of food we eat; with such a dietary the teeth, jaws, and chewing muscles are deprived of the work which fell to them in more primitive times. That this is not the true explanation is proved by this fact. When children are fed, clothed, and exercised exactly alike, all are not affected; only some of them develop irregularities of the palate and jaws. There is a special susceptibility to these imperfections in certain races and in certain families.

Amongst modern British people are to be seen various facial characters, particularly in the orbits, in the cheek bones, and in the bony supports of the nose, which are never to be noted in the facial framework of people who lived in Britain during the pre-Norman period. When a Continental cartoonist seeks to represent John Bull he always emphasises these new facial characteristics. Such changes in the form of the facial bones, like contraction of the palate, which they usually accompany, are not the result of a nasal obstruction such as might be caused by enlarged adenoids or tonsils; the cause lies deeper. The incidence of irregularities in the growth of the face follow the same laws as hold for all abiotrophic structures such as the appendix, the sclerotic coat of the eye, the thymus, and the tonsil. Further research will likely prove that the disorders of growth which overtake all these structures are linked to a disturbed action of lymphocytes and of all the constituent elements of the lymphoid tissues. Dr. W. Cramer has become convinced that lymphocytes are actively concerned in assimilation of food and in the nutrition of tissues, and that the nature of the dietary does directly affect their activities. It seems to me very probable that a fuller knowledge of the life-histories of lymphocytes, particularly of the office they perform in growing tissues, will go far to explain the disharmonies which civilisation is producing in the bodies of some of us. But the problem of explaining why some members of our community are highly susceptible to these new conditions, while others are less so, and why the majority remain unaffected, will still remain.

I have touched only the fringe of a great subject; I have left undiscussed the numerous imperfections and disharmonies which civilisation has made manifest in structures concerned in the maintenance of posture,[27] and in those which are concerned with the circulation of blood and with the duties of respiration. I have said enough, I believe, to show that Metchnikoff was right when he declared that civilisation had launched man on a great experiment. From this experiment there is no turning back. We cannot return to the conditions of human life which prevailed in Britain 6000 years ago; there are more people in one of the lesser back streets of London than could find an existence in the whole length and breadth of the Thames valley if we were to resume the manner of living of our distant ancestors. We cannot go back; we must go on. Seeing how differently we are now circumstanced in every relationship of life—in food, in drink, in shelter, in warmth, in occupation, and in amusement—the wonder is, not that structural imperfections and functional disharmonies should develop in a proportion of our numbers, but that so many of us should escape harm altogether and enjoy good health. It says much for the adaptational reaction which is inherent to the human body that it withstands the artificial conditions of modern civilisation so well as it does.

How are our bodies to be protected against these ills with which civilisation threatens them? Metchnikoff, a declared and open rebel against Nature, hoped that science might discover some short-cut for man's escape, some way of speeding up the evolutionary machinery of his body and so making it perfectly fitted for the life which ever-advancing civilisation is forcing on mankind. I also believe that science will find a means of escape, but not by Metchnikoff's way. The solution of our problem is a fuller knowledge of the use and working of those parts of our bodies which are most apt to give way under our modern manner of living—the use of such structures as the great bowel. When we have replaced our ignorance by real knowledge we shall then be in a position, not to adapt our bodily structures to our mode of living, but our mode of living to our bodily structures. This seems to me the best way out.

[27] I have discussed the "Imperfections of Man's Postural Structures" in the *Bri Med. Journ.*, 1923, vol. 1, pp. 451, 493, 545, 587, 642, 669.

Hypothesis about Push or Contact Force.[1]

By Sir OLIVER LODGE, F.R.S.

ONE of the remarkable discoveries of our times has been the pressure of radiation. Though this pressure is ordinarily so extremely minute that it was difficult to discover—and perhaps would not have been discovered had it not been predicted mathematically beforehand by Clerk Maxwell—yet in certain circumstances the pressure of light can be very large and of cosmic importance. Whether it has an influence and ought to be taken into account in the intimate structure of atoms, I am not prepared to say, but I suggest it. The Boscovich contemplation of regions where force changes sign, and our whole knowledge of the stability of Bohr's atomic orbits, represent facts which have not yet been accounted for.

Moreover, I am going to suggest that the pressure of light may have to be taken into account before the most ordinary operations of daily life, even the propulsion of a wheelbarrow, are properly explained. The force of ether-waves may encroach on the region of mechanism, and be needed for a fuller interpretation of the familiar mechanical force exerted by one body in contact with another. When denying action at a distance we must not slur over a difficulty by pleading that the distance is small.

It may seem absurd to demand a theory of the manner in which one piece of matter pushes another. Even if one denies actual contact between atoms, it is reasonable to think of each atom as so surrounded by planetary electrons as to oppose similar electrifications to each other, and thus account statically for the repulsive

[1] From the first Norman Lockyer Lecture, "On the Link between Matter and Matter," delivered to the British Science Guild in the Goldsmiths' Hall, E.C., on November 16.

force. But the electrons are in motion, and that suggests further non-static possibilities. Moreover, one effect of close approach is attraction followed by cohesion, if the approach is close enough—the atoms themselves, being charged, naturally arrange themselves for some collateral mutual attraction—a sort of residual affinity between the molecules. Why should there be repulsion instead of attraction at a certain distance ?

The one thing that always gives repulsion without reference to sign of charge is radiation. Can any of this repulsion be due to radiation pressure ? The idea is not to be turned down off-hand without consideration, unlikely as it may appear at first. The alternations of attraction and repulsion, at different distances apart, have to be accounted for somehow.

The pressure of radiation is proportional to the energy in unit volume, and in the case of heat radiation depends on the fourth power of the temperature, which again is proportional to the square of the atomic speed. The speed associated with any given temperature is not great; for example, the speed of helium atoms at ordinary temperature is reckoned by Eddington at 1 mile a second, and at 4 million degrees is still only 100 miles a second. The speed of electrons at the same temperature would be 40 times greater, but even that is not quick for an electron. They may be moving at anything up to 100,000 miles a second in an atom. But they are moving regularly; and regular motion is not temperature: temperature requires irregular motion. Well, my point is that the mutual perturbation of approaching atoms may cause the necessary irregularity, and that the radiation thus caused, at really close quarters, may be very intense.

We know that radiation is emitted or absorbed whenever an electron jumps from orbit to orbit. I picture the electrons of closely juxtaposed atoms as jumping up and down, like caged birds, from perch to perch. Each bird jumping up consumes energy, each bird jumping down restores it. No matter whether radiation is emitted or absorbed, the result is still repulsion. At each jump a quantum is emitted, and at very high frequencies the quantum is by no means negligible. The temperature comparable to a thirtieth of the speed of light is some thousands of millions of degrees, and the energy and pressure of radiation corresponding to that temperature are enormous; quite enough to account for any mechanical force.

Between the contiguous surfaces I picture radiation going and coming, emitted and absorbed, continually. There is no loss of energy, the radiation does not escape, but it can be very intense and can produce an enormous pressure, as it does in the interior of stars.

I spoke of the orbital electrons being perturbed by proximity, but they cannot be perturbed infinitesimally. Nothing short of a quantum of disturbance is effective. An orbital electron will not yield to any inferior disturbance; it cannot respond slightly, it responds by a jump or not at all. It is apparently under some constraint to remain in a stable orbit, until it can jump out; and if it jumps, it either emits or absorbs radiation. The quantised orbits are not susceptible to continuous perturbation: every occurrence in an atom is discontinuous. The frequency of the radiation, and therefore the energy of the quantum, will be determined by the speed-energy-difference between the orbits.

What reason is there to suppose that proximity would introduce perturbation of any kind? Well, in inverse square orbits, equilibrium is only preserved by a certain tangential velocity. Any sluggishness or retarding force causes a projectile to drop in; any tendency to increase the speed makes it move farther away. The law of conservation of areas will no longer be obeyed when a repulsive force is applied in the plane of the orbit. On one side the particle will be accelerated, on the other retarded. Ordinarily, revolution of the apses would occur. But this may become too violent to be thus conveniently described, and it is doubtful how much ordinary perturbations are permissible in the very peculiar stable orbits of Bohr. In a quantised orbit the above sort of influence must at some stage of violence lead to a jump. A jump cannot leave the particle's energy as it was: it gains too much by a fall, some must be emitted.

That is my present idea of the force which keeps bodies apart and enables one to push another.

Parenthetically we may observe that in massive atoms the inner electronic speed is very great, and so, from these, extremely high radiation may perhaps escape, and may stimulate spontaneous radioactivity in other atoms, by getting down to and ejecting some of the deep-seated nuclear electrons. If two of those go away, an alpha particle is likely to be driven out violently by electrical repulsion.

The state of matter in or near a nucleus may be comparable to the state inside a star like the companion of Sirius, except that gravitation is inoperative. The close-packed density is prodigious.

These ideas are crude, granted; but a working hypothesis is a thing to be worked, its consequences to be traced, and then either improved or discarded. Anyhow our aim ought to be to explain those facts on dynamical principles, perhaps not the ordinary dynamics, but etherial dynamics, and that is far from having been worked out; perhaps it cannot be said to have been begun.

Already some attempt has been made to assimilate radiation with matter by the unlikely path of thermodynamics. Radiation has been used as the working substance in a theoretical heat engine. Its pressure has thus been mechanically employed. It has been dealt with almost like a gas. The laws of gases—the statistical behaviour of discontinuous random particles—have been applied to electricity, and even to radiation. By this means not only can the known law of Stefan, connecting *total* radiation with temperature, be deduced, but also a law regulating the distribution of energy among different wave-lengths has been formulated by the genius of Wien: which formulation, though it is not yet fully explained, is nevertheless true. The average energy associated with any particular wave-length must be equal to some function of the product of wave-length and absolute temperature, divided by the fifth power of the wave-length. That is Wien's law. This law involves an unknown function, as well as the curious idea of the temperature of space or of radiation; for it deals with the waves statistically, after the manner of the kinetic theory of gases. The flying about of the radiation inside a completely reflecting enclosure has a complete irregularity, which justifies the application of the term " temperature " to the energy therein contained.

As for the unknown function—the discovery of that was elucidated by Rayleigh, and completed by Planck; and it is there that the " quantum " made its appearance. For if the energy could be absorbed or emitted continuously, all the energy of matter would go into the ether, and the universe would fade away and die, or at least would cease to be active. The effect of discontinuous emission and absorption saves the universe from destruction, and makes this lively planet possible. If radiation could go on from atoms continuously, all the energy would get into the ether: matter would have none, and none of us would exist.

These discoveries have no human significance, people think. They are chock-full of significance. We are down among the foundation-stones of reality, the laws which make activity possible, the laws which perpetuate the atoms of which our own bodies are composed.

Scientific and Industrial Research in 1924–25.[1]

THE latest report issued by the Department of Scientific and Industrial Research consists, as usual, of a short summary report by the Committee of the Privy Council, a long report by the Advisory Council, a summary of the work done by research institutions directly under the Department, numerous appendices, and a good index. In the first report the view is expressed that the embarrassments and losses which British staple industries are suffering do not arise primarily from the neglect of science, although in many cases delay in recovery is caused by lack of scientific leadership. The successful application of scientific discoveries to industry is a slow and expensive business, as witness the delay of two generations in applying Faraday's work on electro-magnetism, and the interval of twenty years which elapsed between the discovery of artificial indigo and its successful exploitation at a cost of 1,000,000*l*. The Fuel Research Station is apparently following these precedents, for in spite of an expenditure of more than 400,000*l*. in seven years, it has found no solution of the problem of producing smokeless fuel at an economic cost. It is, however, stated that the work has produced profits and economies in other directions which exceed in monetary value the total expenditure on fuel research. Attempts to manufacture power alcohol from beets, mangolds, and Jerusalem artichokes have also proved abortive, although the last-named are still being cultivated in various localities for use in future tests.

The Food Investigation Board has devoted most of its attention to the handling and preservation of food in order to reduce loss and to increase supplies. The problem of the freezing of beef has been attacked from the point of view of the freezing of colloids, and it has been found that if a mass of colloid, *e.g.* a disc of jelly, be frozen slowly, ice forms on the external surface, whereas if the rate of freezing be high, congelation takes place within the mass. When eggs are preserved by cold, protein is thrown out of solution and is not redissolved on thawing. In the living organism highly insoluble substances are often held in solution by other substances, and freezing apparently renders them permanently insoluble. Changes undergone by fruit and vegetables during storage and transport are still under investigation, but the work on fish preservation has been held up owing to the impossibility of conducting experiments at an inland station. Many problems connected with cold storage are being studied at the National Physical Laboratory, such as the inflammability of heat-insulating materials, the physical properties of refrigerants, hygrometry, rate of flow of fluid in the circuit of a refrigeration plant; and on the chemical side, work is being continued on the higher unsaturated fatty acids, glycogen, and the formation of fat by yeast.

The Geological Survey has surveyed the coalfields and adjacent areas, investigated mineral deposits, water-supplies, and examined rocks and soils exposed during the construction of new roads. The Museum of Practical Geology and the Geological Survey are to be permanently housed in buildings to be erected adjoining the Natural History and Science Museums at South Kensington. A site has been acquired at Princes Risborough for the Forest Products Laboratory, but for the next two years work will be continued at the Royal Aircraft Establishment in Hampshire. Investigations in progress include the cause of brittleness in timbers, preservatives for wood other than creosote, and the improvement of kiln-drying practice.

Building research is assuming greater importance owing to the serious housing situation, and so a new and larger research station is about to be opened at Watford. The fundamental problems that are being attacked, under the advice of four expert committees, include: (1) architectural acoustics, moisture-condensation on internal wall-coverings, and the rate of transmission of moisture through building materials; (2) setting and hardening of cements, including non-corrosive oxychloride flooring materials, and changes in volume of building materials due to moisture changes; (3) preservation of stonework, and attempts to express " weathering " in terms of temperature and moisture variations; (4) wind-pressure on roofs, bridges, etc., vibration due to machinery, or road and rail traffic, permeability of concrete and its movements due to moisture and temperature changes, standardisation of tests for compression, abrasion, and hardness. Some of these investigations are already yielding results of immediate practical importance.

The work of the National Physical Laboratory (N.P.L.) is so vast and diverse that reference can only be made here to some of the investigations in pure science which it has undertaken recently, namely, calorimetry at high temperatures, the magnetic properties of iron and other alloys, properties of dielectrics, the vertical-force magnetometer, the efficiency of power transmission by gears, ferrous alloys free from carbon, and methods of spectrographic analysis of metals and alloys.

Important duties are also carried out by the various co-ordinating research boards. In chemistry, the commercial production of formaldehyde as a cheap

[1] Report of the Committee of the Privy Council for Scientific and Industrial Research for the Year 1924–25. Pp. 155. Cmd. 2491. London: H.M. Stationery Office. Price 3*s*. net.