Journal of Science and Arts, a description of a fish-nest which Prof. Agassiz obtained from the seaweed of the Sargasso Sea in December last.

In this interesting paper Prof. Agassiz identifies the embryos which he acquired from the nest as the young of the *Cheironectes pictus*, which, as its name implies, has fins like hands. From the description given I have no doubt but that my specimen is the *Cheironectes*, and I lose no time in forwarding to you the result of my reading. J. E. MERYON

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OCEAN CURRENTS

IN the *Philosophical Magazine* for October 1870 and 1871 I have examined at considerable length the arguments which have been advanced in favour of the theory that Oceanic Circulation is due to differences of specific gravity between the ocean in equatorial and polar regions. Since then a point in reference to the influence of the earth's rotation has suggested itself to my mind which appears to be wholly irreconcilable with the gravitation theory of currents.

It is one of the properties of a fluid that the resistance which it offers to motion is equal in all directions. It follows, therefore, that when an ocean current is flowing in any particular direction, the forces acting on the moving water must be greatest in the direction of motion. According to the theory that oceanic circulation is due to difference of specific gravity, resulting from the difference of temperature between the equatorial and polar waters, the direction of motion at the surface of the ocean is from the equator to the poles, and at the bottom from the poles to the equator, subject to a deflection caused by the earth's rotation. According to this theory gravity tends to impel the water from the equator towards the poles along the line of meridian; while rotation tends to deflect the water towards the east. If the total amount of work performed on the moving water by these two forces were equal, then the water on the northern hemisphere would take a north-easterly direction, and that on the southern hemisphere a south-easterly direction. But owing to the way in which the two forces vary in relation to each other, the path taken is not a straight line but a curve, the particular character of which has been determined with great labour by Mr. Ferrel.

But whatever view we may adopt in regard to the influence of rotation on the moving waters, whether it be that advocated by Dr. Colding and others, or that propounded by Mr. Ferrel, it is evident that if we assume the amount of the impelling energy of gravity to be not greater than the deflecting energy of rotation, we shall be led to the conclusions that there can be no such general interchange of equatorial and polar water in the Atlantic as Dr. Carpenter maintains. For under such conditions water leaving the equatorial regions for the Arctic seas would move as rapidly eastward as northward, and would consequently be deflected against the western coast of the old continent, and arrested in its progress before it reached even the latitude of England.

I need not, however, dwell further on this point, for I do not suppose there are any advocates of the gravitation theory who will not freely admit that the impelling energy is at least equal to the deflecting energy, and if this be admitted, it is all that is necessary for my present argument.

What proportion then does the impelling energy of gravity bear to the deflecting energy of rotation?

The velocity of rotation at the equator is about 1,526 feet per second, and at lat. 60°, about 773 feet per second. Were water frictionless, and did it offer no resistance to motion, then a pound of water flowing from the equator in the direction of the pole would, on arriving at latitude 60°, have, according to hitherto received ideas, an easterly velocity relative to the earth's surface of 763 feet per second. Mr. Ferrel has, however, shown that the relative velocity would be much greater. But not to run the risk of over-estimating the velocity, I shall be content to take it at 763 feet. Water flowing from the equator towards the poles, instead of having an actual velocity of 763 feet per second on reaching latitude 60°, has, at the utmost, a velocity not over one or two feet. If we suppose the velocity to be, say, 3 feet per second, then 760 feet per second of velocity derived from rotation is consumed by friction and other resistances in the passage of the water from the equator to that place. A pound of water moving with a velocity of 760 feet per second possesses in virtue of that velocity 9,025 foot-pounds of energy. This enormous amount of energy is all consumed, not in impelling the pound of water from the equator to latitude 60°, but in simply deflecting it to the east during its motion. Consequently 9,025 foot-pounds is the amount of energy required to perform the work of deflection. But since the resistance offered by a fluid to motion is equal in all directions, the resistance offered to the impelling force must be as great as that offered to the deflecting force. It is, I trust, admitted that in the passage of the pound of water from the equator to latitude 60°, the distance traversed by the water under the influence of the impelling force is as great as the distance traversed under the influence of the deflecting force, or, in other words, the distance from the equator to latitude 60°, measured along the meridian, is as great as the distance to which the water is deflected to the east during its passage. Then, if this be the case, 9,025 foot-pounds of energy of the impelling force must be also consumed in overcoming the resistance to the motion of the pound of water; that is, the impelling force requires to perform 9,025 foot-pounds of work before it can convey a pound of water from the equator to latitude 60°. Can gravitation, therefore, be the impelling force? Can gravity, according to Dr. Carpenter's theory, perform 9,025 foot-pounds of work on a pound of water in impelling it from the Equator to latitude 60°?

Taking Dr. Carpenter's own data as to the temperature of the ocean at the poles and equator, and the rate at which the temperature at the equator decreases from the surface downwards, I have shown* that 9 foot-pounds is the greatest amount of work which gravity can perform on a pound of water (placed under the most favourable circumstances) in carrying it from the equator to either pole. Assuming the slope from the equator to the poles to be uniform, 6 foot-pounds will be the total amount of work that gravity can perform upon a pound of water in its passage from the equator to lat. 60°. But this is only $\frac{1}{1500}$ part of the amount of energy required. Hence, if there is any circulation of water between the equatorial and polar regions, it must be produced by a cause 1,500 times more powerful than the one to which he appeals.

But in reality the amount of energy impelling the water must be far more than 1,500 times greater than what can be derived from gravity, for the water moves more in the direction of the impelling force than in the direction of the deflecting force, thus proving that the impelling force is greater than the deflecting force.

Although it will be admitted that the resistance offered by fluid friction is equal in all directions, yet it may be urged that, owing to the influence of the winds or some other cause or causes which I have not taken into account, the actual resistance to motion may be greater in some directions than others. This no doubt may be the case, but it cannot possibly affect the conclusion at which I have arrived, unless it be shown that the resistance to pole-ward motion is 1,500 times less than the resistance to eastward motion.

But these results are as conclusive against the theories of Maury, Colding, Ferrel, and in fact against every possible form of the gravitation theory, as against the theory of Dr. Carpenter. And I need hardly add that they are equally fatal to the theory that ocean currents are caused

* Phil. Mag., Oct. 1871.

by the heaping up of the water by the winds; for any amount of power which could possibly be derived from such a source must fall enormously short of that required.

It may be noticed that we have here a means of making a somewhat rough estimate of the absolute amount of resistance offered to oceanic circulation, a rather obscure point. It shows that the resistance to motions arising from friction is far greater than was hitherto supposed. The amount of the work of the resistance to a pound of water passing from the equator to lat. 60° cannot be less than twice 9,025 foot-pounds.

It follows also that if the resistance to motion in the waters of the ocean be as great as it has thus been proved to be, then there is no warrant for the generally received opinion that a force such as that of the winds acting on the surface of the ocean cannot produce motion extending to any considerable depth. For if the resistance to motion be as great as the foregoing consideration shows it to be, it is impossible that the upper layers of the ocean can be constantly pushed forward in one direction without dragging the underlying layers after them.

The inadequacies of the gravitation theory may be shown in an even still more striking manner. Conceive a column of water in any part of the ocean extending from the surface to the bottom. Suppose the column to be a foot square, and the depths of the ocean to be four miles. We have in this case a column a foot in thickness, and four miles in height measured from its base. According to Dr. Carpenter's theory, gravity tends to move the water forming the upper part of the column in the direction from the equator to the pole, and the water forming the under part from the pole to the equator. What then is the amount of force exerted by gravity on the entire column? In the next part of my paper on Ocean Currents in the *Philosophical Magazine* I shall demonstrate by an exceedingly simple and obvious method, that the total amount of force exerted by gravity on the whole mass of water constituting the column is only $\frac{9}{16}$ of a grain. That is, $\frac{9}{16}$ of a grain on 600 tons of water.

Edinburgh, April 15 JAMES CROLL

THE FOSSIL MAMMALS OF AUSTRALIA

THE substance of this communication was given orally at the meeting of the Royal Society, April 18, 1872.

Prof. Owen commenced by alluding to the series of fossils brought in 1836 by the then Surveyor-General of Australia, Sir Thomas Mitchell, from the bone caves discovered by him in Wellington Valley, New South Wales. The determination of these remains required study of the osteology and dentition of the existing marsupial animals, which formed the subject of papers in the "Transactions of the Zoological Society" (vol. ii., 1838, and vol. iii., 1845).

In these papers indications were given of a second species of living wombat, distinct from the type peculiar to Tasmania, such indications being yielded by a skull sent from Australia. In 1853 the author published, in his "Osteological Catalogue of the Museum of the College of Surgeons," the cranial characters of a third living species of *Phascolomys*, also from a skull, which, like that of the second species, was from the continent of Australia. These materials seemed to some naturalists inadequate for the acceptance of a *Phascolomys latifrons* and a *Phascolomys platyrhinus*, in addition to the first discovered Tasmanian *Phascolomys vombatus;* and Gould in the part published in 1855 of his great work, "The Mammals of Australia," containing the fine figure of that species, hesitated to admit more, although a drawing which he had received of the head of a wombat killed in South Australia "afforded good reason for concluding that the continental animal is really distinct." In 1859 this distinguished naturalist was able to publish in Part XI. of his work a figure of a wombat from the southern parts of the continent of Australia, which he recognised as distinct from the small wombat of Tasmania, and referred to the *Phascolomys latifrons;* it was, however, the larger bare-nosed species, *Phascolomys platyrhinus.*

* "On the Fossil Mammals of Australia," No. VIII.: Genus *Phascolomys;* species exceeding the present in size, by Prof. Owen, F.R.S.

In 1865 and 1866 specimens were received at the Zoological Gardens of London, of both the continental Australian wombats, which the able Prosector, Dr. Murie, showed to have respectively the cranial characters of *Phascolomys latifrons* and *Phasc. platyrhinus.* The *Ph. latifrons* had the nose or muzzle clothed with hair. This confirmation greatly encouraged the speaker in the investigation and comparison of the cranial and dental characters of the fossil remains of the genus; and in November 1871, he felt that he had grounds for submitting to the Royal Society such characters of four other species of wombat, not exceeding in size the largest of the existing kinds, which four species appeared to have become extinct on the continent of Australia. The differentiation of the actual platyrhine and latifront species from some of the extinct forms was not the less interesting and instructive; though it seemed small in degree, it was, however, definite, in comparison with other fossil remains which could not be distinguished from the existing *Phascolomys platyrhinus* and *Ph. latifrons.*

The determination of the species propounded on cranial and dental characters in the present paper was much easier and more decisive, by reason of the marked superiority of size of the fossils. These large and gigantic wombats were differentiated, not only by bulk, but by modifications of the skull and proportions of certain teeth, notably the incisors and premolars.

On these grounds the author characterises a *Phascolomys medius*, which, although markedly larger than *Phascolomys platyrhinus*, was intermediate in bulk between the two now known extremes of size in the genus. Next followed a *Phascolomys magnus*, and finally a *Phascolomys gigas.* Of the latter species a restoration was given in a diagram of the natural size, which was that of a tapir or small ox. The dental and certain cranial characters were illustrated by highly finished drawings of the fossils.

With respect to the large extinct wombats described in his present paper, the author remarked that it was not likely they could have escaped detection if still existing in any of the explored parts of the Australian Continent. The knowledge that such species have existed may excite to research and help to their discovery, if any of them should still be in life, in the vast tracts of the northern and warmer latitudes of Australia.

The author exhibited in a tabular view the localities of the known existing and extinct Australian wombats as follows:—

Where found	By whom found	Species of Phascolomys.
Breccia Cave, Wellington Valley, N. S. Wales	Sir Thomas Mitchell, C.B., 1836	*Mitchelli*
Lacustrine Bed, Victoria	E. C. Hobson, M.D., 1845...	*Gigas*
Drift Deposits, Queensland ...	Geo. Bennett, M.D., F.L.S., 1861	*Mitchelli*
Ib. King's Creek, Darling Downs	S. Turner, 1847 ...	*Parvus, Medius*
Ib. Gowrie, *Ib.*	Fred. Neville Isaac, 1861	*Mitchelli*
Ib. Eton Vale, *Ib.*...	Ed. S. Hill, 1865 ...	*Platyrhinus, Medius, Magnus, Gigas*
Ib. St. Jean Station, *Ib.*	M. Satche St. Jean, 1864	*Gigas*
Ib. Drayton, Queensland	Sir Danl. Cooper, Bt., 1865	*Thomsoni, Medius Magnus, Gigas*
Freshwater Beds, Clifton Plains, *Ib.*...	F. Nicholson, 1866 ...	*Gigas*
Caves, Wellington Valley, N.S. Wales	Professor Thomson, G. Krefft, 1867	*Mitchelli, Kreffti, Latifrons*

The author then touched upon some generalisations suggested by the present stage of discovery. The disappearance of the larger species was explicable on the principle of the "contest of existence," as applied by him to the problem of the extinction of the fossil birds of