To return from this digression, it is clear that we are now acquainted with the mode in which oxidation is effected in the body, as far as the earlier stages go. Oxygen is absorbed in the lungs, combines with the cruorine, and is aftewards given out again. But at this point we are compelled to pause to consider two more complex and exceedingly important questions. These are, firstly, what is oxidized? and, secondly, where is the oxidation effected? Liebig, as everybody knows, divided the substances oxidized in the body into great classes, corresponding with the chief constituents of food. These were the non-nitrogenous, or "respiratory" elements, and the nitrogenous, albuminous, or "plastic" elements. The former embraced fat, sugar, starch, etc., and all its members were supposed by him to be oxidized in the blood, and to evolve no force but heat as the result of their combustion. The latter consisted of the organized tissues, and in particular the muscular tissue, the oxidation of which chiefly resulted in the production of mechanical work. It is an obvious corollary from this hypothesis, that the oxidation of a solid tissue must be effected in the tissue itself, outside the walls of the capillaries, and we are therefore compelled to believe in two distinct modes of oxidation. Substances in the blood are in direct contact with the corpuscles, and may therefore be supposed to unite directly with the oxygen of the scarlet cruorine; whereas, for the direct oxidation of a tissue, it is necessary to assume that some of the oxygen leaves the corpuscles, traverses the walls of the blood-vessels, and arrives at the comparatively distant fibres in a state of solution, but in an uncombined condition. In its extreme form, Liebig's hypothesis has long been known to be untenable, for it cannot be doubted that nitrogenous substances, as well as non-nitrogenous ones, are oxidized in the blood, and contribute to the animal heat; and it has recently been demonstrated by the conjoined efforts of Traube, Heidenhain, and Donders, and still more distinctly by Fick and Wislicenus, Frankland and Parkes, that the oxidation of nitrogenous substances cannot account for nearly all the work done in the body. Traube, indeed, has started a rival hypothesis, which has been accepted by Fick and Wislicenus in their celebrated memoir; namely, that the oxidation of muscle contributes nothing whatever to muscular power, but that the whole of the latter is derived from the oxidation of non-nitrogenous bodies, such as fats and the so-called hydrates of carbon. But as they agree with Liebig in placing the seat of this oxidation in the tissue, there is no great difference, as far as the blood is concerned, between the two views.

But are there, indeed, two distinct kinds of oxidation going on in the body, one inside and one outside the walls of the blood vessels? Is it probable, or indeed possible, that sufficient oxygen can pass out through the thin walls of the capillaries to account for enormous force exerted by the body in twenty-four hours? Mayer thought not, and argued against the notion in his immortal treatise, "Organic Motion in its connection with Change of Matter," published more than twenty years ago. I believe he was right in this, as in so many other things, and I have elswhere drawn attention to his arguments, and endeavoured to add others to them. The question is one of immense theoretical and practical importance, and I will therefore enter into it in some detail.

To begin with, it is necessary to bear in mind another well-known and most important function of the blood. All the tissues of the body, the muscles among the number, are subject to a ceaseless process of disintegration and destruction. The elementary parts of which a tissue consists, have a definite term of life. They are born, grow, decay, and die, having previously developed new germinal matter from which their successors arise.

There is no doubt about this, and it is equally certain that the nutrient matter, the *pabulum*, from which the new parts are formed and nourished, is derived from the blood, some portion of which must travel through the thin walls of the capillaries, and irrigate the tissue. Extreme uncertainty exists as to the mode in which this exudation takes place. At first sight it would appear to be simply a question of liquid diffusion; but, apart from the colloidal nature of the albuminous bodies of the blood, there are some striking points of difference between the composition of the blood and that of the muscular juice, in respect even of some of the most diffusible substances. Thus common salt, an extremely diffusible compound, is found in large quantity in the blood, but is almost entirely absent in muscular juice, and the blood, is invariably and necessarily alkaline; whereas the liquid of the tissue is acid, and may even contain, as Liebig has remarked, enough acid to neutralize the blood. Probably the pressure under which the blood flows, influences in some manner the exudation, but it would be vain to pretend that it explains it. (1)

The excess of the nutrient fluid, together with the products of the disintegration of the tissues, returns to the blood, a portion perhaps direct to the capillaries, but the great bulk, in all probability, through the lymphatics, which seem to act as overflow-pipes to the tissues. Mayer therefore suggested that the quantity of lymph might be taken as a measure of the quantity of fluid exuded in a given time. Bidder and Schmidt estimate the lymph returned to the blood in twenty-four hours at 22 lbs., but it is safer to assume it to be at least 30 lbs. It would hardly do, however, to take even this quantity as a representation of the average exudation through the capillary walls in twenty-four hours, and I have thought it right to treble it, so as to have a decided over-statement of its probable quantity. We thus get 90 lbs. a day, or about 40 litres. Now if oxygen leaves the blood and passes into the tissues, it is evident that it must pass in solution in this 40 litres of exudate. How much oxygen could possibly be dissolved by this 40 litres? There is every reason to believe that the exudate does not differ materially from liquor-sanguinis in composition, and we have before seen that liquor-sanguinis is about equal to water in its power of dissolving oxygen. 40 litres of water would dissolve less than two grammes of oxygen; and this quantity of oxygen, whether it were employed in the oxidation of muscle, of fat, or of sugar, could not yield as much as 3000 metre-kilogrammes (2) of force. But it may be urged that, though unlikely, it is still possible that the exuding fluid may be able to carry with it a larger proportion of oxygen than this. Be it so. Let us make the absurd assumption that every hundred volumes of exudate contains more oxygen than the arterial corpuscles themselves do, when saturated with the gas. If each hundred volumes of exudate contained forty volumes of oxygen, 40 litres would still only contain about 23 grammes, and this, in uniting with oxidizable materials, could only yield about 30,000 metre-kilogrammes of force.

Now the daily work of the heart alone is estimated by Donders at 86,000 metre-kilogrammes, and it is an extreme under-statement to assert that the total daily work of the body in health is 100,000 metre-kilogrammes. To do even this quantity of work, twice the quantity, or 200,000 metre-kilogrammes of force must, as Heidenhain has proved, be provided; so that even taking the highest possible calculation of the quantity of oxygen which could pass into the tissues, we see that it cannot account for one-sixth of the work done in them. It is more probable, indeed, that it cannot account for one-sixtieth. To supply the minimum force per diem exerted in the body, there must be a daily exudation of about 264 litres, or $\frac{1}{4}$-ton, if the exudate contains as much oxygen as arterial corpuscles; or,

3500 litres, or $3\frac{1}{2}$-tons, on the more probable supposition that it will not dissolve more than water will.

These figures appear to me to furnish a complete answer to the current theory of tissue-oxidation, and to force us inevitably to the conclusion so clearly pointed out by Mayer, namely, that

dentally in the above experiments a confirmation of the previously known fact, that carbonic oxide is disengaged during the absorption of oxyen by potassic pyrogallate. Air from which the oxygen had been removed by this re-agent, when added to reduced cruorine, caused the latter to give a two-line spectrum, which lasted for weeks.

(1) Some of these arguments were suggested to me by Dr. Marcet, F. R. S., who has studied the bearings of dialysis on pathology with great care and success.

(2) A metre-kilogramme is the force required to raise one kilogramme one metre. It is equal to about $7\frac{1}{4}$ foot-pounds, and is now almost universally employed as the measure of force.