extension provides far more mathematical variables than the physicist can utilise. Einstein's development is more promising, since he boldly accompanies this extension with a restriction; and room is made for the new variables by sweeping away old ones. Moreover, he renders his restriction plausible by putting it in the form of a geometrical postulate of distant-parallelism.

It will thus be seen that Einstein makes a striking new departure; the rest of the development may be briefly summarised. The condition for integrability of (3), namely, the vanishing of the curvature tensor, leads to two important identities satisfied by the $\Lambda_{\sigma\tau}^{\mu}$. This rather raises an expectation in the reader's mind that the field laws are about to appear as identities; but this is not fulfilled. A field law of simple form is duly announced, looking indeed so much like one of the identities that it requires a careful inspection of the suffixes to see the distinction. Here I would venture on a criticism. Can any theory which requires field laws other than identities give real satisfaction? To introduce a field law limiting the geometrical possibilities is a confession that the initial geometry was too wide. The ideal should surely be either to start with a geometry which precisely fits the phenomena so that it needs no supplementary field laws, or to start with the most unrestricted geometry and treat every limitation as a field law.

The consequences of the field law are worked out only to a first approximation, and therefore some of the questions we should wish to put remain unanswered. "A fuller investigation will have to show whether a Riemann-metric in conjunction

with distant-parallelism actually gives an adequate conception of the physical qualities of space. According to this research it is not improbable."

In any comparison of these theories it should be borne in mind that what is being given is a graphical representation bound by no particular rules. To say that Einstein's or Weyl's or Eddington's illustrative geometry is the only right one would be like saying that a graph of a moving particle with time and space as co-ordinates is right but a graph with velocity and curvature as co-ordinates is wrong. World-geometry is very like other graphs; if wisely chosen it may exhibit or suggest relationships, provide useful nomenclature, and generally assist the mind in orderly thought. More hazardously it may be supposed to shadow the structure of the substratum of physical phenomena. I do not think Einstein has this last aspect in mind, or he would have stressed the vanishing of the curvature tensor (which might be visualised as a structural attribute of the æther) rather than the formal property of distant parallelism. I take it that he commends his graph to our notice as a means of exhibiting in its simplest form the mutual interdependence of gravitational and electrical quantities. For my own part I cannot readily give up the affine picture, where gravitational and electrical quantities supplement one another as belonging respectively to the symmetrical and antisymmetrical features of world measurement; it is difficult to imagine a neater kind of dovetailing. Perhaps one who believes that Weyl's theory and its affine generalisation afford considerable enlightenment, may be excused for doubting whether the new theory offers sufficient inducement to make an exchange.

Human Speech.¹

By Sir RICHARD PAGET, Bart.

HUMAN speech—which is practised by all races of mankind—is a rough combination of two separate arts, namely, phonation, due to the reed-like action of the vocal cords, and articulation, due to the various movements of the jaw, lips, tongue, soft palate, epiglottis, and false vocal cords. Phonation is the language of the emotions, while articulation is the language of the mind—phonation being, as Darwin realised, the older art.

The mechanism of the vocal cords may be very simply imitated by cutting a longitudinal slit about 3 cm. long in an indiarubber tube of, say, 1 cm. internal diameter. If the tube be stopped at about 5 cm. from the slit, and air be blown in at the other end, the air passing through the slit may be set in vibration so as to produce a musical note. The conditions for this effect are most easily obtained by adjusting the resonance of the air inside the tube adjoining the slit—by varying the position of a constriction or partial stop applied between the slit and the air supply. At any position at which 'phonation' occurs under normal conditions of the slit, a musical range of about six or seven

semitones can be obtained by varying the tension of the slit portion of the tube, the note rising as the tube is stretched. As the resonating length is shortened (so as to raise the resonant pitch) the musical range is transposed to a higher key, the range of transposition in the present experiment being also about seven semitones.

It is suggested that the so-called 'registers' of the human voice are due to a similar set of conditions, and that the changes of resonance are produced by variation of the size and shape of the cavity into which the vocal cords 'deliver,' namely, that made by the false vocal cords and other movable parts of the pharynx. At each setting of this cavity a new range of notes is then obtained, depending on the tension and thickness of the vocal cords.

The lips of a trumpeter behave in a very similar way, but the resonance changes, if any, must then be made (as in the rubber-tube model) in the passage behind the reed instead of in the cavity into which it delivers, as in the case of the vocal cords.

The lungs, besides functioning as bellows, are a very efficient sound absorber, the branching air

¹ Substance of two lectures delivered at the Royal Institution on Dec. 6 and 13, 1928.

passages and air cells acting like a shelving beach towards waves of the sea, to convert the sound waves that pass down the windpipe into heat.

In whispered speech we have articulation without phonation. Whispered speech, therefore, lacks the emotional range of voiced speech. All the English speech sounds can be rendered in a whisper, and it appears that the real distinction between the so-called voiced and unvoiced consonants, such as *b* and *p*, *v* and *f*, *dh* and *th*, *z* and *s*, etc., is due to the action of the false vocal cords.

The action may be illustrated by a model in which the vocal cords are shaped in plasticine, as if in an open (whispering) position, and deliver their air jet into a rubber tube 2.5 cm. in diameter, which acts as the pharynx of a vowel-sounding tube. If, while air is supplied to the model, its mouth is alternately obstructed and released by hand, a whispered *p* is heard when the pharynx tube is uncompressed, but the sound is changed to a whispered *b* if the pharynx tube is compressed so as to form a constriction at 2 to 3 cm. in front of the fixed vocal cords. These conclusions have been confirmed by direct observations made in America by Prof. Oscar Russell, of Ohio University.

Another recently observed action of the pharynx is its production of the high-pitched resonances—of the order of 2500-3000~—which I have observed by ear in the case of certain of my own vowel sounds, and which have also been disclosed by instrumental methods at the Bell Telephone Laboratory in New York. That these resonances (in my own case) are pharyngeal, is shown by the fact that they can be lowered in pitch by five or six semitones by external (transverse) pressure on the throat immediately above 'Adam's apple.' They cannot be consciously varied without external aid. It is evident that the pharynx plays a very large part in the process of articulation in modern speech.

Originally, it is suggested, articulation was evolved as a specialised form of pantomimic body gesture, by which primitive man, like his animal relations, was accustomed to explain himself to his fellows. Darwin, in "The Expression of the Emotions," pointed out that there is, in man, a natural sympathy of movement between the human jaw and tongue and the human hand, so that children learning to write are seen to twist about their tongues as their fingers move 'in a ridiculous fashion.' As primitive man pantomimed with his hands and body generally, his tongue took part in the game without his being aware of the fact, and thus it developed a pantomimic technique of its own. When the pantomimist wished to direct attention to his actions, he made grunting or blowing noises, and the (unconscious) movements of his tongue then modified the air flow and the acoustic resonances of the vocal cavities through which the air passed. In this way the bodily pantomimic code became associated with an acoustic code, which developed into speech.

The various tongue gestures were necessarily simpler and fewer in number than the corresponding hand gestures, since (as would be found by experience) lateral movements of tongue, lips, and

jaw do not appreciably alter the vocal resonances. The movements of articulation are therefore practically limited to two dimensions, whereas the hand and body gestures work in three. It follows that in human speech a particular gesture of articulation may represent several originally different body gestures—in other words, that speech was always more ambiguous than the pantomimic sign-language.

The original pantomime and speech of primitive man may be conceived as analogous to the bodily pantomime which is naturally developed by deaf-mutes, and by which a deaf-mute of one country can without difficulty make himself understood by one of another country, of whose written and spoken language he is wholly ignorant. Just as various communities of deaf-mutes naturally evolve new signs and conventions of their own—which other deaf-mutes cannot understand until they have especially learnt them—so the tribes of primitive men may be imagined to have evolved local words, idioms, and conventions from which the various language groups of the world were developed.

The theory that speech is due to mouth pantomime was, I believe, first enunciated by Dr. J. Rae, of Honolulu, in *The Polynesian* newspaper for 1862, but Socrates, according to Plato in the *Cratylus*, came very near the same idea; Dr. A. R. Wallace, writing in 1895 in *The Fortnightly Review* (No. 64), also put forward the theory that mouth pantomime constituted a "fundamental principle which has always been at work, both in the origin and in the successive modifications of human speech."

The evidence which has now been accumulated seems to justify a more serious consideration than has yet been given to the theory. Thus it appears, on experimental grounds, that in listening to speech our ears are not primarily interested in the sounds themselves, but rather in the evidence which the sounds afford as to the postures or gestures of the tongue and other organs of articulation. The facility with which the deaf may be taught to understand speech by 'lip-reading,' in spite of the very limited information which sight alone can afford as to the movements going on inside the mouth and throat, points in the same direction. Children, when inventing words of their own, very commonly employ a form of mouth pantomime—thus, of 18 such words mentioned by Prof. O. Jespersen at p. 152 of his book on "Language," 12 appear to be pantomimic: for example, 'fu-we = soap—a gesture of blowing away soapsuds; de-detsh = horse—a galloping gesture made with the tongue.

Grown-up people occasionally do the same—as witness the invention of the word 'blimp' to denote the small podgy dirigible balloons which were developed during the War. The word is produced by a small-mouth gesture (producing the sound *bī*) followed by the 'podgy' gesture *mp*, with an intermediate upward flick of the tongue, *l* (as if to suggest an attachment to the middle of the 'bimp'), which completes the word—'blimp.'

Arguments of this kind seem at first sight fantastic, but it must be remembered that in the

evolution of speech we are dealing with a product of man's subconscious mind—"such stuff as dreams are made of"—and that it is no more strange that our speech symbolism should be fanciful than that our dreams should be so. For flights of fancy we come into life fully fledged—but we moult early or are plucked in the course of our education, and we come to despise the arts of imaginative flight at which our distant ancestors were such adepts.

There are other ways of testing the theory. We may invent 'synthetic' words by making (consciously) a pantomimic gesture with our tongue, or tongue and lips, and convert it into speech by grunting as we make the gesture. Of 19 such words, 18 were identified by Dr. Neville Whyment as actually occurring with the same meaning, and in the same or a phonetically allied form, in Polynesian, early Japanese, Indo-Chinese, or related languages. Thus, the tongue symbolising "to dance up and down to and fro" produced the synthetic word *li-lo* (lee-law). Dr. Whyment cited the Indo-Chinese words 'li-lo' and 'li-lü,' meaning to dance; Prof. Louis Gray, of Columbia, cites the Sanscrit word 'lila,' meaning game or enjoyment; to these I would add the English word 'lulla-by,' meaning to 'dance (a child) up and down, to and fro' in order to put it to sleep.

It is evident that if the pantomimic theory is true, it should appear (more or less) in all languages; a preliminary study has therefore been made of several 'unrelated' language groups, namely, Indo-European, archaic Chinese, Sumerian (as written at Ur of the Chaldees), Semitic, Polynesian and allied languages, and the Hoka languages of the west coast of North America. In all of these, pantomimic words are found to be common. Thus, of the first 100 'Aryan roots' listed in Skeat's "Etymological Dictionary," 77 were found to be pantomimic, 12 were probably pantomimic, and only 11 showed no evidence. In Karlgren's "Analytic Dictionary of Archaic Chinese," 85 per cent of the 73 word-groups listed in the first twenty pages showed pantomimic structure, while in a list of comparable Polynesian and allied words, and Hoka words, published by Paul Rivet ("Les Malayo-Polynésiens en Amérique"), 86 per cent of the word groups showed the same principle.

Many words are common to each of these groups; thus, in all of them the word for *one* is made by an erect tongue gesture—symbolic of the index finger held up. Thus, Indo-European has 'oin,' archaic Chinese has 'iet,' Sumerian has 'as' (compare with our word 'ace'), Semitic has 'ahad,' Polynesian has 'ta,' Hoka has 'ta,' 'tsâ,' 'cha,' and forms like 'pun' and 'pola.' In all of these the characteristic gesture is an erection of the tongue. A similar analogy is found in the case of the numerals *two* (made by a protrusion of the two lips) and *three* (made by protruding the tongue between the two lips).

Figs. 1 and 2 show the approximate tongue positions which correspond with the various English vowels and consonants; from these it is possible to draw the approximate tongue track of any given

word so as to compare the gesture with its verbal meaning. It then becomes apparent that the same gesture may be construed in several different ways. Thus the tongue track may represent a direction of motion, or the outline of a form—it may be

FIG. 1.

FIG. 2.

construed literally or figuratively—and, finally, it may be significant at the beginning, middle, or end of its course. For example, the archaic Chinese word 'kân,' of which the tongue track is shown in Fig. 3, means 'dawn' (sun rising up) or the trunk of a tree (an up-swinging outline). Of figurative words may be instanced the Sumerian 'daria' or 'duria,' meaning 'eternity,' in which the tongue track (see Fig. 3) forms a closed figure very similar to that of the hand gesture which deaf-mutes make to-day to express the same idea.

As to the significance of different parts of the tongue track, a good example is the word 'al'—formed by an upward thrust of the tongue—which may mean (1) 'up' or 'high' (Latin 'altus'), or (2) 'slack,' 'weak,' 'relaxed,' or (3) 'sweet,' that is, touching the palate as in tasting. In (1) the first part of the travel, in (2) the return journey, in (3) the mid-portion is significant.

It follows that 'homophones' (words with two or more different meanings) are natural to human speech. It also follows from our theory that the many instances in which the same sound bears a similar meaning in (presumably) unrelated languages are not due to chance, but to a common method of production—if not actually to a common origin. It is not a matter of chance that in archaic Chinese 'ma' meant mother (a sucking gesture) and that it also meant 'leach' (one who sucks); or that 'kât' meant 'cut,' 'suk' meant 'suck,' 'pa' meant 'father,' 'k'âp' meant 'cup,' 'kap' meant 'cap' (of a seed or bud), and 'sieu' meant 'sew' (embroider); such coincidences are rather to be expected.

Surveying human speech, as a method of symbolising thought by gesture of the organs of articulation, we can scarcely escape the conclusion that it is still in a very barbaric and imperfect condition. It is full of ambiguities, anomalies, and homophones; it is cumbered (in most cases) by a quite unnecessary complexity of grammar and syntax; it mixes up voiced and unvoiced speech sounds with a corresponding loss in audibility, intelligibility, and musical and emotional quality.

FIG. 3.

The notation of language—especially in the case of English—is in worse case than the language itself, since in it our spelling now lags some centuries behind the spoken word. It is of prime importance for the advancement of human thought that we should now prepare for the systematic improvement and purification of our own language, so as to make it a more perfect and artistic method of symbolism for our thoughts. It is equally important that we should co-ordinate our efforts with those of the other English-speaking com-

munities, so as to aim, in the future, at a standardised language and pronunciation with a rational spelling. The development of world broadcasting will make unification comparatively easy.

In the meantime we should ensure that our children are taught, in the first instance, to read and write phonetically, to articulate clearly, and to take an interest in the history and structure, the virtues and defects of our language, so that they may be prepared for the important task which lies before them.

Obituary.

SIR W. BOYD DAWKINS, F.R.S.

BY the death of Sir William Boyd Dawkins on Jan. 15, at his residence, Richmond Lodge, Bowdon, Cheshire, the sciences of geology and archaeology have alike lost one of their most outstanding personalities. He was born on Dec. 6, 1837, at Buttington Vicarage, Welshpool, and was therefore just over ninety-two years of age at his decease. He was the only son of the late Rev. Richard Dawkins.

Boyd Dawkins was educated at Rossall and at Jesus College, Oxford: he won the (first) Baroness Burdett-Coutts Scholarship and graduated first class in natural science in 1860, and second class in Classical Mods., and was the first undergraduate to take geology in the honours school. Afterwards he became an honorary fellow of his College.

On leaving Oxford, Boyd Dawkins was given an appointment in 1861 as a field geologist on the staff of H.M. Geological Survey of Great Britain, and was allotted to the unit then surveying the south-eastern counties of England. In 1869 he resigned to take the post of curator to the Manchester Museum and lecturer in Owens College. He became professor of geology and palæontology in 1872 at the Victoria University, Manchester, and acted as a consultant on questions of mining and civil engineering involving geological problems. This post he held until 1908, but after his resignation he occasionally gave lectures on geology as an honorary professor.

Boyd Dawkins was not content to confine his researches to his own country, but was always keen on comparing the story of the rocks elsewhere, and so he travelled widely in North America and Australia during the long period, 1874–1890. It was on one of these visits that he gave his notable lecture at the Lowell Institute, Boston, on ancient man.

The discoveries by Boucher de Perthes of flints presumably worked by man in the valley of the Somme led to much controversy on both sides of the Channel, and was one of the contributory causes of the intensive search among the river gravels and cave deposits for reliquiae of man. A distinguished band of observers, including Evans, Lyell, Lubbock, Prestwich, and Boyd Dawkins attacked this problem, and as a result raised the study of archaeology from its former position as an amusement for the dilettante to that of scientific philosophy.

As a palæontologist Boyd Dawkins will always rank high, because he did not allow his conclusions to get beyond the region of legitimate inferences

drawn from available evidences. As an archaeologist he preferred the 'field-work' of exploration to theorising about results in the museum and library, and he therefore was always sympathetic with other workers who were labouring under the disadvantages of imperfections of the geological record, but was rather impatient in later years with some who held advanced views as to classification.

Boyd Dawkins' earliest work was his explorations of Wookey Hole, near Wells, in the Mendips, one of the great limestone caverns which was occupied by Pleistocene beasts. The fossil bones embedded in the cave breccias and cave-earths were a source of inspiration that led him to make a critical examination of that and of other caves in different parts of England, and the knowledge gained by the discoveries then made, and also those in the gravels and brick-earths of the river valleys was partly expressed in his classical monograph on the British Pleistocene Mammalia, published by the Palæontographical Society. In this piece of research he co-operated with the late W. A. Sandford. His "Cave Hunting," published in 1874, was dedicated to "The Baroness Burdett-Coutts as a slight acknowledgment from her first scholar." In this volume he described and discussed the notable discoveries of human relics not only in the caverns of England, but also in those of Aquitaine, Belgium, Switzerland, and other countries. His conclusions as to the antiquity and sequence of the different races of Stone Age man, expressed in this book, were more or less maintained to the last: namely, that the hunting and fishing race of cave-dwellers in the remote Pleistocene age in possession of France, Belgium, Germany, and Britain were probably of the same stock as the Eskimos, living and forming a part of a fauna in which northern and southern living and extinct species are strangely mingled with those now living in Europe.

Boyd Dawkins followed up his attack on the problem of prehistoric man by detailed examination of the fluvial deposits of the European rivers, and to prepare himself for the inquiry he visited the more important museums in France and Italy and some of those in Germany and Switzerland, where he became a welcome visitor and friend of the curators. In the preface to his next work, "Early Man in Britain" (Macmillan, 1880), he acknowledges his debt to a number of geologists and archaeologists who now rank among the fathers of the sciences, and include Sir Charles Lyell, Sir John Lubbock, Sir John