of these samples yielded, with peptone, Bacteria; not so the other two. All three were prepared with the utmost caution respecting atmospheric dust, &c. That, moreover, the positive result could not be caused by an accidental admixture of germs was amply proved by the often repeated control-experiments. It appears, therefore, that, besides the glucose and the peptone, a third substance is needed for generating Bacteria, a body present in the ordinary glucose (starch-sugar), but removed by purification. The nature of this body I have not yet been able to ascertain. But however important, this matter has no direct bearing upon the question of abiogenesis. For that this third unknown body cannot be (as some will probably presume) a germ, my control-experiments and also the above-described experiment, wherein the sugar was boiled with acid, do sufficiently prove. D. HUIZINGA

Groningen, May 23

Flight of Birds

SOME time since I had occasion to ascend a mountain in the neighbourhood. The wind was blowing over the ridge-like crest of the mountain with a velocity of, I should say, ten or twelve miles an hour, sweeping with increased rapidity through certain transverse gorges cutting the ridge at right angles. In one of these I observed a hawk hovering in search of prey. In the midst of this rapid air current the bird remained apparently *fixed* in space, without fluttering a wing, for at least two minutes. After a time it gently changed its position a few feet with a slight motion of its wings, and then came to rest again as before, remaining apparently as motionless as the rocks around it. From my nearness to it a change of position of an inch would have been clearly visible, and yet except when it seemed to desire to change its point of observation no motion of any kind could be detected. How is this to be accounted for? Does a bird possess the power of giving an extremely rapid tremulous motion to its wings invisible even at a small distance, similar in its nature to the wing vibration of certain insects, which, as any one may have noticed, have a similar power of apparently fixing themselves in space over a flower, for example, notwithstanding a condsiderable amount of motion in the air in which they are suspended?

If any of your correspondents would kindly take the trouble to throw some light on these points they would greatly oblige one who is unfortunately placed out of reach of the ordinary means of reference. J. GUTHRIE

Graaff Reinet, Cape Colony, April 2

THERMO-ELECTRICITY

THE subject I have chosen is one intimately connected with the names of at least two well-known members of this University—the late Prof. Cumming and Sir William Thomson. It possesses at present peculiar interest for the physicist; for, though a great many general facts and laws connected with it are already experimentally, or otherwise, secured to science—the pioneers have done little more than map the rough outlines of some of the more prominent features of a comparatively new and almost unexplored region. Some of its experimental problems are extremely simple, others seem at present to present all but insuperable difficulties. And it does not appear that any further application of mathematical analysis can be safely, or at least usefully, made until some doubtful points are cleared up experimentally.

The grand idea of the conservation, or indestructibility, of energy:—pointed out by Newton in a short Scholium a couple of centuries ago, so far at least as the progress of experimental science in his time enabled him to extend his statements:—conclusively established for heat at the very end of last century by Rumford and Davy; and extended to all other forms of energy by the splendid researches of Joule:—forms the groundwork of modern physics.

Just as, in the eye of the chemist, every chemical change is merely a re-arrangement of indestructible and unalterable matter; so to the physicist, every physical change is merely a transformation of indestructible energy; and thus the whole aim of natural philosophy, so far at least as we yet know, may be described as the study of the possible transformations of energy, with their conditions and limitations; and of the present forms and distribution of energy in the universe, with their past and future.

It is found by experiment that some forms of energy are more easily or more completely transformable than others, and thus we speak of higher and lower forms, and are introduced to the enormously important consideration of the degradation, or, as it is more commonly called, the dissipation, of energy. The application of mathematical reasoning to the conservation of energy presented no special difficulties which had not, to some extent at least, been overcome in Newton's time: but it was altogether otherwise with the transformations of energy. And it is possible that, had it not been for the wonderfully original processes devised by Carnot in 1824, we might not now have secured more than a small fraction of the immense advances which science has taken during the last thirty years.

For a transformation of heat we must have bodies of different temperatures. Just as water has no "head" unless raised above the sea-level, so heat cannot do work except with the accompaniment of a transference from a hotter to a colder body. Carnot showed that to reason on this subject we must have *cycles* of operations, at the end of which the working substance is restored exactly to its initial state. And he also showed that the test of a *perfect* engine (*i.e.* the best which is, even theoretically, attainable) is simply that it must be *reversible*. By this term we do not mean mere backing, as in the popular use of the word, but something much higher—viz. that, whereas, when working directly, the engine does work during the letting down of heat from a hot to a cold body; when reversed, it shall spend the same amount of work while pumping up the same quantity of heat from the cold body to the hot one. As a reversible engine may be constructed (theoretically at least) with any working substance whatever, and as all reversible engines working under similar circumstances must be equivalent to one another (since each is as good as an engine can be) it is clear that the amount of work derivable from a given amount of heat under given circumstances (*i.e.* the amount of transformation possible) can depend only upon the temperatures of the hot and cold bodies employed. In this sense we speak of Carnot's Function of Temperature, which is as imperishably connected with his name as is the Dynamical Equivalent of Heat with that of Joule.

Building upon this work of Carnot, Sir W. Thomson gave the first *absolute* definition of temperature—that is a definition independent of the properties of any particular substance. Perhaps there is no term in the whole range of science whose meaning is correctly known to so few even of scientific men, as this common word temperature. It would not, I think, be an exaggeration to say that there are not six books yet published in which it is given with even an approach to accuracy. The form in which the definition ultimately came from the hands of Joule and Thomson enables us to state as follows the laws of transformation of energy from the heat form.

1. A given quantity of heat has a definite transformation equivalent.

2. But only a fraction of this heat can be transformed by means even of a perfect engine: and this fraction is DEFINED as the ratio of the range through which the heat actually falls to that through which it might fall—were it possible to obtain and employ bodies absolutely deprived of heat.

This definition has two great advantages. 1st, The utmost amount of work to be got from heat under any circumstances of temperature is determined by precisely the same law as that assigning the work to be had from

* Abstract of the Rede Lecture delivered in the Senate House, Cambridge, May 23, 1873.