almost equal to the *initial* velocity of rotation, in order that it may be exactly equal to the *mean* velocity of rotation. A strict equality being no longer necessary, the paradox does not exist any more. The explanation is nevertheless incomplete. What is the reason of this approximate equality, of which the probability is no longer zero, it is true, but still very small? And, especially, why does not the moon undergo slight oscillations about its position of equilibrium (if we eliminate, of course, its numerous librations, due to other well-known causes)? These oscillations must originally have existed; they must have become extinct by a kind of friction, and everything tends to make us believe that the mechanism of this friction is that which I have just analysed with respect to the ocean tides.

When the moon was not yet solid, and formed a fluid in the form of a spheroid, this spheroid must have experienced enormous tides, by reason of the proximity of the earth and of its mass. These tides could only have ceased when the oscillations became almost entirely extinct.

It seems that Jupiter's satellites, and the two planets nearest the sun, Mercury and Venus, have also a rotation, the duration of which is the same as that of their revolution; it is doubtless for the same reason.

It might be thought that this tidal action has no connection with our subject. I have as yet only spoken of rotations, and in the studies relative to the stability of the solar system the movements of translation are only dealt with; but a little attention shows that the same action makes itself equally felt on the latter.

We have just seen that the attraction of the moon on the earth does not act exactly through the centre of the earth. The attraction of the earth on the moon, which is equal and exactly opposite, would not pass either through this centre; that is to say, through the focus of the lunar orbit. A disturbing force is the result, very small in reality, but sufficient to make the moon increase in energy. The active force of translation thus gained by the moon is evidently smaller than that of rotation, lost by the earth; because a part of the energy must be transformed into heat in consequence of the friction engendered by the tides. The period of revolution of the moon lasting about twenty-eight sidereal days, a very simple calculation shows that this body gains twenty-eight times less *vis viva* than the earth loses.

I have already explained the action of a resisting medium; I have shown how, by making the planets lose energy, their movements are accelerated; on the contrary the action of the tides, by increasing the energy of the moon, retards its movements; the month lengthens therefore as well as the day. Now if this cause acts alone, what is the final state towards which the system will tend? Obviously this action would only stop when the tides have ceased—that is to say, when the rotation of the earth would have the same duration.

This is not all: in the final state the orbit of the moon must have become circular. If it were otherwise, the variations of the distance of the moon to the earth would suffice to produce tides. As the movement of rotation would not have changed, it would be easy to calculate what angular velocity would be common to the earth and to the moon. One finds that, at the limit, the month, like the day, would last about sixty-five of our actual days.

Such would be the final state if there were no resisting medium, and if the earth and the moon existed alone.

But the sun also produces tides, the attraction of the planets likewise produces them on the sun. The solar system therefore would tend to a condition in which the sun, all the planets and their satellites, would move with the same velocity round the same axis, as if they were parts of one solid invariable body. The final angular velocity would, on the other hand, differ little from the velocity of revolution of Jupiter. This would be the final state of the solar system if there were not a resisting medium; but the action of this medium, if it exists, would not allow such a condition to be assumed, and would end by precipitating all the planets into the sun.

It must not be thought that a solid globe which was not covered by seas would, by the absence of tides, find itself free from actions analogous to those just mentioned, even by admitting that the solidification had reached the centre of the globe. This body, which we suppose solid, would not on that account be an invariable one; such bodies only exist in textbooks on rational "mechanics." It would be elastic and be subject, by the attraction of neighbouring celestial bodies, to

deformations analogous to tides and of the same order of magnitude.

If the elasticity were perfect, these deformations would occur without loss of work, and without the production of heat. But perfectly elastic bodies do not exist. There would be in consequence development of heat, which would take place at the expense of the energy of rotation and translation of the bodies, and which will produce absolutely the same effects as the heat engendered by the friction of the tides.

This is not all: the earth is magnetic, and very probably the other planets and the sun are the same. The following well-known experiment is one which we owe to Foucault: a copper disc rotating in the presence of an electromagnet suffers a great resistance, and becomes heated when the electromagnet is brought into action. A moving conductor in a magnetic field is traversed by induction currents which heat it; the produced heat can only be derived from the *vis viva* of the conductor. We can therefore foresee that the electrodynamic actions of the electromagnet on the currents of induction must oppose the movement of the conductor. In this way Foucault's experiment is explained. The celestial bodies must undergo an analogous resistance because they are magnetic and conductors.

The same phenomenon, though much weakened by the distance, will therefore be produced; but the effects, being produced always in the same direction, will end by accumulating; they add themselves, besides, to those of the tides, and tend to bring the system to the same final state.

Thus the celestial bodies do not escape Carnot's law, according to which the world tends to a state of final repose. They would not escape it, even if they were separated by an absolute vacuum. Their energy is dissipated; and although this dissipation only takes place extremely slowly, it is sufficiently rapid that one need not consider terms neglected in the actual demonstrations of the stability of the solar system.

ON THE USE OF METHYLENE BLUE AS A MEANS OF INVESTIGATING RESPIRATION IN PLANTS.

IT has long been known that methylene blue is capable of being decolorised by reducing agents, and the object of the present communication is to point out its use as a means of demonstrating in a striking manner the reducing power possessed either by living protoplasm or at any rate by substances intimately associated with the exercise of its vitality. Its employment is not new to animal physiologists, but botanists appear not to have recognised the possibilities latent in the method, perhaps because some ten years ago Pfeffer ("Oxydationsvorgänge in Lebenden zellen") stated that although fermenting yeast would decolorise the blue solution, green plants would not do so. Doubtless this was true under the conditions of Pfeffer's experiments, but nevertheless many green plants are, as a matter of fact, found to give admirable results.

If germinating seedlings of barley or peas be placed in test tubes filled with a 0.0005 per cent. solution of methylene blue, which has been boiled in order to expel air, it will be found that in the course of a few hours the liquid around them will have lost its colour. The most striking way of performing the experiment is to suspend the peas in the solution, then a decolorised zone is formed between the upper and lower parts of the liquid, each of which still retain its blue colour. Gradually the clear zone extends until the entire mass of the liquid, except just at the surface where it is in contact with the air, becomes decolorised. At first the radicles of the seedlings are strongly stained; they finally again become white.

If some of the decolorised liquid be drawn off by means of a pipette, and shaken up with air, the blue tint speedily returns. If some of the seedlings be removed from the now colourless liquid, and be rinsed in boiled water and then exposed to the air, they soon become blue, and the stain gradually extends into the internal tissues as these become gradually aerated. The "development" of the blue can readily be seen in sections, quickly made, under the microscope.

Cress seedlings are far more active than either barley or peas, just as would have been expected from the relations which they exhibit towards oxygen.

But perhaps the most remarkable results are those obtained from a plant like *Chara*. This alga is suspected to possess peculiar properties in regard to its connection with

oxygen (*Annals of Botany*, vol. x. p. 288), and I have since ascertained in several ways that the plant is nearly as greedy for oxygen as are many seedlings. A branch of *Chara* placed in the methylene blue and *put in the dark*, will decolorise the surrounding liquid in a few hours; but if the tube containing it be exposed to the action of bright daylight the colour soon returns when the plant is alive, owing to the evolution of oxygen consequent on its splitting up the carbon dioxide which has been evolved by it, and which has been accumulating in the water, during the plant's stay in darkness. (Of course it is hardly necessary to state that the carbon dioxide is not itself the cause of the loss of colour in the liquid.) The experiment can be repeated several times with the same *Chara* plant, and we have succeeded in keeping it alive (as proved by the continuance of the protoplasmic movement) for four days. Naturally if the experiment is performed in continuous daylight no decoloration is effected.

Many other plants fail to give such quick results; thus *Elodea* requires about two days in darkness to obtain the reaction. All the plants experimented on give a result much more quickly if they have previously been starved of oxygen. And this indicates that under these conditions, as also under those of the experiments above described, the oxygen is not directly utilised either by the protoplasm, or some of the normal combustible bodies present in the cell, but by some dissociation product formed during the metabolic activity of the protoplasm. Of course decoloration of the blue does not occur when the plants are exposed to the action of free oxygen; this element can then be obtained more cheaply than by reducing the aniline dye. But this is not the place in which to discuss the meaning of the reaction or the nature of the substance which primarily reduces the methylene blue. The facts have been arrived at during an investigation, which is still proceeding, into the respiratory processes of plants. The method here detailed is, however, so simple, and seems likely to prove useful to teachers and others as a demonstration-experiment, that it appeared worth while to make it generally known.

J. B. FARMER.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—In connection with the extracts printed last week (p. 165) from the reports of the delegates of the University Museum, referring to the want of accommodation and equipment for research in certain branches of science, it may be worth while directing attention to the leading article in *Literature* of June 11, regretting that little original work is being done in the domain of letters. The opinion is expressed that the Royal Commission which sat on the Universities rather more than twenty years ago, "made Oxford and Cambridge much more effective places for teaching and examining than they had been before, while at the same time it helped to ruin them as places for study." The leader concludes with the words:—"Englishmen are by nature somewhat too much inclined to look for an immediate advantage; to bring all things to a common-sense, even a commercial, test; to distrust theory; to despise action for an abstract end. One of the functions of a University is to keep alive a higher faith by giving an example of thorough and devoted work done without a commercial object. Our Universities, as they are at present managed, do no such thing."

The research degree of Bachelor of Science was conferred upon Mr. A. E. Tutton in Congregation on June 16. Mr. Tutton is the first recipient of a degree for research in natural science or natural philosophy, the only other research degree yet conferred being for mathematical work. In order to qualify for the degree eight terms must be kept, and one or more original theses presented. Mr. Tutton presented two theses—one his paper on the crystallography of the selenates of potassium, rubidium and cesium, and the other on the new interference dilatometer exhibited by him at the recent conversazioni of the Royal Society. The B.Sc. research degree ranks with the B.C.L. immediately after the M.A. degree, and before the B.A. degree. It is hoped that, by requiring a high standard of qualification for the new degree, research will be encouraged, and the scientific work of the University will be increased in value and amount.

CAMBRIDGE.—Among the ten recipients of honorary degrees on June 15 were the Italian Ambassador (General Ferrero) and Mr. F. C. Penrose. General Ferrero early distinguished himself

in mathematics, and, after an active military career, he became connected with the military and geographical Institute of Florence, editing all its publications from 1873 to 1893, and being at its head from 1885 to 1894. He organised the general topographical and cadastral survey of Italy, which led to the publication of important maps of the country, in the preparation of which valuable aid was derived from photography. In 1883 General Ferrero was made a Member of the Accademia dei Lincei, and in 1892 a Senator of Italy. Since 1874 he has taken an important part in the International Commission for the measurement of the earth's surface, and in this respect (amongst others) he has a European reputation.

Mr. Penrose has not only made valuable contributions to archaeology, but also to astronomy, and his papers on the orientation of Greek temples exhibit the rare combination of archaeological and astronomical knowledge.

The following are the speeches delivered by the Public Orator, Dr. Sandys, in presenting General Ferrero and Mr. Penrose for the honorary degree of LL.D. and Litt.D. respectively:—

Olim in hoc ipso loco Italiae legatum belli et pacis artibus illustrem salutavimus; hodie eiusdem adiutorem atque adeo successorem insignem non minus libenter salutamus. In Academia Taurinensi scientia mathematica excultus, et rei militaris et geographiae studiis deditus, Italiae toti accurate dimetiendae et describendae summa cum laude est praepositus. Huic imprimis debemus regionum Italiae tabulas depictas, partim lucis ipsius auxilio in lucem emissas; hunc non modo Linceorum Academia Romana sociis suis, sed etiam Italia tota senatoribus suis merito adscriptis; huius fama ultra patriae fines a se ipso tam diligenter descriptos etiam in alias Europae partes latissime diffusa est. Asiae regiones pulcherrimae (Vergilio si credimus) Italiae cum laudibus certare nequeunt; Europae gentes maximae Italiae legatum insignem certatim laudant. Belli certe et pacis artes feliciter consociatae sunt Italiae in legato illustri, ANNIBALE FERRERO.

Hodie reducem salutamus alumnus nostrum qui abhinc annos fere septem et quinquaginta Thamesis inter undas e certamine nautico cum Oxoniensibus commissio semel tantum victus, plus quam semel victor evasit. Olim Academiae nomine in Italiam et Graeciam missus, de Atheniensium templis opus egregium edidit, in quo Parthenonis et columnas et epistylum columnis impositum lineis non rectis sed leviter curvatis contineri primus omnium ostendit, et ordinis Dorici maiestatem artificio tam minuto adjuvari demonstravit. Idem nuper de templis Graecis ad stellas quasdam orientes conversis ingeniose disputavit. Illud vero felicitatis conspicuae documentum Nestori nostro contigit, quod et Athenis et Londinii architecturae studiis diu deditus, non modo Sancti Pauli ecclesiae cathedralis in culmine sed etiam Iovis Olympii columnarum in fastigio solus omnium mortalium constitit. Viro ad tantam altitudinem evecto non sine reverentia quadam in hoc templo honoris lauream nostram laeti decernimus.

Duco ad vos Collegii Magdalenae socium, Britannorum Scholae Archaeologicae Atheniensi et Regio Architectorum Instituto nuper praepositum, FRANCISCUM CRANMER PENROSE.

THE vote of 8,520,175*l.* for public elementary education in England and Wales, was passed by the Committee of Supply of the House of Commons on Friday. To this sum of money, contributed towards elementary education by the Imperial Government, must be added the sums derived from voluntary subscriptions and the rates. Last year the former amounted to 845,000*l.*, and the latter to 2,325,801*l.* There is no reason to believe that in the coming year these sums will substantially decrease; therefore it may be assumed that in the coming financial year a total sum of no less than 11,690,762*l.* will be spent by England and Wales upon elementary education.

THE annual Commencement at Columbia University on June 8 was noteworthy as the first to be held in the new and permanent home of the University on Morningside Heights. The number of degrees conferred was greater than on any previous occasion, amounting to 485 in cause, and four honorary. An unusual feature was the presentation of the Loubat prizes for the best works on the history, geography, archaeology, ethnology or numismatics of North America. These prizes, amounting to 1000 dollars for the first and 400 dollars for the second, are to be awarded every five years, beginning with the present year; and are not to be less than the amounts named, but may hereafter exceed those amounts. The first prize was awarded to William Henry Holmes, for his book