geometric analysis in space-time may savour of reproducing the infinite with finite appliances.

It was already implicit in the Maxwellian æther-theory of half a century ago that a loss of energy $\delta E$ from a material system, if it occurs by radiation, involves proportionate loss of inertial mass, of amount $\delta E/c^2$, where $c$ is the speed of radiation: and vice versa. Such loss would have to fall on the internal relative potential and kinetic energies of the constituents of the radiating atom. There appears to be some astronomical knowledge now available, following on the lines of an idea recently introduced and explored by Dr. Jeans (Monthly Notices R.A.S., November 1924, just now to hand), to estimate extreme superior limits restricting the amount and duration of radiation from the sun or a star that could be conceivable from this source of supply. This new type of limit, doubtless, however, quite unapproachable, and uncertain as depending on an estimate of the internal mutual energies of the atom that may be available for running away into radiation, would stand in contrast, for example, with the famous historical estimate, enormously smaller, afforded by the running down into radiation of energy located outside the atoms, that of the mutual gravitation of the parts of the system in bulk; which was put forward in the early days of the conservation of energy by Kelvin and independently in more searching and complete manner by Helmholtz to explain the solar heat, but is now regarded on cogent grounds as inadequate for the facts of cosmic evolution when taken by itself.

Data are perhaps not entirely wanting for an estimate of the kind here described, along two ways of approach. The total energy of relative positions and motions of electrons and other ultimate nuclei in the atom, such as might by the hypothesis possibly escape into energy of radiation, can on the lines of present general ideas of atomic structure be roughly set out. Indeed, the maximum possible transfer into radiant energy for all time would be measured by the total mutual energy of the initially disgregated elements, electrons and nuclei, that first fall into chemical atoms, of orbital type, and then ultimately on their destruction lapse together into closest contact. It is conceded that if atomic nuclei are regarded as finite electric charges concentrated almost into mere points, thus involving practically infinite space-density and so allowing the charges to approach infinitely near, this amount of possible radiation could tend to increase beyond measure. But that would introduce infinities in all directions, for example, infinite inertia of an atom, and is perhaps not contemplated on any kind of theory. (As the complete transformation, vice versa, of the gases from 1 c.c. of radium releases heat to the order of $10^7$ calories, an easy computation shows that the preponderant nuclear energies of the atoms must there be very deeply drawn upon, as, of course, is now familiar, though not so much as to involve recognisable diminution of mass. Cf. Rutherford and his coadjutors, as reported in his treatise.)

There seems to be another corroborating mode of approach, which must indeed be obvious; one which also affords some confirmation of our postulate of indestructibility of the primordial atoms. It lies in the cardinal discovery of Aston that the standard relative atomic masses of all the chemical elements are expressible in high approximation by integers, with only one challenging exception. When in the cosmic process two atoms are imagined to combine, forming an atom of a more complex kind of matter, there would thus be no room for much conversion of mass into energy: the mutual energy, residing in the local fields, that can become free to run away into radiation, must correspond to the equivalent of a very small portion, perhaps on the experimental results not more than one-tenth per cent., of the total mass, however intimate be the consolidation that is required into one central nucleus for the new atom.

For astronomical purposes Dr. Jeans has made an estimate of the course of evolution for the universe, if all the matter in it were classed as a form of energy convertible into radiation. He finds, on Eddington's hypotheses, that durations of the present cosmic order ranging around two hundred millions of millions of years would become conceivable. Perhaps if only the mutual positional and motional energies of the ultimate discrete constituents of atoms could at the very most run into radiation, the energy thus assumed to be available (which is no measure of the duration of the system) must be reduced on the first estimate above by a factor which might be as small as $10^{-8}$ or as great as $10^{-5}$, and on the other by a factor which could not exceed $10^{-3}$.

Apart from such interesting change in formulation of an ultimate cosmic problem, the object of the present discussion is to concentrate on one fundamental question, which has become conspicuous in much recent ultra-physical speculation. Is matter to be regarded as consisting irrevocably of primordial atomic structures absolutely permanent: or alternatively, discarding all structural analogies based on classical dynamical principles, are the atoms, if such then really are retained, to be considered as mere concretions or aggregations liable to dissipate entirely into energy of radiation and so vanish?

## Biographical Byways.[1]

By Sir ARTHUR SCHUSTER, F.R.S.

### 7. OSBORNE REYNOLDS (1842–1912).

WHENEVER I hear of a man who is described as being lovable, the figure of Osborne Reynolds rises up before me; and yet I doubt whether on a casual acquaintance or in official intercourse that adjective would have suggested itself. In ordinary conversation he often took a cynical view of things; he was obstinate in adhering to his own opinion, absolutely uncompromising, and sometimes a little hasty in imputing selfish motives to his opponents. But the discordant elements of his character were fused together by an almost primitive simplicity of mind, and after closer acquaintance few could resist the charm of his strong personality.

His loyalty to friends and colleagues knew no bounds.

[1] Continued from p. 199.

In 1883, Mr. E. J. Stone, formerly Astronomer Royal at the Cape of Good Hope and—at the time—president of the Royal Astronomical Society, made a series of communications to the Society in which he claimed to show that the discrepancies between the lunar tables and the observed position of the moon had no reality, but were only natural consequences of the changes which had, from time to time, been introduced in the adopted mean solar day; and in particular, that the errors of Hansen's tables of the moon were due to the adoption of Leverrier's solar tables by the British Nautical Almanac. The matter was of the highest importance, as it affected our fundamental unit of time. The subject is intricate and full of pitfalls, but clear-headed men like Adams, Cayley, and Newcomb all came to the conclusion that Stone's assertion could not be maintained. I must have mentioned the matter to Osborne Reynolds. He had no special interest in astronomy; in fact, he knew very little about it, but he had been a fellow of Queen's College, Cambridge. So had Stone, and that was sufficient reason why Stone should be right. When I quoted Cayley and Adams it made no impression. Reynolds maintained the general thesis that when a man of established reputation has the whole scientific world against him, it is quite certain that the man who stands alone is right. After considering the subject for a few days he came to me and said: "I have gone into the question, and I remain convinced that Stone is right." Again two days later he expressed the same opinion. Another week passed and he recanted, admitting that Stone was wrong. But he had spent more than a week on a new, and probably uncongenial, subject in the forlorn hope of being able to support a friend.

An interesting chapter in the history of science could be written on the hampering effect of knowledge that is either deficient or too complete. Ignorance may lead astray, but perfect knowledge often acts as a brake and stops the car when a reckless spurt would take the driver into new territory. For the moment I am thinking of the early history of the radiometer, though this is not perhaps the best example that could be chosen. The manner in which Crookes was led from certain irregularities of weighing to the construction of his interesting little instrument was wholly admirable, and some of the steps in the research, such as the improvement of air-pumps, marked considerable advances, while other incidental results are of permanent value. But it is permissible to ask whether any one wholly conversant with the property of gases at low pressures, and therefore able to anticipate the effect discovered by Crookes, would have taken all the trouble to spend two years in demonstrating it. Even if familiar with Maxwell's radiation pressure, perfect knowledge would have recognised that there was no immediate hope of verifying it experimentally until the methods of obtaining high vacua were improved to a degree not dreamt of in those days.

There can be no doubt that the driving power of Crookes's work was the hope of discovering a new property of radiation. The first communication read before the Royal Society in December 1873 concludes with the following statement: "In the radiant molecular energy of cosmical masses may at last be found that 'agent acting constantly according to certain laws,' which Newton held to be the cause of gravity." He modified his views later, and ascribed the effect to light "even where there is no heat" (NATURE, Vol. 12, p. 124).

Reynolds recognised that the apparent repulsion could be explained without the help of unknown forces in the belief, at first, that they were due to condensed moisture evaporating under the influence of thermal radiation; but he soon replaced this view by the now generally accepted theory. Johnstone Stoney had put forward similar ideas which, nevertheless, differed in essential points.

During the winter of 1873–74 I suggested to Reynolds, as I had done to others, that the main question whether the repulsion was caused by internal or external forces could be solved in a very simple manner, by the reaction on the containing vessel. When I returned in November 1875 from the Siamese eclipse, I found controversies still raging, but no one had taken the trouble to try the crucial experiment. I was reluctant to do so myself, as a number of persons were working on the subject, and I have perhaps an exaggerated objection to cutting into what I consider to be other people's work. I repeatedly spoke to Reynolds about it in the hope that he would take the matter up. One evening after lecturing hours, while I was working alone in the Physical Laboratory, Osborne Reynolds entered the room and said: "I want you to do that experiment you spoke of, and to do it now. I have got everything ready for you." I went with him to the lecture room. We suspended the radiometer with an attached mirror, and, at the first trial, it behaved as it should. The vessel swung round as soon as the light fell on the blackened surfaces, and returned to its position of rest when the rotation of the vanes had reached the steady state. Reynolds would not listen to the proposal of a joint communication, and my paper appeared in due course in the Philosophical Transactions.

In his writings, as in his speech, Reynolds was difficult to understand. His brain seemed to work along lines different from those of the majority of us. He looked upon all things in an original manner, and the education of his children was one of them. I once found him playing with his little son, and nothing seemed to give him greater pleasure than when the boy did the opposite thing to that which he was asked to do. "Come here," said Reynolds, and when the child went further away Reynolds was delighted, interpreting the act as showing independence of spirit. The incident made a great impression on me.

In his later years Reynolds had difficulty in finding the right word, using sometimes one that had the opposite meaning to that required. This failing ultimately developed into a regular aphasia.

The value of his scientific work is admirably described in the obituary notice published by the Royal Society. It may be added that though his theory of the construction of the universe, on which he concentrated his whole strength at the end of his scientific life, received little support, it may yet find its place in reconciling the old and new physics.

In his lectures Reynolds was often carried away by his subject and got into difficulties. Some humorous incidents are related with regard to the manner in which he got out of them. He was once explaining the slide rule to his class; holding one in his hand, he expounded in detail the steps necessary to perform a multiplication. "We take as a simple example three times four," he said, and after appropriate explanations he continued, "Now we arrive at the result; three times four is 11·8." The class smiled. "That is near enough for our purpose," said Reynolds. It may be imagined that the average student was often puzzled; but nevertheless, the number of scientific engineers of high standing that he trained is a testimony to his teaching power, when he had the right material with which to deal. That power was not one of imparting knowledge but rather of stimulating thought.

Not long ago a representative of the University of Manchester lectured in the United States. At the conclusion of the lecture a gentleman stepped out from the audience, and addressing the lecturer, said: "I understand that you come from Manchester. I owe all my success in life to Osborne Reynolds, and I ask you to accept a cheque for the benefit of the University as a sign of gratitude." No one could wish for a higher testimonial than that.

---

## The Fossil Anthropoid Ape from Taungs.

By Sir ARTHUR KEITH, F.R.S.

THE discovery of fossil remains of a "man ape" in South Africa raises many points of great interest for those who are studying the evolution of man and of man-like apes. No doubt when Prof. Dart publishes his full monograph of his discovery, he will settle many points which are now left open, but from the facts he has given us, and particularly from the accurate drawing of the endocranial cast and skull in profile, it is even now possible for an onlooker to assess the importance of his discovery. I found it easy to enlarge the profile drawing just mentioned to natural size and to compare it with corresponding drawings of the skulls of children and of young apes. When this is done, the peculiarities of Australopithecus become very manifest.

Prof. Dart regrets he has not access to literature which gives the data for gauging the age of young anthropoids. In the specimen he has discovered and described, the first permanent molar teeth are coming into use. Data which I collected 25 years ago show that these teeth reach this stage near the end of the 4th year, two years earlier than is the rule in man and two years later than is the rule in the higher monkeys. In evolution towards a human form there is a tendency to prolong the periods of growth. Man and the gorilla have approximately the same size of brain at birth; the rapid growth of man's brain continues to the end of the 4th year; in the gorilla rapid growth ceases soon after birth.

Prof. Dart recognises the many points of similarity which link Australopithecus to the great anthropoid apes—particularly to the chimpanzee and gorilla. Those who are familiar with the facial characters of the immature gorilla and of the chimpanzee will recognise a blend of the two in the face of Australopithecus, and yet in certain points it differs from both, particularly in the small size of its jaws.

In size of brain this new form is not human but anthropoid. In the 4th year a child has reached 81 per cent. of the total size of its brain; at the same period a young gorilla has obtained 85 per cent. of its full size, a chimpanzee 87 per cent. From Prof. Dart's accurate diagrams one estimates the brain length to have been 118 mm.—a dimension common in the brains of adult and also juvenile gorillas. The height of the brain above the ear-holes also corresponds in both Australopithecus and the gorilla—about 70 mm. But in width, as Prof. Dart has noted, the gorilla greatly exceeds the new anthropoid; in the gorilla the width of brain is usually about 100 mm.; in Australopithecus the width is estimated at 84 mm. The average volume of the interior of gorillas' skulls (males and females) is 470 c.c., but occasional individuals run up to 620 c.c. One may safely infer that the volume of the brain in the juvenile Australopithecus described by Prof. Dart must be less than 450 c.c., and if we allow a 15 per cent. increase for the remaining stages of growth, the size of the adult brain will not exceed 520 c.c. At the utmost the volume of brain in this new anthropoid falls short of the gorilla maximum. Even if it be admitted, however, that Australopithecus is an anthropoid ape, it is a very remarkable one. It is a true long-headed or dolichocephalic anthropoid—the first so far known. In all living anthropoids the width of the brain is 82 per cent. or more of its length; they are round-brained or brachycephalic; but in Australopithecus the width is only 71 per cent. of the length. Here, then, we find amongst anthropoid apes, as among human races, a tendency to roundness of brain in some and to length in others. On this remarkable quality of Australopithecus Prof. Dart has laid due emphasis.

This side-to-side compression of the head taken in conjunction with the small size of jaws throw a side light on the essential features of Australopithecus. The jaws are considerably smaller than those of a chimpanzee of a corresponding age, and much smaller than those of a young gorilla. There is a tendency to preserve infantile characters, a tendency which has had much to do with the shaping of man from an anthropoid stage. The relatively high vault of the skull of Australopithecus and its narrow base may also be interpreted as infantile characters. It is not clearly enough recognised that the anthropoid and human skulls undergo remarkable growth changes leading to a great widening of the base and a lowering or flattening of the roof of the skull. In Australopithecus there is a tendency to preserve the fœtal form.

When Prof. Dart produces his evidence in full he may convert those who, like myself, doubt the advisability of creating a new family for the reception of this new form. It may be that Australopithecus does turn out to be "intermediate between living anthropoids and man," but on the evidence now produced one is inclined to place Australopithecus in the same group or sub-family as the chimpanzee and gorilla. It is an allied genus. It seems to be near akin to both, differing from them in shape of head and brain and in a tendency to the retention of infantile characters. The geological evidence will help to settle its relation-