direction as that below; and that the diminution of temperature with increasing height was greater in clear than in cloudy weather. This last result is in agreement with that of Herr Hann, derived from observations taken at Praya West and Victoria Peak.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, Nov. 19.—"On some Elementary Principles in Animal Mechanics. No. VII. The Law of Fatigue." By the Rev. Samuel Haughton, M.D. (Dubl.), D.C.L. (Oxon), F.R.S., Fellow of Trinity College, Dublin.

The approximate law of muscular action, which I have called the law of fatigue, is thus expressed:—"*When the same muscle (or groups of muscles) is kept in constant action until fatigue sets in, the total work done multiplying by the rate of work done is constant.*"

The following experiments, in illustration of this law, were performed in Trinity College during the spring of the present year.

I instructed a number of medical students, chosen at random, to raise dumbbells of varying weight, one in each hand, in the transverse plane, with hands supinated, raising and lowering the weights in equal times regulated by the beat of a pendulum. This process was continued until the distress of the fatigue produced became intolerable, and the number of times each weight was lifted was noted. The students were required to count "one-two," in time to the beat of the pendulum, so as to prevent them from counting the total number of lifts of the weight. Prof. Macalister assisted me in these experiments; and one of us counted the number of lifts, while the other compelled the experimenters to observe the conditions of the experiment, which were:—

1. To keep time with the pendulum.
2. To raise the weight in the transverse plane.
3. To supinate the hands.
4. To abstain from all bending of the knees or spinal column.

For each experiment I chose twenty students at random, using altogether about fifty different students; and no individual was experimented upon again, until an interval of forty-eight hours had elapsed. The object of this arrangement was to avoid the effects of "training." In my first Table I give the mean result of twenty different students; and in my second Table I have selected one student, set aside for the purpose, and experimented upon, once a week, so as to prevent the influence of "training."

Let W denote the total work done, and T the time of doing it; then, by the law of fatigue,

$$\frac{W^2}{T} = \text{constant} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If w be the weight held in the hand, and a be half the weight of the arm, and n the number of times the weights are lifted; since the time of raising and lowering the arms is constant, n is proportional to T, and the law of fatigue gives the formula

$$(w + a)^2 n = A \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where A is an unknown constant. In the following Table I give the values of w and the mean value of n for twenty distinct persons. The time of lift is in all cases *one second*.

TABLE I.—*Mean of Twenty Experiments.*

No.	w.	n (obs.)	n (calc)	Diff.
	lbs.			
1.	2·56	131·80	128·0	+3·8
2.	4·25	87·55	78·3	+9·2
3.	5·87	47·35	53·5	−6·2
4.	6·87	40·25	43·7	−3·5
5.	7·75	34·60	37·1	−2·5
6.	9·75	27·15	26·8	+0·3
7.	14·00	17·20	15·4	+1·8

The column containing the calculated values of n was obtained from equation (2) by using the values

$$a = 3{\cdot}50 \text{ lbs.}$$
$$A = 4699.$$

These values were obtained by finding the value of a, which renders A most nearly a constant, or

$$\frac{\delta A}{A} = \text{minimum.}$$

This Table gives 7 lbs. for the mean weight of the arm of all experimented on, a result which accords with the known facts.

In Table II. I give the results obtained from a single student, as already described, each value of n being a mean of several experiments, closely concurrent.

TABLE II.—*Mr. Samuel Warren.*

No.	w.	n (obs.)	n (calc.)	Diff.
	lbs.			
1.	2·56	140·0	137·5	+2·5
2.	4·25	91·0	86·4	+4·6
3.	5·87	63·0	60·1	+2·9
4.	6·87	43·0	49·0	−6·0
5.	7·75	40·0	42·5	−2·5
6.	9·75	32·0	31·0	+1·0
7.	14·00	18·5	17·9	+0·6

The calculated values of n were found from equation (2), using the values

$$a = 3{\cdot}9 \text{ lbs.}$$
$$A = 5737,$$

which were obtained from the principle of least variation of A, or

$$\frac{\delta A}{A} = \text{minimum.}$$

In the accompanying diagrams I. and II., I have plotted the cubical hyperbola represented by equation (2); and also the several observations which lie sufficiently near the curve to justify me in considering the law of fatigue to be a first approximation to one of the fundamental laws of muscular action. I have elsewhere * shown that the law of fatigue corresponds with other experiments based on different data.

If we consider the *useful work* only, we have from equation (2),

$$\text{useful work} = wn = \frac{A\,w}{(w + a)^2} \quad . \quad . \quad . \quad . \quad (3)$$

This equation represents a cuspidal cubic, whose ordinate has a maximum value, when $w = a$ = half the weight of the arm.

The foregoing observations are in accordance with this deduction, as may be seen from Table III.

TABLE III.—*Useful Work.*

No.	w.	wn (20 experiments).	wn (Mr. Warren).
	lbs.		
1.	2·56	338	358
2.	4·25	372	387
3.	5·87	277	370
4.	6·87	276	295
5.	7·75	268	310
6.	9·75	264	312
7.	14·00	241	250

It is to be observed, that in the foregoing experiments the muscles in action were not allowed to *rest* during the whole time of work.

Linnean Society, Nov. 18.—Dr. G. J. Allman, F.R.S., president, in the chair.—The following paper was read:—On the organisation and systematic position of the Ornithosauria, Part i., by Prof. H. G. Seeley, F.L.S. The different results obtained by investigators who have written upon Pterodactyles, led the author to propose a method of research in Comparative Anatomy by which the true nature of these animals could be determined. It consists chiefly in an attempt to distinguish between the characters which make animals members of a class of Vertebrata, and the characters which make those animals members of vertebrate ordinal groups. The class characters were regarded as furnished by the soft vital organs, while the ordinal characters are derived from the skeleton. This was illustrated by an argument tending to show that since the form of brain,

* "Principles of Animal Mechanics" (London, 1873).

and the peculiar respiratory organs of birds, are class characters, any animal would be a member of the class Aves which possessed them; and since the form of skull, of vertebræ, of the carpus and tarsus are ordinal characters in the existing sub-class of birds, they will not necessarily be found in an extinct sub-class or order of Aves. He then showed that Pterodactyles have the brain identical with the bird's brain in every detail; and the pneumatic perforations of the bones for the prolongation of air-cells from the lungs into the bones were identical in both types and are found in no other group of animals. Hence it was concluded that, judged by class characters, Ornithosaurs must be placed in the class Aves. The author then gave an analysis of the characters of the Ornithosaurian skeleton. In the skull, he thought that the bone hitherto named post-frontal is the quadrato-jugal, and that although the malar bone meets the quadrate bone, there are no reptilian features in the skull, and nothing which is inconsistent with the Avian organisation. The vertebral column is the most reptilian part of the skeleton in being procœlous, but the fore limb was shown to be constructed on the Avian plan; the carpus being nearly identical in both groups; while the elongated finger for flight was proved by its carpal articulation to be the index finger as in birds; and in one Pterodactyle it contained two phalanges, as in birds. The petagial membranes of the Pterodactyle were also shown to be extensions of the similar membranes of birds. The characters of the pelvis and hind limb were less unlike those of a bird than had been supposed, the tibia terminating distally in a trochlear end formed as in birds by the anchylosed proximal tarsal bone. From the whole skeleton (excluding the evidence of the cerebral and respiratory characters) the author concluded that it is impossible on morphological grounds to exclude the Ornithosauria from the Avian class, and that their resemblances to reptiles are not more important than their resemblances to mammals.

Geological Society, Nov. 17.—Mr. John Evans, V.P.R.S., president, in the chair.—Mr. Robert Elliott Cooper, C.E., 1, Westminster Chambers, Victoria Street, S.W.; Mr. George Fowler, Assoc. Inst. C.E., Basford Hall, Nottinghamshire; and Mr. William Frecheville, Assoc. Royal School of Mines, 51, Scarsdale Villas, Kensington, W., were elected Fellows of the Society.—On a new modification of Dinosaurian Vertebræ, by Prof. Richard Owen, F.R.S. The peculiar modification of the Dinosaurian vertebra noticed by the author occurs in *Tapinocephalus Atherstonii* and *Pareiosaurus bombidens*. In the dorsal vertebræ of the former the centra are nearly flat on both fore and hind surfaces, a structure to express which the author proposes the term "amphiplatyan." The hind surface is very slightly the more concave. The middle of each surface is pierced by a small foramen leading into a cylindrical canal, first slightly expanding and then rapidly contracting to a point, which meets the apex of the similar hollow cone coming from the opposite surface. Similar characters were observed upon the free surface of the anterior sacral and upon that of the posterior of four anchylosed sacrals. The dorso-lumbar vertebræ of the *Pareiosaurus* had centra relatively longer than those of *Tapinocephalus*. Their articular surface is subundulate, convex along a fourth of the periphery, concave at the centre, where there is an excavation corresponding to that in *Tapinocephalus*, but a relatively wider aperture, a rather more constricted canal, a shorter terminal cone, and an interval of osseous tissue separating the apices of the cones from the fore and hind surfaces. In what is probably the first cervical vertebra of the same Dinosaur, the centrum is so concave on both surfaces as to become amphicœlian. In these unossified tracts of the middle of the centrum in the two genera above mentioned the author sees indications of a persistent trace of the primitive "chorda dorsalis;" and he calls attention to the resemblance thus set up between these probably Triassic Dinosaurs and the lower Ganocephalous reptiles of the Carboniferous series, in which, however, the vertebral centra are more widely perforated.—On the presence of the Forest-bed Series at Kessingland and Pakefield, Suffolk, and its position beneath the Chillesford Clay, by Mr. John Gunn. In this paper the author described a section from the cliff at Kessingland and Pakefield, from the examination of which he arrived at the conclusion that the Forest-bed series underlies the Chillesford Clay and sands. At the foot of the cliff there is an estuarine deposit forming the soil of the Forest-bed, consisting of blue clay and gravel, the "Elephant-bed" of the author's former paper. Above this is the Forest-bed, cotaining large stools and stems of trees, but no fossil bones. This is followed by a fresh-water deposit, consisting of black soil with fresh-water shells, corresponding to a similar bed at Mundesley and Runton known as the "*Unio*-bed," and including the "Rootlet-bed" of oozy clay, regarded by Mr. Prestwich as an indication of the forest. The author considers the supposed rootlets to represent brushwood which succeeded the true forest. Above this come Fluvio-marine deposits, in which Cragshells occur, although but rarely. To this division the author was inclined to refer the Norwich Crag, which at Bramerton underlies the next division, regarded by the author as the Chillesford Clays and Sands. Of the overlying deposits the first is supposed to be the "Pebbly-bed" by the author; it has been regarded as Middle Drift, and the uppermost is Upper Boulder-clay. The paper was illustrated by the exhibition of a fine series of bones, chiefly Cervine, from the lowest deposit noticed by the author.

Physical Society, Nov. 27.—Prof. G. C. Foster, F.R.S., vice-president, in the chair.—The following candidates were elected members of the Society:—Prof. Osborne Reynolds, M.A., Prof. H. J. Smith, M.A., LL.D., Prof. R. B. Clifton, M.A., F.R.S., C. Busk, J. Thomson, J. W. W. Waghorn, W. Esson, M.A., F.R.S., F. W. Bayly, and Prof. R. W. Emerson Mac Ivor.—Prof. Guthrie briefly described Dr. Kerr's recent experiments to show that glass, resin, and certain other substances exhibit a depolarising effect when under the influence of powerful electrical tension, and he exhibited the arrangement of apparatus employed in the research. He also showed certain experiments connected with the investigation.—Dr. Guthrie then made a communication on "Stationary Liquid Waves," in continuation of that which he made to the Society in June last. If water in a cylindrical vessel not less than 9 inches in diameter be agitated by depressing and elevating a flat circular disc on its surface at the centre, a form of oscillation is set up which the author terms "binodal." He finds that these fundamental undulations in an infinitely deep circular vessel are isochronous with those of a pendulum whose length is equal to the radius of the vessel, and further, a fact which is extremely interesting, that the motions of the pendulum and water keep together throughout their entire paths. An arrangement was exhibited for experimentally demonstrating these facts. To the upper end of a short pendulum with a heavy adjustable bob is attached a cardboard sector in the plane of vibration of the pendulum. A silk thread, attached to the edge of this sector, carries a small paraffin disc which rests at the centre of the surface of the water contained in a cylindrical vessel. The pendulum-length is adjusted until the motion of the disc is isochronous with that of the water when the two are not in contact. Two other forms of motion may be produced in cylindrical vessels, namely (1), by alternately compressing and extending opposite ends of a diameter as in the motion of a bell—this gives two diametral nodes at right angles to each other; and (2), by rocking the vessel, which gives a single diametral node. Each of these has its own period of vibration, the last being the slowest. They may be superimposed on each other, and a rotation of the water, however great, does not interfere with their formation. In rectangular troughs a binodal and a mononodal wave system may be established. The former is induced by raising and depressing a wooden lath at the middle of the surface, and the latter by tilting. Binodal vibration in a circular trough may be compared with a vibrating pair of triangular laths, and in rectangular troughs to the balancing of two rectangular laths. In this latter case the nodes are at $\frac{1}{4}$ of the trough length from each end. Some discrepancies are met with when we compare times of vibration in rectangular troughs of various lengths, and these are due to a scraping action which takes place against the ends of the vessel. The result of the experiments on binodal motion in rectangular vessels is to show that the undulations are isochronous with the oscillations of a pendulum whose length is $\frac{2}{\pi}$ times that of the trough. The chief points in connection with this subject to which the author referred as still requiring explanation, are: (1) Why are the motions pendular? (2) How is it that in circular binodal motion the times are identical with that of a pendulum of the given length? and (3) What is the mathematical connection between the individual motion of each particle and that of the mass? Mr. Lodge thought that valuable results might be obtained by treating the mass of moving water as a pendulum with two bobs oscillating about the node. This might be specially useful with small oscillations, when the surface is practically plane.

Anthropological Institute, Nov. 23.—Colonel A. Lane Fox, F.S.A., President, in the chair. The President read a full

report, prepared by himself, on the excavations lately made by the Exploration Committee of the Anthropological Institute in Cissbury Camp, near Worthing, Sussex, and illustrated it by a series of diagrams and models and a large collection of flint implements, flakes, &c. The animal remains found in the excavations, including the skeleton of a woman, were exhibited and described by Professor Rolleston, F.R.S.

Institution of Civil Engineers, Nov. 23.—Mr. Thos. E. Harrison, the president, in the chair. The paper read was On experiments on the movement of air in pneumatic tubes, by M. Charles Bontemps, Engineer in the French postal service.

EDINBURGH

Scottish Meteorological Society, Nov. 15.—At a meeting of the council of this society there was read a correspondence between Mr. Archibald Young, Fishery Commissioner, and Mr. T. Stevenson, the honorary secretary, regarding an investigation into the habits of the salmon.—Besides other elaborate investigations of a national character which the society has at different times undertaken, an inquiry, suggested by the president, the Marquis of Tweeddale, into the meteorological conditions which are supposed to affect the migrations of the herring, is being carried out by Mr. Buchan. For this purpose the temperature of the sea is observed at different parts of the coast; and stations where maximum and minimum thermometers are constantly immersed have been established. The investigation into the habits of fishes is now to be further extended to those of the salmon. For some years back observations have been made by Mr. Paulin on the depth and temperature of the water and the takes of fish in the Tweed, and these are being discussed by Mr. Paulin and Mr. Buchan. Observations were also made for some years on the temperature of the Doon in Ayrshire. But the inquiry suggested by Mr. Young has more especial reference to the question of the earliness or lateness of the different rivers, which among other causes may be found to be due to the temperature of the fresh water as compared with that of the salt water into which the rivers discharge. It is hoped that by means of this investigation the causes which produce late and early rivers may be elicited, and the best times for closing and opening different rivers for fishing may be more satisfactorily determined than at present. On the suggestion of Mr. Young, different late and early rivers have been selected for observation, and the necessary arrangements for carrying these on are being established, and those connected with the river Ugie, in Aberdeenshire, are now completed, and the observations will be commenced immediately. At Peterhead the Harbour Commissioners have on the suggestion of Mr. Stevenson established a station for thermometers under continuous immersion, which has for some years been superintended by Mr. Boyd, who is a member of the Committee, and who has kindly undertaken, in connection with the sea-temperatures at Peterhead, to ascertain those of the fresh waters of the Ugie.

DUBLIN

Royal Irish Academy, Nov. 8.—Dr. Stokes, F.R.S., president, in the chair.—Dr. S. Ferguson, V.P., read a paper On the alleged literary forgery respecting Sun-worship on Mount Callan.—The Secretary read a paper by Dr. Doberck, On the binary stars, 44 Böotis, ζ Cassiopeiaæ, and μ Draconis (this paper will appear in an early number of the "Transactions.")—Dr. Macalister read Notes on anomalies in the course and distribution of nerves in man. The following parts of vol. xxv. of "Transactions" were laid on the table:—Part 16, Researches on the Structure of the Spines of the Diadematidæ, by H. W. Mackintosh plates 31* to 33; part 17, on Nine-point Contact of Cubic Curves, by Dr. Hart; part 18, Experiments on the Movements of Water in Plants (part ii.), by Prof. M'Nab, M.D.; part 19, on the Binary Stars σ Coronæ, τ Ophiuchi, γ Leonis, ζ Aquarii, 36 Andromedæ, and ι Leonis, by Dr. Doberck; part 20, Report on the Superinduced Divisional Structure of Rocks called Jointing, and its Relation to Slaty Cleavage, by Dr. W. King (plates 34 to 38); this part concludes vol. xxv., and is accompanied by a title-page and table of contents; also the July and October parts of the "Proceedings."

PARIS

Academy of Sciences, Nov. 22.—M. Frémy in the chair.—The following papers were read:—Thermal researches on citric acid, by MM. Berthelot and Longuinine.—Remarks on the interpretation of two tables of chemical analyses, by M. Duchartre. This refers to treatment of beet.—On the periodicity of great movements of the atmosphere, by M. Sainte-Claire Deville. From two years' observations he shows a quadruple, dodecuple, and tridodecuple period in recurrence of barometric maxima and minima in the year.—Continued observations of eclipses of the satellites of Jupiter, made at the Observatory of Toulouse, by M. Tisserand.—New observations on the law of expansion in steam-engines, by M. Ledieu.—Remarks on the Balænides of the Japan seas, *àpropos* of the cranium of a Cetacean of this group sent to the Museum by the Japanese Government, by M. Gervais.—M. Pierre exhibited a specimen of fibres of remarkable length and tenacity, obtained by setting a stem of *Lavatera*.—On the mechanism and the causes of changes of colour in the chameleon, by M. Bert. There are two sets of nerves, the one bringing the coloured corpuscles out to the surface (and comparable to vaso-constrictor nerves), the other bringing them under the dermis (corresponding to the vaso-dilator nerves). Each cerebral hemisphere commands nerves on both sides of the body, and is generally excited through the eye on the other side; but it acts chiefly on nerves of the vaso-constrictor type on its own side, and the other kind on the opposite side. Blue violet rays act directly on the corpuscles, bringing them to the surface.—Granitic diluvium in the neighbourhood of Paris; Lithology of the sands of Beynes and St. Cloud, by M. Salvetat.—On the electrolysis of bodies of the aromatic series, by M. Goppelsroeder.—On the fixation of atmospheric nitrogen in soils, by M. Truchot.—Water of the Vanne, and distilled water; examination of the salt of brine, by M. Monier.—On the construction of lightning conductors, by M. Saint-Edme.—On the formation, structure, and decomposition of the swellings produced on the vine by Phylloxera, by M. Max. Cornu.—Observations on the planet Jupiter (continued), by M. Flammarion.—New examples of representation, by geometrical figures, of the analytical conceptions of geometry of n dimensions, by Mr. Spottiswoode.—On employment of marine chronometers in the German navy, by M. Peters.—On coordinated surfaces, such that at every point considered as centre of a sphere of constant radius, the normals to the surfaces, form in this sphere the apices of a spherical triangle of constant area, by M. Aoust.—On the numbers of Bernouilli, by M. Le Paise.—On a reaction of the homologues of ethylene, which may explain their absence in the natural petroleums, by M. Le Bel.—Remarks *àpropos* of the discovery of gallium, by M. Mendeleef. In accordance with a law he enunciated in 1869, he thinks the new metal may be ekaaluminium.—On the saccharification of amylaceous matters, by M. Bondonneau.—On stripping off the leaves of the beet, by M. Violette.—Troïlite; its true mineralogical and chemical place, by Mr. Lawrence Smith.—On certain alterations of agates and silex, by M. Friedel—On explosive compounds; influence of the fuse on compressed gun-cotton, by MM. Champion and Pellet.—Researches on the functions of the spleen, by MM. Malassez and Picard. The increase of globular richness in the blood of splenic tissue is not due to concentration of blood, for the quantity of iron diminishes.—On the ichthyologic fauna of the Isle of Saint Paul, by M. Sauvage.—Examination of rain-water in the udometers of Paris Observatory, Oct. 14 to Nov. 15, 1875, by M. Gerardin.—On the action of monohydrated and trihydrated phosphoric acid on coagulation of blood, by M. Oré.

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