by which these rays are carried outside of the object-glass of the telescope or the eye of the observer. These deviations are produced by extraordinary refractions or irregularities in layers of air condensed or rarified, placed at great distance from the observer, and at the precise spot where by atmospheric dispersion the rays of the different colours directed by the object-glass are separated from one another, so as to be only partly contained in the irregularly refracting layers of air. The most important result of M. Respighi's observations is this:—the layers of heterogeneous air are not reached by the luminous rays of different colours by means of the internal movement of atmospheric masses, but by their general movement caused by the rotation of the earth; which shows that the rotation of the earth is one of the principal elements in causing the twinkling of the stars. M. Respighi next described a very ingenious zenith telescope by means of which he can obtain the zenith distance of stars in their passage across the meridian.

In the Section of Geography, Political Economy and Statistics, various papers were read on methods of education.

The first session of the Association lasted eight full days, during which excursions were made to Arcachon, and to the Troglodyte Caves of Eyzies. On the condition and civilisation of the people whose remains they contain, M. Broca gave a very interesting lecture, in which he concluded that these men were savages, but in a state of partial civilisation, having at their disposal abundant food, and consequently leisure, applying themselves to the arts, and already exhibiting the perfectibility of the race. Another excursion was made to the Pointe de Grave, and one, which lasted three days, to the Industrial and Scientific establishment of Landes as far as Bidassoa. The Monday, Wednesday, Thursday, and Friday were devoted to *séances*, the morning for the sections, and the afternoons for general meetings. These public meetings were well attended, especially the evening lectures of MM. Broca and Cornu, who had audiences numbering about 800. Much interest was also manifested in the narratives of MM. Janssen and Respighi, who recounted the results of their researches into the constitution of the sun, and of their visit to India last year.

The reports of the Congress speak in lavish terms of the hospitality and considerateness in all respects of the Bordelais, whose city seems to be one of the foremost in France in respect of educational and scientific institutions. There can be no doubt about the success on the whole of the first meeting of the French Association; and we only hope that by the time it re-assembles at Lyons next year it will have advanced to the same ratio as it has done from its foundation till now, and that ere very long it will have taken as firm root as a recognised and universally beneficial French institution, as the British Association has done among ourselves.

ON PULSE FREQUENCY AND THE FORCES WHICH VARY IT*

THE circulation of the blood is an uniform circulation, the pulsations being neglected, and a uniform circulation is one in which the quantity of fluid flowing through all segments of the circulating system is the same; otherwise there would be a tendency for the fluid to accumulate at certain points, which is contrary to the premises.

To arrive at precise conclusions respecting the circulation there are two points which must be considered—1st., The laws which regulate the flow of fluids through capillary tubes. 2nd., The variations in the capacity of the circulating system under different pressures. These will be considered separately. Poiseuille found that the flow of fluids through capillary tubes varies directly as the pressure and as the fourth power of the diameter of the tubes. The author has verified the former of these results on the vessels of the animal system by a different method. Respecting the capacity of the arteries and ventricles under different blood pressures, it is evident that the capacity of the former must depend on the pressure only, for they are simple elastic tubes, and must be more capacious under high than under low pressures; reasons are given below for a more precise statement of this relation. To maintain a uniform circulation with a pulsating motor, like the heart, it is evident from the above considerations that variations in the resistance at the small arteries must produce variations in pulse-rate; and that unless the capacity of the arteries and heart vary directly as the pressure, variations in blood pressure must be also attended with change in pulse frequency. That the capacity of the ventricles is dependent on the arterial blood pressure can be proved by the varied amount of opening up of the ventricular cavities which follows different fluid pressures in the coronary arteries.

Next, the different forces which vary the pulse-rate must be considered. It can be shown that any change in the resistance to the flow of blood through the capillaries varies the pulse-rate, increased resistance rendering the pulse slower and the reverse. As instances of these effects may be given, the pulse-slowing effects of stripping in a cold air, of a cold bath, and of compression of large arteries; the pulse-quickening effects of a hot bath, whether air or water. Numerous experiments by the author prove that the effect of copious blood-letting is not to modify the pulse-rate at all, thus showing that the law given by Marey respecting pulse frequency is not correctly based. The above points, namely the law of Poiseuille, the dependence of the capacity of the arteries and ventricles on the pressure of the blood, the dependence of the pulse-rate on the peripheral resistance and its non-dependence on the blood pressure, can all be correlated by only one theory, namely, that the heart always re-commences to beat when the tension or pressure in the arteries has fallen at invariable proportions, which also assumes that the capacity of the heart and arteries varies directly as the pressure. The facts that the arteries are generally empty after death, and that the cavity of the heart is sometimes found to be obliterated on *rigor mortis*, show that absence of pressure and capacity go together.

This theory explains the known peculiarities in pulse rate attending change in position, by showing that while standing all the pressure of the body weight is borne by non-compressible rigid tissues and so the circulation is normal, but while lying, the soft parts are compressed and resistance introduced into the circulation, reducing the rapidity of tension-fall, and therefore the frequency of the pulse; an intermediate condition attends the sitting posture. The pulse quickens during inspiration, and becomes slower during expiration; for during the former act the reducing pressure in the chest lowers the aortic blood pressure, and makes the tension-fall more rapid, while in expiration the reverse occurs.

This theory also is the only one which throws light on the cardiograph law published by the author (see *Journal of Anatomy and Physiology*, 1870–73), which may be thus stated —For any given pulse-rate the first part of the heart's revolution has a constant length, but it varies as the square root of the length of the complete pulsation. The pulse-rate not depending on the blood pressure, and the length of the first cardiac interval not varying when the rate is constant, its length also does not depend on the blood pressure. The first cardiac interval may be divided into the systole and the interval between that and the closure of the aortic valve (the diaspasis); these combined not varying as the blood pressure, it is almost certain that separately they do not do so either; so it may be said that neither the length of the systole nor of the diaspasis depends on the blood pressure. But the fall of tension between the pulse beats being but small, and the diaspasis length not depending on the blood pressure, there is no reason why it should vary in length with different pulse-rates; and assuming this in connection with the measured diaspasis length in a particular case (·00183 of a minute), it can be deducted from the above cardiograph law, that the systolic length varies as the square root of the diastolic. From these facts the relation of the nutrition of the heart to the time of heart nutrition (diastole); and to the blood pressure, may be deduced; for the systolic length not varying with the blood pressure when the pulse rate is constant it is evident that the cardiac nutrition must vary directly as the blood pressure in the aorta; and the systole varying as the square root of the diastolic time, shews that the nutrition of the heart varies as the square of the time of nutrition (diastole), for with a quadruple resistance to the peripheral circulation, the heart would be four times

* Paper read before the British Association at Brighton in Section D, Department of Anatomy and Physiology,) by A. H. Garrod.

the time in emptying itself, but it is only double that time, which demonstrates the statement.

A complete logical explanation of the action of the pneumogastric can be given on this theory, by assuming that its function consists in diminishing the calibre of the small arteries of the coronary system, and always keeping them somewhat contracted.

PHENOMENA OF COAGULATION IN FROG'S BLOOD *

I WAS endeavouring in the autumn of last year, at Prof. Sanderson's instigation, to demonstrate upon the frog some of Brücke's fundamental experiments on the coagulation of the blood, which he performed on the tortoise; I was surprised at the apparent failure of some of them. For instance, having tied a glass tube into the animal's aorta and allowed it to fill with blood, I expected that which was in the tube speedily to coagulate, that which remained in the heart to continue liquid for a considerable time. But no such contrast was observable, both portions of blood remained perfectly fluid for an indefinite time. I say apparently, for, in fact, on subsequently turning out the blood, a slight film of coagulated fibrin was observable attached to the walls of the tube. Of course the corpuscles being the heavier gravitate to the bottom, and the blood thus becomes divided into two portions, a clear fluid above and a mass of red corpuscles below, with a thin filmy stratum of white again on the surface of the latter.

To show that the clear fluid is plasma and not merely serum, that is to say, that it fully retains its coagulability, it is sufficient to take a little up into a very fine, almost capillary, glass tube. The extent of surface to which it is thus exposed very quickly determines its coagulation.

Following up the subject still further, I found the same thing to happen when the blood is allowed to drop into a glass vessel, the whole remaining fluid, except that portion in immediate contact with the sides, the corpuscles subsiding as before, and the supernatant liquid being readily coagulable in a capillary tube.

But frog's blood does not always behave in this manner. It is not unfrequently the case, especially at this season of the year, that the blood of these animals behaves to all appearance precisely as we are in the habit of expecting that blood should behave, that is to say, the commencing subsidence of the corpuscles is arrested, the fluid solidifies, seemingly throughout. And, indeed, in rare instances, the coagulation is complete to the centre, and the mass soon separates into clot and serum, which latter, in these cases, never yields a coagulum in a capillary tube. More frequently, however, on breaking the surface with a knife, the interior of the coagulated mass is seen to be occupied by still fluid blood.

In either case, the coagulated fibrin soon begins to contract; and this contraction proceeds to such an extent that not only is the serum of the blood expressed from it, but it comes to pass that there is no longer room in its meshes for the involved corpuscles, which consequently begin to be squeezed out and to fall to the bottom of the glass. This diminution in volume of the clot may proceed so far that in the course of a few hours the blood may present an appearance precisely as if it had not undergone coagulation at all, there being a mass of corpuscles at the bottom of the vessel, and a clear supernatant fluid. The contracted remains of the clot may however be always found, although often obscured by the liberated corpuscles. Now, this disappearance of the clot of frog's blood under certain circumstances was noticed some years ago by v. Reclinghausen, and ascribed by him to a re-liquefaction of the fibrin; and not un naturally, if we consider the astonishing diminution in bulk which it undergoes, and the fact that the serum in such cases is frequently found to yield a further coagulum.

But in every case of the latter kind, *i.e.* in every case in which the supernatant fluid yields a coagulum in a capillary tube, it will have been found that the primary coagulation was incomplete, *i.e.* that the central parts of the blood remained fluid, whereas on the other hand it is certain that when the primary coagulation has been complete, no further coagulum is *ever* obtainable, although, in this case also, the clot may have contracted to a relatively exceedingly small bulk, in fact, may have almost disappeared.

A further proof, if one were needed, that the diminution of the clot is due merely to contraction and not re-liquefaction of fibrin, is to be found in the examination under the microscope, using an immersion objective, of the process as it occurs in a very thin walled and fine capillary glass tube.

The phenomena here observed are wholly those of contraction: first simply serum, then white corpuscles, and finally red corpuscles being expressed, until a mere thread of fibrin remains, almost obscured by the corpuscles and still including a few.

Throughout the whole process, however, there is no trace of a re-liquefaction of fibrin; this would of course involve the dropping away of the corpuscles from the sides; on the contrary, they are most evidently squeezed out, some of them being actually ruptured in the passage and appearing on the exterior of the clot as small reddish spheroids. The facts then, briefly, are these: that frog's blood, especially if taken during the winter months, exhibits but very little tendency to coagulate, with the exception of the portion in immediate contact with a foreign surface; that, when apparently coagulated throughout, the central portions are very apt to remain fluid, and to impart coagulability to the expressed serum; that the clot when formed frequently tends to attain a relatively very small bulk; and, finally, that this diminution in bulk is due to contraction merely, not reliquefaction of the fibrin.

* Paper read before the British Association at Brighton in Section D. (Department of Anatomy and Physiology), by E. A Schäfer, M.B.

PHYSICS

Acoustic Experiments on the Seine during the Siege of Paris

IN the experiments made by Colladon and Sturm on the Lake of Geneva, in 1827, to determine the velocity of sound in water, the source of sound was a bell, weighing sixty-five kilogrammes, fixed to a boat immersed in the water near Rolle. Another boat, moored near Thonon, carried the observers, who employed a long acoustic tube made of metal, one extremity of which, widened and closed with a membrane, was thrust into the water. The distance from Rolle to Thonon is about 13,500 metres, so that the range of the sound was considerable. The water in that part of the lake is of great depth.

During the siege of Paris, the idea arose of establishing an acoustic telegraph by means of the Seine, between the invested city and provinces that had not been invaded. The Geneva experiments appeared to favour the proposal.

M. Lucas was charged by the Minister of Public Works to make some experiments on the subject, which he accordingly did in November, 1870. He gives an account of these to the Paris Academy.

In the first series, a bell weighing forty kilogrammes was lowered by a windlass from the bow of a barge, to a position twenty or thirty centimetres from the bottom. It contained a clapper, which was moved by means of wires carried up to the barge. Two workmen were charged to ring the bell at certain fixed intervals, while the observers, in another boat, marked the effect at different distances, being carried along by the current. The acoustic tube employed was 1·50m. long, and the membrane of its orifice, immersed in the water, was turned towards the bell. At the distance of a few metres, a dull sound was heard (like that of a drum beat with a drum-stick), at each stroke given to the bell. The intensity diminished with the distance, and the sound ceased to be perceptible at about 1,800 metres. The result was constant for experiments repeated at different parts of the river.

In a second series of experiments, a bronze bell, weighing 354 kilogrammes, was used. This was hung in a wooden frame weighing 446 kilogrammes, constructed in the form of a quadrangular pyramid. The hammer of the bell weighed sixteen kilogrammes, and was moved by wires, as in the other case. The frame and bell were suspended by chains from the four corners, between two barges, and then lowered into the water. The mode of observation was the same as in the former case.

A few metres from the barge a slight metallic sound was heard, doubtless from the acoustic tube vibrating with the membrane. The sound soon became dull, its intensity decreased rapidly with the distance; at 1,400 or 1,500 metres there was no perception of it.

Comparing these experiments with those of the first series, we have the unexpected result that the very intense sound of a bell weighing 354 kilogrammes has a less range than the weaker sound from a bell of forty kilogrammes.

In a third series, a small bell, twelve centimetres diameter, was sounded in the water alternately with the bell of forty kilo-