lattice if the metal is pure. Obviously, the composition of this layer will depend upon that of the bulk of the liquid and upon the affinities of the iron ions for the nitric acid and the water. We may regard the nitric acid as ionised, but not so the water, because its ionisation is known not to be increased by the presence of dissolved electrolytes. Owing to the symmetry of the water molecule, it is impossible to say which H atom will break away and which will remain in the OH group in the event of ionisation.

Now it is highly probable that the chemical force, between ions even, is not wholly electrical, and we may assume that the nitrate ion and the water molecule will be attracted to their respective iron ions with forces which result in the setting up of an e.m.f. in the metal. If this e.m.f. is large enough, one of the metal ions will be discharged into the liquid momentarily as ferric nitrate, and in the model the atoms marked (*a*) will form water, the remaining H will be momentarily liberated, and positive current will flow as indicated by the arrows.

Two factors will make for passivity: a low electrode potential and homogeneity of the double layer above AB. Impurities in the metal will modify its electrode potential as well as the composition of the double layer. We find passivity a common property of the noble metals almost irrespective of the composition of the double layer, whereas with highly positive (active) metals passivity is never observed. In the case of intermediate metals passivity occurs only with certain kinds of double layers, and if these are unstable periodic action may result. Since the forces are not wholly electrical there is less chance for an electrostatic equilibrium—and consequent passivity—to be set up, and for this reason it seldom occurs with these metals.

A sufficient disturbance of the surface layer, by scratching, touching with a more electro-positive metal such as zinc, placing in a magnetic field, or heating, will, in conformity with experience, activate passive iron. It is significant that Smits and Lobry de Bruyn (Proc. K. Akad. Wetensch. Amsterdam, vol. xxi., p. 382, 1919) find that chlorine ions activate anodically polarised iron. Thus it seems that iron ions in the surface of the metal have a preferential affinity for Cl' over NO_3'. W. HUGHES.

Bedford Modern School, January 10.

The Space-Time Hypothesis before Minkowski.

IT is, perhaps, not generally realised that the theory of space and time, to which Minkowski was led on experimental grounds, had been formulated on general principles sixty-five years previously by Hamilton, the Irish mathematician. The point is, however, of interest, not merely as a question of priority, but for the insight it affords into the philosophic basis of the theory, as well as for the useful mathematical methods it suggests.

It is curious, therefore, that there should be a lack of recognition that the world of Minkowski is in all points identical with the system of quaternions of Hamilton, and that the latter mathematician specifically regarded this system as a four-dimensional expression of space and time, in which space bears to time the relation which $\sqrt{-1}$ bears to unity, time being the scalar part of the quaternion.

Quotations may be given from Hamilton's letters and manuscripts, cited in his "Life" by Graves, which leave no doubt on this matter.

Thus, vol. ii., p. 478:

"Let me suggest one leading thought, which will perhaps sound paradoxical, that time and space are imaginary, each with respect to the other. . . . Any expression for the peculiar relations of space in the forms of time, or for those of time in the forms of space, must therefore involve a seeming contradiction . . . it will be a 'mathematical imaginary.' This seems to me to be the clue, the secret of the matter."

Vol. iii., p. 635:

"The mathematical quaternion . . . in technical language may be said to be 'time *plus* space,' or 'space *plus* time,' and in this sense it has, or at least it involves a reference to, four dimensions."

In another place:

"My real is a kind of fourth dimension equally inclined to all directions of space."

Many other allusions will be found which prove that this idea was fundamental in the views of Hamilton, and that he held to it with the greatest tenacity, although there were at that period no experimental considerations to justify it, and although De Morgan and other mathematicians seem to have discouraged it, or ridiculed it. At the same time it does not appear that Hamilton has given an analysis of space and time which exhibits with sufficient clearness the concept of direction in space as being peculiarly attached to the symbol $\sqrt{-1}$, and the concept of positive and negative unity as being similarly connected with the two directions of time, towards the future and the past.

It is, however, easy to supply such an analysis, the clue being given by noting that to define a number by the equation $x^2+1=0$ virtually defines it as "a unit which cannot be differentiated from its own negative by any *qualitative* distinction."

It indeed appears to have been in the thought of Hamilton, as it must occur to anyone who considers the matter, that the connection between a root of the equation $x^2+1=0$ and a direction of space is to be looked upon as more than a mere symbolism; but the general philosophic bearing of such considerations on the whole nature of space and time is scarcely appropriate for discussion here. It may, however, be remarked that they indicate a point of view in which time and three-dimensional Euclidean space lose their apparently contingent character, and approach the necessity of the laws of arithmetic, of which they appear as a kind of derivative.

It should be added that practical advantage might be derived by mathematicians from the application of the methods of quaternions to the theory of relativity, for, besides offering a convenient mode of development of the geometry of four dimensions, either Euclidean or hyperbolic, according as Tq or $\sqrt{Sq^2}$ is taken as the element of length, they suggest important possibilities in connection with the inversion of a linear quaternion function analogous to the physical applications by Tait of the linear vector function. E. H. SYNGE.

Dublin, January 6.

Heredity and Acquired Characters.

WILL you permit a statement from a humble student? Between twenty-two and twenty-seven years ago, while in Malabar, opportunity was taken by me to ascertain whether the arms of rowers on the backwaters and the arms of the toddy-drawers were longer in proportion to the height than in the case of the rest of the population, for here seemed to offer a test whether "inheritance of the effects of use" was evident. In both cases the men belonged to a caste which had not changed its occupation for many hundreds, perhaps some thousands, of years: the former indigenous, while legend attributed the ancient home of the latter to Ceylon, where they were occupied in the same way—climbing and tapping the palm-trees