to casein, may be affected when boiled with serum or white of egg, in the same manner as milk ; and the result of a trial, with a mixture of serum and a strong emulsion of sweet almonds, has confirmed the inference. After boiling, the fluid expressed from the coagulum was not precipitated by acetic acid.

As the serum of the blood of even the same species of animal is liable to slight variations, affecting the degree of temperature at which it coagulates, and, as milk is subject to some variation, in regard to the same quality, as indicated by the effect of rennet—a variation, perhaps, most of all depending on season of the year, and the time that the milk has been exposed to the atmosphere—should the experiments I have described be repeated, some little difference in the results may perhaps be perceived, depending on the circumstances just referred to.

The action of one animal fluid on another, and those so similar as regards their albuminous part, as milk and serum, offers curious matter for speculation, and may be deserving of special attention, not only in relation to the culinary art, and processes of manufacture in which vegetable juices are concerned, but also in connexion with physiology. It may be found that the principle of rennet exists in the blood, and that the analogous power of both, as regards the coagulation of milk, depends on the same cause ; and, if so, then it may be farther deserving of attention, in connexion with pathology and processes of morbid softening.

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