In the deposit with the human remains were found a number of obsidian tools mainly of a more primitive type than those from Nakuru, but including a few lunates and other Nakuru types. There was also a certain amount of pottery, some of it with the same decoration as found on the Nakuru examples; numerous animal bones, including skulls, mandibles, and teeth; disc shell beads; and one stone bowl similar to one of the Nakuru types.

At first it was thought that the skulls from the two sites were of the same type, but this is not substantiated by a close comparison made recently, although there are certain similarities. It is even doubtful if all the skulls from the Elmenteita site will prove to belong to the same race. Nevertheless, all the mandibles from this site show common characters, while they differ markedly from the Nakuru mandible.

Skull A from Elmenteita is certainly different from Skull No. 9 from Nakuru. The photographs (reproduced as Figs. 1 and 2) show both the similarities and the differences. In the Elmenteita skull the forehead is low and receding; the nose is much longer than in the Nakuru skull, while the width is much the same, this resulting in a lower index, which is actually 47·4. Moreover, instead of a sill at the base of the nose there is a groove; there is a trace of sub-nasal prognathism, the alveolar index being 103; the height of the vault is nothing like so great, while the mandible is of a quite different type. This is amply brought out in the photograph. The similarities lie in the length of the skull as compared to the breadth, the cranial indices being 68·2 (Elmt.) and 69·8 (Nak.); the upper facial length, which is 80 mm. in both specimens; and the bi-zygomatic breadth, which in each case is greater than the maximum skull breadth, being 136 mm. (Elmt.) and 140 mm. (Nak.).

Another skull type found at Elmenteita has a much broader skull, giving a cranial index of 76. It has a good forehead, and is orthognathous. This type, however, also differs from the Nakuru type.

Perhaps the most surprising feature of the Elmenteita crania is the narrowness of the nose as compared with the length. The four specimens upon which it is possible to take measurements yield the following results:

	Length.	Breadth.	Index.
Skull 'A' . .	59 mm.	28 mm.	47·4
Skull 'B' . .	60 mm.	24 mm.	40
Skull 'C' . .	50 mm.	22 mm.	44
Skull 'D' . .	50 mm.	22 mm.	44

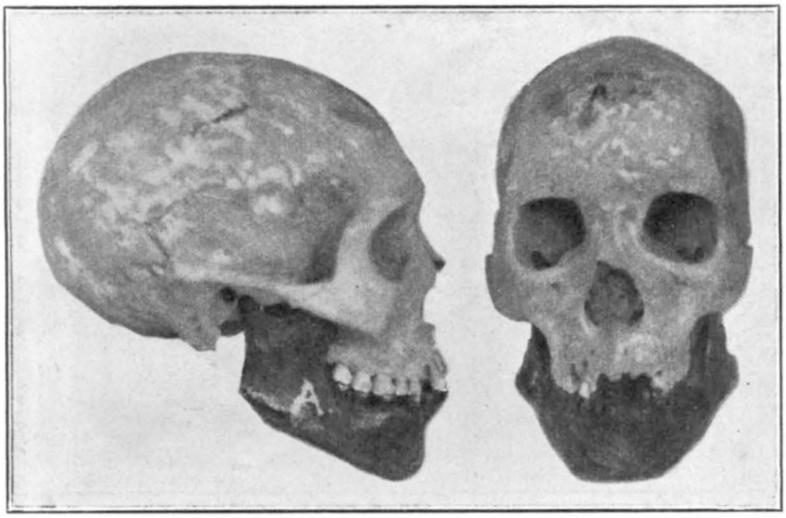

FIG. 2.—Side and front views of Skull A from the Elmenteita site.

These figures are certainly not those suggestive of negro affinities. It seems doubtful even if those Negroid races which to-day have narrow noses can approximate to these figures.

Full details of the work done and objects found will be published as soon as possible after our return to England in September with this season's specimens.

In NATURE for Jan. 8, p. 61, there is a short note on my work based on a report in the *Times* of Dec. 28, 1926. This note contained some inaccuracies and I would be grateful if I may be permitted to correct two of them. I am referred to as "of the Cutler Dinosaur Expedition." I am not a member of this expedition, nor, so far as I know, has an expedition under such name existed out here. In 1924 I had the honour of being, for one year, a member of the British Museum East Africa Expedition which was excavating for Dinosaur remains in Tanganyika Territory under the leadership of the late Mr. Cutler. Further on, reference is made to my "work in investigating stone-age remains in Uganda." Nairobi and Nakuru are towns in Kenya Colony, and it is regrettable that the archæological work in the two countries should be confused.

Some Difficulties in Relativity.

By Prof. S. BRODETSKY, University of Leeds.

THE special theory of relativity was formulated by Albert Einstein twenty-two years ago. The general theory with its application to universal gravitation was published eleven years ago. The relativistic viewpoint has become an accepted principle and instrument in physical science. Yet a complete understanding of the ideas underlying it is comparatively rare among laymen, and far from being universal even among men of science. This is natural, since the theory of relativity presupposes a break with preconceived notions, hallowed by unquestioning acceptance at the hands of untold generations of experience and thought. We shall in this article consider a few of the difficulties that have come to the notice of the writer.

At bottom, the cause of all the difficulties associated with the special theory is the fact that the signals, which we have used from time immemorial for the purpose of correlating events at different places, travel so fast that it only became possible quite recently to measure their speeds. Even sound travels much faster than anything experienced in actual life until a few generations ago. Light travels so fast, indeed, that to many people it is still a matter of surprise to hear that it is not instantaneous in its effects. Our primitive conceptions of time and space are therefore such as correspond to an infinitely fast signal, and a readjustment of ideas is required in order to reach conceptions of time and space that correspond to a signal that travels with finite and measurable speed.

Thus it appears to some people somewhat arbitrary to lay down the postulate that in empty space (infinitely far removed from the influence of matter) the speed of light must be the same to all observers, no matter what velocities they may have relatively to one another. Not everybody can visualise readily two frames of reference and argue from one to the other. Perhaps the argument will appear simpler if put as follows.

It is as much a fundamental of classical mechanics as it is of relativity mechanics that we cannot discover the absolute motion of a material body. Modern astronomy has long since discarded such views as the fixity of the centre of the earth, or of the centre of the sun, or of the centre of mass of the solar system, or of the centre of mass of the stellar system in which we live. We cannot say, therefore, what is the absolute motion of any material body, such as a long bench. Take two points, AB, fixed on this bench: Can we correlate the times at these two points? This is only possible by sending a signal from A to B. If A sends out this signal at, say, ten o'clock on his watch, B receives the signal and knows that it is then ten o'clock to A.

The signal, however, takes some time to go from A to B, and naturally B will make a correction for this by saying that he receives the signal later than it leaves A, the delay being the distance AB divided by the speed of the signal. Now the bench AB is itself in motion in a manner which is quite unknown. Suppose that it moves with velocity u from A to B: then the speed of the signal relative to AB will be diminished by this amount, so that if its absolute speed is c the delay between A and B is $AB/(c-u)$. But u is unknown. Hence the delay is unknown, and we reach the conclusion that it is quite impossible to correlate the times at A and at B!

We refuse to accept such a conclusion, because it destroys the basis of all natural knowledge. There are only two ways of escaping this conclusion. One is to suppose that c is infinite; the other is to assume that the speed of the signal relative to the bench is quite independent of the motion of the bench, so that if this speed is called c, the delay is always AB/c.

Now even if we could imagine or postulate a mystical signalling agency which travels with infinite speed, we must remember that scientific observations are made with the aid of instruments like telescopes and microscopes, which presumably cannot philosophise, and can only register events as impressed on them by natural agencies. All our observations, whether directly or with instruments, depend upon visual or optical coincidences (sound is never used for really accurate measurements). We are therefore forced to postulate that light travels with a finite speed which is independent of the motion of the observer. Further, we must restrict this postulate to light, and accept that other speeds are affected by the motion of the observer: otherwise we would come into conflict with common experience. Besides, the convection coefficient $1-1/\mu^2$, which gives the amount by which the speed of light in a medium like water (refractive index μ) is affected by the motion of the medium itself, is a direct proof that the fundamental speed which remains unaffected by the motion of the observer is indeed the rate at which light travels in a vacuum.

Another difficulty that has been mentioned is the following. According to relativity, apparently, if an interval of time is measured by two observers A and B, then the value obtained by A will bear to the value obtained by B the ratio $(1-v^2/c^2)^{-\frac{1}{2}}$, where v is the velocity of B relative to A. But the velocity of A relative to B is $-v$, so that the value obtained by B should also be $(1-v^2/c^2)^{-\frac{1}{2}}$ times the value obtained by A. This sounds absurd, and is reminiscent of the rather tantalising game with paradoxes that exponents of relativity used to indulge in before admiring and bewildered audiences. But consider the facts carefully.

The Lorentz transformation is:

$$x' = \frac{x-vt}{(1-v^2/c^2)^{\frac{1}{2}}}, \quad y'=y, \quad z'=z, \quad t'=\frac{t-vx/c^2}{(1-v^2/c^2)^{\frac{1}{2}}},$$

where (x, y, z, t) refer to A, and (x', y', z', t') to B, the direction of the relative motion being along the x, x' axes. Hence we get

$$\Delta t' = \frac{\Delta t - v/c^2 \, . \, \Delta x}{(1-v^2/c^2)^{\frac{1}{2}}},$$

$$\frac{dt'}{dt} = \frac{1 - v/c^2 \, . \, dx/dt}{(1-v^2/c^2)^{\frac{1}{2}}}.$$

The ratio of the intervals dt, dt' thus depends also on dx/dt. If dx/dt is zero, we get $dt'/dt=(1-v^2/c^2)^{-\frac{1}{2}}$. But now let $dx/dt=v$; then $dt'/dt=(1-v^2/c^2)^{\frac{1}{2}}$. Whereas in the first case we measure an interval between events at a place fixed relative to A, we are in the second case measuring an interval between events at a place fixed relative to B. There is no inconsistency; the results are in fact consistent and logically correct.

A further difficulty arises in a similar way. If B have velocity v relative to A, then both x' and t' in terms of x and t have the same factor $(1-v^2/c^2)^{\frac{1}{2}}$ in their denominators. Hence it would seem that any velocity ought to appear the same to both A and B!

The fallacy lies in arguing from

$$x' = (x - vt)/(1 - v^2/c^2)^{\frac{1}{2}}$$

with $t = 0$, and from

$$t' = (t - vx/c^2)/(1 - v^2/c^2)^{\frac{1}{2}}$$

with $x = 0$, and then applying the two results, obtained for different conditions, to a velocity, in which the length and the time refer to the same conditions. The correct procedure is thus:

$$\frac{dx'}{dt'} = \frac{dx - vdt}{(1 - v^2/c^2)^{\frac{1}{2}}} \Big/ \frac{dt - vdx/c^2}{(1 - v^2/c^2)^{\frac{1}{2}}}$$

$$= \frac{dx - vdt}{dt - vdx/c^2} = \frac{dx/dt - v}{1 - v/c^2 \,.\, dx/dt}.$$

In order to get $dx'/dt' = dx/dt$ we must have

$$\frac{dx}{dt}\left(1 - \frac{v}{c^2}\frac{dx}{dt}\right) = \frac{dx}{dt} - v$$

which leads to (i.) $v = 0$ or (ii.) $dx/dt = \pm c$. (i.) is trivial; (ii.) means that only the speed of light is the same to both observers.

In the general theory of relativity very few persons attempt to follow the reasoning that establishes the equations of the gravitational field, and most people are prepared to take for granted the definition of ds^2 in terms of the differentials of the four space-time co-ordinates. Where they begin to see 'physical' arguments is in connexion with the statement that the path of a particle of very small mass must be a 'geodesic' in the space-time continuum thus defined. The following difficulty has been raised: "It is said that the nearest way from any place to any other place on the earth is by following a geodesic. Surely this is not the case, for the nearest way is through a tunnel cut in a straight line."

It is an unfortunate fact that the best examples of geodesics are in connexion with curves on surfaces. These examples are therefore invoked in order to bring nearer to the minds of laymen the notion of geodesics in general. The effect is seen in the puzzle just quoted, and in the conclusion reached by the questioner: "Einstein's idea of space seems to be that which a fly might have walking round inside a glass globe."

When we talk about a geodesic on a surface, then we postulate a being that is restricted to moving about on the surface, and is physically and constitutionally incapable of getting away from the surface. The being may have intellectual knowledge of points off the surface, but such points are outside its physical or dynamical ken. Thus a tunnel through the earth is simply irrelevant to the question of geodesics on its surface. This is in actual agreement with life, as tunnels which are of such a length as to produce shortening of the path relative to the geoid are outside the domain of the practical, and all tunnels in use are constructed for the purpose of keeping as close as possible to the geoid and realising the geodesics on it.

Simplification, however, does not always lead to intelligibility, and it is doubtful whether the non-mathematical student of relativity is well advised to envisage geodesics on a surface, in order to understand geodesics in the four-dimensional space-time continuum. Consider rather geodesics in three dimensions in the following sense. In modern practical life time is often more important than distance, the former being endowed with an economic cash value denied to the latter. If A, B are two points in space, how can one go from A to B in the shortest possible time? If the space is empty, and there are no aids or hindrances in the form of accelerative forces or resistances, intuition tells us that the geodesic (in the time sense) is what we ordinarily call the straight line joining A to B in empty Euclidean space. But now suppose that the space contains aids and hindrances to the motion. Suppose, for example, that between A and B there is a slab of matter through which the motion is necessarily slower than in the empty space. Then one needs no mathematics to see that unless the slab has plane parallel faces perpendicular to the line AB, the geodesic is not the straight line AB. The path of a ray of light in passing obliquely through a thick plate of glass is a relevant and clear example. Still more striking is the path of a ray through a prism. The time taken by the light in travelling between two points, one on each side of the plate or prism, is less than what would be required for any other path between these points, and deviating only slightly from the actual path.

The advantage of considering geodesics in three dimensions is two-fold. In the first place there are no 'tunnels' to distract attention. In the second place it is not very difficult now to conceive that the four-dimensional space-time continuum has varying properties from place to place, so that a geodesic would not in general be straight as understood in the empty space of Euclid. The path of a particle would thus be curved, as viewed from the standpoint of empty Euclidean space, and it is not difficult to see that the natural paths may be, say, circular or elliptical, or in accordance with the more complicated results of the general theory of relativity.

This brings us to the last difficulty which we shall discuss here: it is in connexion with the bending of light rays which are affected by the sun's gravitational field, or rather by the properties of the space-time continuum in the neighbourhood of the sun. Can this not be attributed simply to the attraction exerted by the sun on the light—since we now know light to have both corpuscular and wave properties? It has been argued that even if the observed deflexion is found to be double that given by Newton's law of gravitation in accordance with classical mechanics, yet one might "doubt whether such a calculation is possible until we know the size and mass of the corpuscular element of light with the same degree of accuracy as we know the size and mass of electrons."

The fact is, of course, that the deflexion that would be obtained on the basis of the Newtonian theory is quite independent of the size and mass of the hypothetical corpuscular element of light. One might indeed invent some modification of the classical Newtonian theory so as to obtain the observed deflexion. But there is surely no point in postulating a theory which does not exist, in order to avoid accepting a theory which sums up in a remarkable manner so many of the laws and phenomena of mechanics, astronomy, and optics.

We all love sensations, and recently a prominent daily newspaper published a column about an alleged forestalling of Einstein by a German astronomer, who a century ago calculated the deviation of a ray of light on the basis of Newton's law of gravitation and the corpuscular theory of light. The formula there given is actually a correct deduction from the inverse square law, but when it is worked out numerically the result is just half of Einstein's value, and of the average value obtained at the eclipses in recent years. The relativity theory of gravitation not only 'explains' gravitation in the sense of representing it as a deduction from reasonable views of the space-time continuum, giving as a first approximation the Newtonian inverse square law, but also yields just the correction required to account for the observed motion of Mercury, and further gives a deflexion of light rays passing near the sun in agreement with observed fact.

Obituary.

MR. A. D. MICHAEL.

THE debt which natural science owes to the work of amateur microscopists has often been commented on. Not a few names of weight in systematic zoology are those of men who turned a fascinating hobby into a serious study, and by patient and prolonged observation acquired a familiarity with the living creatures that the professional zoologists often have cause to admire and envy.

Of this type was Mr. A. D. Michael, well known as an authority on the mites (Acarina), whose death at an advanced age was recently reported. Not only did he produce admirable systematic monographs on several families of the group, but also he was successful in unravelling many details of their often complicated and puzzling life-histories. Together with his wife, who assisted in all his researches, he acquired remarkable skill in minute dissection, and his accounts of the internal anatomy of many forms will not soon be superseded. One of his most interesting discoveries concerned the forms known by the name Hypopus, which are minute, hard-shelled mites with vestigial mouth-parts, found attached to various winged insects by means of suckers. Their nature had been the subject of a great deal of discussion, but by patient observation and experiment Michael was able to show conclusively that the Hypopus is an alternative developmental stage in the life-history of various Tyroglyphidæ (the family which includes the cheese-mite) adapted to secure the dispersal of the species.

Mr. Michael was born in London in 1836. He was educated at King's College, London, and became a solicitor, succeeding to his father's practice. He seems to have taken up microscopy shortly after his marriage in 1865, but his first published paper on the Acari appeared in 1878. His later publications, some fifty in number, appeared mainly in the *Journal of the Royal Microscopical Society*, the *Journal* and the *Transactions* of the Linnean Society, and the *Journal of the Quekett Club*. Nearly all of these were finely illustrated by his own pencil, as were also his monographs of the British Oribatidæ (2 vols., 1883, 1888) and British Tyroglyphidæ (2 vols., 1901, 1903) published by the Ray Society. In 1898, he contributed a revision of the Oribatidæ of the world to "Das Tierreich." He was in succession president of the Quekett Microscopical Club (1885–87) and of the Royal Microscopical Society (1893–96), and vice-president of the Linnean Society (1896–1900). Shortly before his death he presented his large collection of finely prepared microscopic slides of Acari to the British Museum (Natural History) and his microscopes to the Royal Microscopical Society. He died in a nursing home at Bournemouth on June 16 last.

W. T. C.

AN appreciation by C. Hart Merriam in *Science* of April 8 of Dr. William Henry Dall, reminds us that by the death of this veteran conchologist on Mar. 27 last, zoology is deprived of one of the last remaining naturalists of the old school. Although chiefly known as a student of the Mollusca, Dr. Dall's activities were by no means confined to this group, his papers and monographs on a variety of subjects all ranking high in scientific literature. His earlier work was chiefly on the natural history of Alaska, which he visited as one of the scientific staff, and later as head, of the Western Union International Telegraph Expedition. Besides exploring and mapping much of the Yukon River, he found time for observations on birds, fishes, and whales, the results of which, as well as geographical works on Alaska, were all published before 1880. From 1871 until 1874, Dr. Dall was surveying the Aleutian Islands and adjacent coasts; from 1880 until his death he was honorary curator in the National Museum, and palæontologist of the United States Geological Survey from 1884 until 1925. From 1893 until 1927 he held the chair of invertebrate palæontology in the Wagner Institute of Science, from 1899 until 1915 was honorary curator of the Bishop Museum, Hawaii, and in 1899 again visited Alaska with the Harriman Alaska Expedition as one of the scientific guests. Dr. Dall's unique experiences thus render his works peculiarly valuable, whether he is remembered as a zoologist, palæontologist, or explorer.