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XXXIII. *On the Degree of Heat which coagulates the Lymph, and the Serum of the Blood; with an Enquiry into the Cauſes of the inflammatory Cruſt, or* Size, *as it is called*: *By* the ſame.

Read Nov. 15. 1770.

IN the preceding paper, beſides mentioning ſome circumſtances which promote the ſeparation of the blood, and which affect its colour, I have enquired into the cauſes to which its coagulation when taken from the veins is owing, and the manner in which it coagulates when at reſt in the body. I ſhall now proceed to lay before this learned Society, an account of ſome other experiments which I have made upon this fluid.

Beſides being coagulated when expoſed to the air, the coagulable lymph, as well as the *ſerum*, is known to be fixed by heat; but the degree of heat has not, I think, been determined. It has been ſuppoſed to require a degree of heat almoſt equal to that which coagulates the *ſerum* *; but a much leſs is neceſſary, as will appear from the following experiments.

* Vide Traité du Cœur. T. ii. p. 93. Schwenk, Hæmatolog. p. 138.

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Experiment VII.

Having found, from a number of trials, that blood, kept fluid by being mixed with neutral ſalts, had its lymph coagulated by a heat of 125° of Fahrenheit's thermometer, I ſuppoſed that the degree neceſſary for fixing it in its natural ſtate could not be very different from this. I therefore prepared a lamp-furnace with a ſmall veſſel of water upon it; this water was heated to 125°; and then laying bare the jugular vein of a living dog, I tied it properly, cut a piece of it out, and put it into this water: after eleven minutes, I took out the vein, opened it, and found the blood entirely coagulated; thence I concluded, that 125°, or leſs, was ſufficient to coagulate the blood of a dog. It may be neceſſary to obſerve here, that the part coagulated was only the lymph; for the *ſerum* requires a much greater heat to fix it, that is heat of 160°, as will appear hereafter.

Experiment VIII.

The ſame experiment was repeated in ſuch a manner, that the heat was never higher than 120° and an half; and I found, on opening the vein at the end of eleven minutes, that the lymph was entirely coagulated, even in this heat.

Experiment IX.

I next repeated the experiment, ſo that the heat was never higher than 114°, and was commonly at

that degree during the eleven minutes, at the end of which time the vein being opened, the blood was found to be fluid, and in a few minutes after, being laid open to the air, it coagulated as it uſually does. Now as the blood, in the laſt experiment but one, was coagulated, when the heat had never riſen above 120° and an half; and in this experiment was fluid, though it had been expoſed to a heat of 114°; we may therefore conclude, that the coagulable lymph in the blood of a dog, in health, is fixed in a degree of heat between 114° and 120 ½ of Fahrenheit's thermometer.

As to the degree of heat at which the lymph in human blood coagulates, I have not yet had an opportunity of trying it in a more ſatisfactory way, than with the mixture with Glauber's ſalt, in which ſtate it coagulates at 125°. As we find that the human blood and that of a dog jelly nearly in the ſame time, when expoſed to the air, I think it is probable, that the preciſe degree of heat at which the lymph of the human blood coagulates, is between 114° and 120° ½. I have thought of making the experiment on the umbilical cord of a recent *placenta*, which is the moſt likely way of coming at the truth.

The degree of heat, at which the *ſerum* of the blood (which ſhould not be confounded with the lymph) coagulates, is generally ſaid to be 150°; but from the trials I have made, I am inclined to believe it requires a greater heat to fix it. My experiments were made in the following manner.

Experiment X.

I took a wide-mouthed phial, containing *ſerum*, and placed a thermometer in it, and then put it into water which was kept warm by a lamp underneath; and, in making this experiment with as much accuracy as I could, I found the heat required was 160°, which is above forty degrees more than is neceſſary for the coagulation of the lymph.

As the blood is coagulable by heat, and as the heat of an animal body is increaſed in fevers, it has been ſuppoſed that the blood might be coagulated by the animal heat, even whilſt it is circulating in the blood-veſſels; but there is little foundation for ſuch a ſuppoſition, ſince the animal heat is naturally only 98 or 100°, and in the moſt ardent fever is not raiſed above 112°.

I ſhall next proceed to enquire into the formation of the inflammatory cruſt, or *ſize*, as it is called.

This remarkable appearance is frequently met with in inflammatory diſorders, and is formed by the coagulable lymph's being fixed, or coagulated, after the red particles have ſubſided. It has indeed been ſuppoſed to be formed from the *ſerum* of the blood; and an excellent writer on this ſubject ſeems in doubt to which it ſhould be attributed. But that it is formed by the coagulable lymph alone, after the red particles have ſubſided, appears from the following experiments.

Experiment XI.

In the month of June, when the thermometer in the ſhade ſtood at 67°, I bled a man who had laboured

boured under a *phthiſis pulmonalis* for ſome months, and at that time complained of a pain in his ſide. The blood, though it came out in a ſmall ſtream, yet flowed with ſuch velocity, that it ſoon filled the baſon. After tying up his arm, I attended to the blood, and obſerved that the ſurface became tranſparent, and that the tranſparency gradually extended deeper and deeper, the blood being ſtill fluid. That the coagulation firſt began on the ſurface, where it was in contact with the air, and formed a thin pellicle; this I removed, and obſerved it was ſoon ſucceeded by a ſecond. I then took up a part of the clear liquor with a wet tea-ſpoon, and put it into a phial with an equal quantity of water; a ſecond portion I kept in the tea-ſpoon; and I found afterwards that they both jellied or coagulated, as did the ſurface of the *craſſamentum*, making a thick cruſt. On preſſing with my finger that portion which was in the tea-ſpoon, I found it contained a little *ſerum*.

From this experiment it is evident, that the ſubſtance which formed the ſize was fluid after it was taken from the vein, and coagulated when expoſed to the air; and as this is a property of the coagulable lymph alone, and not of the *ſerum*, there can be no doubt that the cruſt was formed of the former, and not of the latter.

The following experiment, made on the blood, without expoſing it to the air, likewiſe proves the ſame fact.

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EXPERIMENT XII.

Immediately after killing a dog, I tied up his jugular veins near the *ſternum*, and hung his head over the edge of the table, ſo that the parts of the veins where the ligatures were might be higher than his head. I looked at the veins from time to time, and obſerved that they became tranſparent at their uppermoſt part, the red particles ſubſiding. I then made a ligature upon one vein, ſo as to divide the tranſparent from the red part of the blood; and, opening the vein, I let out the tranſparent part, which was ſtill fluid, but coagulated ſoon after. On preſſing the *coagulum*, it was found to contain a little *ſerum*. The other vein I did not open till after the blood was congealed, and then I found the upper part of the *coagulum* whitiſh like the cruſt in pleuritic blood *.

It has been a very generally received, opinion that inflammation thickens the blood, and makes it more ready to coagulate. Nay, ſome have gone ſo far as to ſay, that in thoſe diſorders where the inflammatory cruſt is ſeen, the blood is almoſt coagulated

* This is not the only animal that ſeemed to be in health, whoſe blood had a cruſt; I have ſeen it in others: whence I at firſt ſuſpected that merely keeping the blood fluid for a little time was ſufficient to produce this appearance; but I altered my opinion, on ſeeing, that in the greateſt number of animals it did not occur; nor is it commonly met with in the hearts of thoſe that die a violent death, though the blood remains longer fluid in ſuch caſes than it does in the baſon where a ſize appears.

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even before it is let out of the vein. Now I am perſuaded from experiment, that the coutrary of this is true; or that inflammation, inſtead of increaſing the diſpoſition of the blood to coagulate, really leſſens it; and inſtead of thickening the blood, really thins it; at leaſt, that part which forms the cruſt, viz. the coagulable lymph.

In the firſt place, that inflammation really leſſens the diſpoſition to coagulate, will appear evident to every one who attends to the jellying of ſuch blood as has a cruſt. For in all thoſe caſes the blood will be found to be longer in congealing, than it is commonly. To this opinion, I was firſt led by attending to the phthiſical patient's blood above-mentioned; but I have ſince made a compariſon, which ſeems to prove the fact. For, from a variety of experiments made on the blood of perſons nearly in health, or at leaſt who had no inflammatory complaints, and no cruſt on their blood, I found that the blood, after being taken from a vein, began to jelly in about three minutes and an half. The firſt appearance of coagulation is a thin film on the ſurface near the air-bubbles, or near the edge of the baſon; this film ſpreads over the ſurface, and thickens gradually till the whole is jellied, which is in about ſeven minutes after the opening of the vein; and in about ten or eleven the whole is ſo firm, that, if the cake be cut, the gaſhes are immediately filled up by the *ſerum*, which now begins to ſeparate from the *craſſamentum*. But in thoſe perſons whoſe blood has an inflammatory cruſt, the coagulation is much later; and in general, I believe, is lateſt in

thoſe caſes where the cruſt is thickeſt, and *vice verſa*. The following experiments ſeem to prove this.

EXPERIMENT XIII.

I bled a woman who was ſeven months gone with child, and the blood was received into a baſon. In five minutes after the vein was opened, a film firſt appeared; but this ſpread ſo ſlowly, that in ten minutes it did not cover the whole ſurface: in fifteen minutes it had nearly ſpread over the ſurface; but the reſt of the blood was quite fluid, at leaſt for ſome depth, and even in half an hour it was not ſo firmly jellied as it was afterwards. In this caſe there was a very thick and ſtrong cruſt or ſize.

EXPERIMENT XIV.

Having bled a perſon with a violent rheumatic pain in his breaſt, the blood was received into three tea-cups, and each of them had afterwards a cruſt. In the firſt I obſerved the progreſs of the coagulation, as follows. The beginning of the coagulation was not marked, but at the end of half an hour the film was not thicker than common writing-paper; and this being removed, a little of the clear lymph was taken up with a wet tea-ſpoon, put into a clean cup, and was twenty minutes more in coagulating. Even at the end of an hour and an half, the whole of the blood was not jellied; for at this time I removed the film or pellicle, and took up a ſecond portion of clear lymph with a ſpoon, and put it into a tea-cup, where it jellied afterwards,

terwards; though this jelly was not indeed quite ſo firm as the *craſſamentum* itſelf.

Experiment XV.

A woman, with a ſlight inflammation in her throat, had eight ounces of blood taken from her arm; the blood was received into a baſon, and the bleeding finiſhed in four minutes and three quarters, when a film was begun to be formed near the air-bubbles; in ſeven minutes a tranſparent ſize appeared over a conſiderable part of the ſurface which was quite fluid, whilſt the reſt of the blood was coagulating, there being now a very diſtinct red cruſt over the reſt of the ſurface.

Now, from comparing theſe experiments with what has been obſerved of the coagulation of the blood, where there is no inflammatory cruſt or ſize, is it not evident that the blood remains longer fluid after being expoſed to the air, and has leſs diſpoſition to coagulate, in thoſe caſes where there is a ſize, than where there is none? for in thoſe caſes where there was none it was found to coagulate completely in ſeven minutes; but in one of the others, where the ſize was very thick, it was found not to coagulate completely in leſs than an hour and an half?

The effect that inflammation has in leſſening the lymph's diſpoſition to coagulate, is likewiſe plain from the following experiment, where the blood in the heart of a dead animal ſeems to have coagulated very ſlowly.

EXPERIMENT XVI.

A dog was killed, eight hours after receiving a large wound in his neck, The wound had during this time inflamed conſiderably. Upon opening him next morning, when he had been dead thirteen hours, a large whitiſh *polypus* was found in the right ventricle of his heart; under this was a little blood ſtill fluid, which being taken up with a teaſpoon, was found to coagulate ſoon after being expoſed to the air.

It may be proper to obſerve here, that in the hearts of animals which had died without any inflammation, I have found the blood entirely coagulated long before this time. And that from opening them at different times, I find it coagulates in their hearts after death, in the ſame gradual manner that it does in their veins, when its motion is ſtopt by ligatures; as related pag. 380.

In the next place, that the blood is really attenuated in inflammatory diſorders, where the whitiſh cruſt or ſize appears, is probable from the following circumſtances; firſt, it even ſeems thinner to the eye; 2dly, the red particles, or globules ſubſide ſooner in ſuch blood, than in that of an animal in health: this ſeems proved by obſerving that in the above-mentioned experiments, where the blood was at reſt in the veins, it was not covered with a cruſt, except in one or two inſtances, though in all thoſe caſes it remained longer fluid than the blood commonly does in a baſon where the cruſt appears. And again, the blood in the heart of an animal that dies a vio-

lent death, is not generally covered with a white cruſt, notwithſtanding it is ſo late in being congealed. Theſe circumſtances ſhew, that ſomething more than merely a leſſened diſpoſition to coagulate is neceſſary for the forming of the cruſt or ſize. 3dly, The globules more readily ſubſide in inflammatory caſes, from the ſurface of the whole maſs of blood, than they will afterwards do from the ſurface of a mixture with the *ſerum* alone, of which the following experiments are a proof; but, before I relate them, let me obſerve, that they were made with a view to diſcover, whether that remarkable appearance, the inflammatory cruſt, could be owing to any other cauſe than to the coagulable lymph's being attenuated, and having its diſpoſition to coagulation leſſened: and as the ſame appearance might be ſuſpected to ariſe from an increaſed ſpecific gravity in the red particles, or from the *ſerum* alone being attenuated, I endeavoured to decide the queſtion by the following experiments.

EXPERIMENT XVII.

Into a phial, marked A, I put an ounce of the *ſerum* of the blood of a perſon, whoſe *craſſamentum* had an inflammatory cruſt.

Into another, marked B, I poured an ounce of the *ſerum* of a perſon whoſe blood had no cruſt; then to each of theſe, I added a tea-ſpoonful of *ſerum*, loaded with the red particles of a perſon whoſe blood had no inflammatory cruſt or *buff*. In attending to them, I could not obſerve that the red particles ſubſided at all, ſooner in the *ſerum* of the blood

blood that had a cruſt, than they did in the *ſerum* of that blood which had no cruſt. Thence I am to conclude, that the *ſerum* is not attenuated in thoſe caſes where the inflammatory cruſt appears.

To ſee whether the ſpecific gravity of the red globules was increaſed, I tried as follows.

Experiment XVIII.

I poured into a phial C a portion of the *ſerum* of the blood which had no cruſt; and likewiſe into another D a ſecond portion of the ſame *ſerum*. I then added to C a tea-ſpoonful of the ſame *ſerum*, loaded with red particles from the blood which had an inflammatory cruſt. And into D I poured a tea-ſpoonful of the ſame *ſerum*, loaded with the globules of blood which had no cruſt. In viewing theſe, I could not obſerve that the globules of the blood which had an inflammatory cruſt ſubſided at all, ſooner than thoſe of the blood which had none; thence I am inclined to conclude, that the ſpecific gravity of the red particles, or globules as they are called, is not increaſed in thoſe caſes where the cruſt appears. And, therefore, ſince that inflammatory cruſt or ſize, ſeems neither owing to the *ſerum's* being attenuated, nor to an increaſed ſpecific gravity in the red particles, it is probably intirely owing to a change in the coagulable lymph. And, what ſeems farther to confirm this inference, in none of theſe experiments did the red particles ſubſide from the ſurface of the *ſerum* in 20 minutes, though where the cruſt appears, they ſubſide from the ſurface of the whole maſs of blood in half that time; ſo that the

whole maſs of blood ſeems to be thinner than the *ſerum* alone; or, the coagulable lymph ſeems to be ſo much attenuated in theſe caſes, as even to dilute the *ſerum*, which at firſt ſight appears a paradox.

May we not, therefore, now conclude, that in thoſe caſes where the inflammatory cruſt appears, the coagulable lymph becomes thinner, and its diſpoſition to coagulation is leſſened; both of which circumſtances contribute to the ſubſiding of the red globules before the ſurface of the blood is coagulated, and thence give riſe to this appearance, called the inflammatory cruſt or ſize *?

How contrary to the concluſion, which theſe experiments lead us to, are the opinions of ſome medical writers on this ſubject! How frequently do we find it ſaid, that the blood is thicker in inflammatory diſorders, where that appearance occurs; and that a large orifice is neceſſary to let out the vitiated blood! That a large orifice is preferable to a ſmall one in many caſes, where ſuch blood is found, I believe is a truth: but that its advantages are owing to its letting out the thickened blood, ſeems improbable from what we have ſeen in the experiments above related: they are perhaps nearer the truth, who attribute it to the ſuddenneſs of the evacuation.

It may be proper to obſerve here, that this ſize or whitiſh cruſt, is not a certain ſign of inflamma-

* This remarkable appearance might indeed be accounted for, by ſuppoſing that the lymph had aſcended to the ſurface of the blood in thoſe caſes; but this is improbable, from conſidering, that, in its coagulated ſtate, it is of greater ſpecific gravity than the ſerum, and ſinks in it.

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tion; it is often met with where there ſeems to be no ſuch diſeaſe, in particular in the blood of pregnant women. And we may likewiſe obſerve with Sydenham, that even in thoſe caſes where the blood has a diſpoſition to form a white cruſt, yet if it trickle ſlowly from the vein, this *ſize* will not appear; for in ſuch caſes, probably, the blood begins to coagulate before the whole has done flowing, ſo that the agitation prevents the red particles from ſubſiding from the ſurface. There are therefore ſeveral circumſtances to be taken into the account, before we judge, from the preſence or want of this *ſize*, whether there is, or is, not an inflammation.

The whitiſh cruſt differs much in denſity in different caſes; in ſome it is extremely denſe, in others it is ſpongy or cellular, and contains a quantity of *ſerum* in its cells.

XXXIV. *Further*