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THE ECONOMICAL CHARACTER OF PHYSICAL RESEARCH.

BY PROF. ERNST MACH.[1]

When the human mind, with its limited powers, attempts to mirror in itself the rich life of the world, of which it is itself only a small part, and which it can never hope to exhaust, it has every reason for proceeding economically. Hence that tendency, expressed in the philosophy of all times, to compass by a few organic thoughts the fundamental features of reality. "Life understands not death, nor death life." So spake an old Chinese philosopher. Yet in his unceasing desire to diminish the boundaries of the incomprehensible, man has always been engaged in attempts to understand death by life and life by death.

Among the ancient civilised peoples, nature was filled with demons and spirits having the feelings and desires of men. In all essential features, this animistic view of nature, as Tylor[2] has aptly termed it, is shared in common by the fetish-worshipper of modern Africa and the most advanced nations of antiquity. As a theory of the world it has never completely disappeared. The monotheism of the Christians never fully overcame it, no more than did that of the Jews. In the belief in witchcraft and in the superstitions of the sixteenth and seventeenth centuries, the centuries of the rise of natural science, it assumed frightful pathological dimensions. Whilst Stevinus, Kepler, and Galileo were slowly rearing the fabric of modern physical science, a cruel and relentless war was waged with firebrand and rack against the devils that glowered from every corner. To-day even, apart from all survivals of that period, apart from the traces of fetishism which still inhere in our physical concepts,[3] those very ideas still covertly lurk in the practices of modern spiritualism.

By the side of this animistic conception of the world, we meet from time to time, in different forms, from Democritus to the present day, another view, which likewise claims exclusive competency to comprehend the universe. This view may be characterised as the *physico-mechanical* view of the world. To-day, that view holds, indisputably, the first place in the thoughts of men, and determines the ideals and the character of our times. The coming of the mind of man into the full consciousness of its powers, in the eighteenth century, was a period of genuine disillusionment. It produced the splendid precedent of a life really worthy of man, competent to overcome the old barbarism in the practical fields of life; it created the *Critique of Pure Reason*, which banished into the realm of shadows the sham-ideas of the old metaphysics; it pressed into the hands of the mechanical philosophy the reins which it now holds.

The oft-quoted words of the great Laplace,[1] which I will now give, have the ring of a jubilant toast to the scientific achievements of the eighteenth century: "A mind to which were given for a single instant all the forces of nature and the mutual positions of all its masses, if it were otherwise powerful enough to subject these problems to analysis, could grasp, with a single formula, the motions of the largest masses as well as of the smallest atoms; nothing would be uncertain for it; the future and the past would lie revealed before its eyes." In writing these words, Laplace, as we know, had also in mind the atoms of the brain. That idea has been expressed more forcibly still by some of his followers, and it is not too much to say that Laplace's ideal is substantially that of the great majority of modern scientists.

Gladly do we accord to the creator of the *Mécanique céleste* the sense of lofty pleasure awakened in him by the great success of the Enlightenment, to which we too owe our intellectual freedom. But to-day, with minds undisturbed and before *new* tasks, it becomes physical science to secure itself against self-deception by a careful study of its character, so that it can pursue with greater sureness its true objects. If I step, therefore, beyond the narrow confines of my specialty in this discussion, to trespass on friendly neighboring domains, I may plead in my excuse that the subject-matter of knowledge is common to all domains of research, and fixed, sharp lines of demarcation cannot be drawn.

[1] An address delivered before the anniversary meeting of the Imperial Academy of Sciences, at Vienna, May 25, 1882. Translated by μκρκ.

[2] *Primitive Culture.*

[3] Tylor, *loc cit.*

[1] *Essai philosophique sur les probabilités.* 6th Ed. Paris, 1840, p. 4. The necessary consideration of the initial velocities is lacking in this formulation.

The belief in occult magic powers of nature has gradually died away, but in its place a new belief has arisen, the belief in the magical power of science. Science throws her treasures, not like a capricious fairy into the laps of a favored few, but into the laps of all humanity, with a lavish extravagance that no legend ever dreamt of! Not without apparent justice, therefore, do her distant admirers impute to her the power of opening up unfathomable abysses of nature, to which the senses cannot penetrate. Yet she who came to bring light into the world, can well dispense with the darkness of mystery, and with pompous show, which she needs neither for the justification of her aims nor for the adornment of her plain achievements.

The homely beginnings of science will best reveal to us its simple, unchangeable character. Man acquires his first knowledge of nature half-consciously and automatically, from an instinctive habit of mimicking and forecasting facts in thought, of supplementing sluggish experience with the swift wings of thought, at first only for his material welfare. When he hears a noise in the underbrush he constructs there, just as the animal does, the enemy which he fears; when he sees a certain rind he forms mentally the image of the fruit which he is in search of; just as we mentally associate a certain kind of matter with a certain line in the spectrum or an electric spark with the friction of a piece of glass. A knowledge of causality in this form certainly reaches far below the level of Schopenhauer's pet dog, to whom it was ascribed. It probably exists in the whole animal world, and confirms that great thinker's statement regarding the will which created the intellect for its purposes. These primitive psychical functions are rooted in the economy of our organism not less firmly than are motion and digestion. Who would deny that we feel in them, too, the elemental power of a long practised logical and physiological activity, bequeathed to us as an heirloom from our forefathers?

Such primitive acts of knowledge constitute to-day the solidest foundation of scientific thought. Our instinctive knowledge, as we shall briefly call it, by virtue of the conviction that we have consciously and intentionally contributed nothing to its formation, confronts us with an authority and logical power which consciously acquired knowledge even from familiar sources and of easily tested fallibility can never possess. All so-called axioms are such instinctive knowledge. Not consciously gained knowledge alone, but powerful intellectual instinct, joined with vast conceptive powers, constitute the great inquirer. The greatest advances of science have always consisted in some successful formulation, in clear, abstract, and communicable terms, of what was instinctively known long before, and of thus making it the permanent property of humanity. By Newton's principle of the equality of pressure and counterpressure, whose truth all before him had felt, but which no predecessor had abstractly formulated, mechanics was placed by a single stroke on a higher level. Our statement might also be historically justified by examples from the scientific labors of Stevinus, S. Carnot, Faraday, J. R. Mayer, and others.

All this, however, is merely the soil from which science starts. The first real beginnings of science appear in society, particularly in the manual arts, where the necessity for the communication of experience arises. Here, where some new discovery is to be described and related, the compulsion is first felt of clearly defining in consciousness the important and essential features of that discovery, as many writers can testify. The aim of instruction is simply the saving of experience; the labor of one man is made to take the place of that of many.

The most wonderful economy of communication is found in language. Words are comparable to type, which spare the repetition of written signs and thus serve a multitude of purposes; or to the few sounds of which our numberless different words are composed. Language, with its helpmate, conceptual thought, by fixing the essential and rejecting the unessential, constructs its rigid pictures of the fluid world on the plan of a mosaic, at a sacrifice of exactness and fidelity but with a saving of tools and labor. Like a piano-player with previously prepared sounds, a speaker excites in his listener thoughts previously prepared, but fitting many cases, which respond to the speaker's summons with alacrity and little effort.

The principles which a prominent political economist, E. Hermann,[1] has formulated for the economy of the industrial arts, are also applicable to the ideas of common life and of science. The economy of language is augmented, of course, in the terminology of science. With respect to the economy of written intercourse there is scarcely a doubt that science itself will realise that grand old dream of the philosophers of a Universal Real Character. That time is not far distant. Our numerical characters, the symbols of mathematical analysis, chemical symbols, and musical notes, which might easily be supplemented by a system of color-signs, together with some phonetic alphabets now in use, are all beginnings in this direction. The logical extension of what we have, joined with a use of the ideas which the Chinese ideography furnishes us, will render the special invention and promulgation of a Universal Character wholly superfluous.

The communication of scientific knowledge always involves description, that is, a mimetic reproduction of facts in thought, the object of which is to replace and save the trouble of new experience. Again, to

1 *Principien der Wirthschaftslehre*, Vienna, 1873.

save the labor of instruction and of acquisition, concise, abridged description is sought. This is really all that natural laws are. Knowing the value of the acceleration of gravity, and Galileo's laws of descent, we possess simple and compendious directions for reproducing in thought all possible motions of falling bodies. A formula of this kind is a complete substitute for a full table of motions of descent, because by means of the formula the data of such a table can be easily constructed at a moment's notice without the least burdening of the memory.

No human mind could comprehend all the individual cases of refraction. But knowing the index of refraction for the two media presented, and the familiar law of the sines, we can easily reproduce or fill out in thought every conceivable case of refraction. The advantage here consists in the disburdening of the memory; an end immensely furthered by the written preservation of the natural constants. More than this comprehensive and condensed report about facts is not contained in a natural law of this sort. In reality, the law always contains less than the fact itself, because it does not reproduce the fact as a whole but only in that aspect of it which is important for us, the rest being either intentionally or from necessity omitted. Natural laws may be likened to intellectual type of a higher order, partly movable, partly stereotyped, which last on new editions of experience may become downright impediments.

When we look over a province of facts for the first time, it appears to us diversified, irregular, confused, full of contradictions. We first succeed in grasping only single facts, unrelated with the others. The province, as we are wont to say, is not *clear*. By and by we discover the simple, permanent elements of the mosaic, out of which we can mentally construct the whole province. When we have reached a point where we can discover everywhere the same facts, we no longer feel lost in this province; we comprehend it without effort; it is *explained* for us.

Let me illustrate this by an example. As soon as we have grasped the fact of the rectilinear propagation of light, the regular course of our thoughts stumbles at the phenomena of refraction and diffraction. As soon as we have cleared matters up by our index of refraction we discover that a special index is necessary for each color. Soon after we have accustomed ourselves to the fact that light added to light increases its intensity, we suddenly come across a case of total darkness produced by this cause. Ultimately, however, we see everywhere in the overwhelming multifariousness of optical phenomena the fact of the spatial and temporal periodicity of light, with its velocity of propagation dependent on the medium and the period. This tendency of obtaining a survey of a given province with the least expenditure of thought, and of representing all its facts by some one single mental process, may be justly termed an economical one.

The greatest perfection of mental economy is attained in that science which has reached the highest formal development, and which is widely employed in physical inquiry, namely, in mathematics. Strange as it may sound, the power of mathematics rests upon its evasion of all unnecessary thought and on its wonderful saving of mental operations. Even those arrangement-signs which we call numbers are a system of marvellous simplicity and economy. When we employ the multiplication-table in multiplying numbers of several places, and so use the results of old operations of counting instead of performing the whole of each operation anew; when we consult our table of logarithms, replacing and saving thus new calculations by old ones already performed; when we employ determinants instead of always beginning afresh the solution of a system of equations; when we resolve new integral expressions into familiar old integrals; we see in this simply the feeble glimmerings of the intellectual activity of a Lagrange or a Cauchy, who, with the keen discernment of a great military commander, substituted for new operations whole hosts of old ones. No one will dispute me when I say that the most elementary as well as the highest mathematics are economically-ordered experiences of counting, put in forms ready for use.

In algebra we perform, as far as possible, all numerical operations which are identical in form once for all, so that only a remnant of work is left for the individual case. The use of the signs of algebra and analysis, which are merely symbols of operations to be performed, is due to the observation that we can materially disburden the mind in this way and spare its powers for more important and more difficult duties, by imposing all mechanical operations upon the hand. One result of this method, which attests its economical character, is the construction of calculating machines. The mathematician Babbage, the inventor of the difference-engine, was probably the first who clearly perceived this fact, and he touched upon it, although only cursorily, in his work, *The Economy of Manufactures and Machinery*.

The student of mathematics often finds it hard to throw off the uncomfortable feeling that his science, in the person of his pencil, surpasses him in intelligence, —an impression which the great Euler confessed he often could not get rid of. This feeling finds a sort of justification when we reflect that the majority of the ideas we deal with were conceived by others, often centuries ago. In great measure it is really the intelligence of other people that confronts us in science. The moment we look at matters in this light, the un-

canniness and magical character of our impressions are dispelled, especially when we remember that we can think over again at will any one of those alien thoughts.

* * *

Physics is experience, arranged in economical order. By this order not only is a broad and comprehensive view of what we have rendered possible, but also the defects and the needful alterations are made manifest, exactly as in a well-kept household. Physics shares with mathematics the advantages of succinct description and of brief, compendious definition, which precludes confusion, even in ideas where, with no apparent burdening of the brain, hosts of others are contained. Of these ideas the rich contents can be produced at any moment and displayed in their full perceptual light. Think of the swarm of well-ordered notions pent up in the idea of the potential. Is it wonderful that ideas containing so much finished labor should be easy to work with?

Our first knowledge, thus, is a product of the economy of self-preservation. By communication, the experience of *many* persons, individually acquired at first, is collected in *one*. The communication of knowledge and the necessity which every one feels of managing his stock of experience with the least expenditure of thought, compel us to put our knowledge in economical forms. But here we have a clue which strips science of all its mystery, and shows us what its power really is. With respect to specific results it yields us nothing that we could not reach in a sufficiently long time without methods. There is no problem in all mathematics that cannot be solved by direct counting. But with the present implements of mathematics many operations of counting can be performed in a few minutes which without mathematical methods would take a lifetime. Just as a single human being, restricted wholly to the fruits of his own labor, could never amass a fortune, but on the contrary the accumulation of the labor of many men in the hands of one is the foundation of wealth and power, so, also, no knowledge worthy of the name can be gathered up in a single human mind limited to the span of a human life and gifted only with finite powers, except by the most exquisite economy of thought and by the careful amassment of the economically ordered experience of thousands of co-workers. What strikes us here as the fruits of sorcery are simply the rewards of excellent housekeeping, as are the like results in civil life. But the business of science has this advantage over every other enterprise, that from *its* amassment of wealth no one suffers the least loss. This, too, is its blessing, its freeing and saving power.

[TO BE CONCLUDED.]

THE PHILOSOPHY OF A HUMORIST.

WILHELM BUSCH, the famous author of *Max und Moritz* and other witty booklets, published a few years ago a little volume called *Eduard's Traum*, which deserves our attention for its humor and satirical criticisms not less than for the truths it contains. It shows that its author, the man of jokes, is at the same time a thinker; he is a master of fun, but he is also a philosopher and it will not only be interesting to know the philosophy of a humorist, but we shall also enjoy the dress in which he clothes his thought and the way in which he presents his views.

The plot of the little narrative is simple enough. It is a dream, and in this dream the author presents to the reader a number of philosophical problems which he either solves in an aphoristic way, or, having touched upon them, passes by to other problems. He concludes his booklet with the remark "A book is not "an organ with which the organ-grinder mercilessly "tortures our ears. A book is even more unobtrusive "than the picture on the wall, which still looks down "with a certain desire to be noticed. A book when it "lies before us shut, is a bound, sleeping, and harmless animalcule which hurts no one. He who does "not rouse it, at him it does not yawn. Him who "does not put his nose between its jaws it will not "bite."

Let us look into the book, and I will read in a free translation a few passages which appear to me noteworthy; and if my readers understand German I advise them to send for the original. The perusal of these eighty-five pages will fully repay the time spent on them. The book is worth having in one's library and its place is among the philosophers.

Wilhelm Busch's story is as follows:

It is bedtime. Edward is still up. His little boy, Emil, is in bed. Elise, his wife, bids him good-night and retires. But Edward, in complacent rumination, still loiters on the limits of the inconceivable. He yawns, throws away the stump of his cigar, takes the last swallow of his evening-drink (for we must suppose him to be a Bavarian) and decides to retire too. Having stared awhile into the light of the candle he blows it out and goes to bed. Before his eye the image of the flame still remains, and he begins to contemplate it attentively. Then he experiences a feeling as if his spirit, his soul, or whatever you may call it, began to shrink. His ego became smaller and smaller; first like a potato, then like a pill, then like a pin's head, then still smaller, and at last it was a point. But he was a thinking-point and active he was too, moving about in all directions, making his demand of time and space quite *en passant* as a by-product. In this shape he makes several excursions.

1. THE WORLD OF PURE FORMS.

Edward describes his journey into the land of mathematics as follows:

"With telegraphic swiftness of thought I switched directly through the wall and found myself in friendly surroundings. It was the domain of numbers where a pretty little arithmetical township lay.

"Strange! in a dream flourishes even have life.

"Morning dawned. Several peasants in the fields were husbanding their multiplications at an early hour. These people live and multiply honestly; they do not prosper greatly but they are frugal.

"More pretentious are the officials of the town. They were talking about a certion nought which had blocked the way of many an honest fellow, and when one had advanced who, as they thought, had not deserved it, then certainly, it was rumored, that as sure as twice two is four, the old intriguing nought was behind him. In the fashionable quarter the gentry live who can trace their lineage to the oldest primers. A certain Mr. X is the most looked for person of all. But he makes himself so rare that almost daily there are a thousand fools who ask for him, before a wise man can point him out. Other algebraical numbers are very impertinent. Two fellows whom I met in the park-promenade introduced themselves to me twice; first as Mr. A and Mr. B; then again as Mr. B and Mr. A; and they asked me conceitedly whether it wasn't all the same, for $A+B=B+A$. 'Tis all the same to me,' I said courteously, although I knew that the proposition in one respect had a hitch. But even in a dream we allow such little inaccuracies arising from politeness to pass unchallenged.

"I went to the market where the concrete numbers conducted their business. Suddenly a sausage came running in hot haste, and its price was marked ninety-three cents. Seventeen young tailors came after her with open shears and open mouths trying to catch her. 'We have paid our money,' they shouted, 'and now *snipsnap* we will divide.' 'That won't do,' gasped the sausage, which perspired fatty drops in her agony, for the tailors had already pricked her with their shears and had made thirty-four holes. At this moment an expert accountant came. He wore yellow pants, forty-five cents a yard, a hired evening dress, an unpaid-for stove-pipe hat; he made a false equation and brought the sausage on his side; but the tailors did not like the joke. They cut off the tails of his evening dress, ripped the buttons from his pants, and had he not speedily withdrawn, leaving the sausage behind, they would have dissevered him. Before they could again attack the sausage, the wife of the butcher, two hundred and fifty-seven pounds living weight, appeared and caused great consternation, for, she said, she had seen no money, and to give up ninety-three cents for nothing was against her human shortage. At once all the clattering shears were turned against the round sum of the buxom butcher's wife, and the tumult was great. The crowd was swelled by fifty salted herrings, two score and ten eggs, three dozen cheeses, one bottle of whiskey, three-quarters of a pound of dish-butter, six pounds of cooking butter, fifteen ounces of snuff, and numerous dittos. Endangered by the points of the shears the butcher's wife retreated. She stepped into the three-quarters of a pound of dish-butter, fell down upon the six pounds of cooking-butter, and while falling she drew into either of the holes of her nose two ounces of snuff, began to sneeze, in consequence whereof she made a somersault, squeezing three cheeses, and breaking the bottle of whiskey. When she alighted on the ground her heavy heels smashed two herrings so that both their poor souls fled out of their salted bodies. But when the complication was at its height, the crowd dispersed, for a new and superior magnitude, the town police, appeared upon the scene. The tailors made themselves as thin as they could, and the butcher's wife raised the sausage in her right hand, exclaiming: 'There is no justice left in the town; that's what I say.' But the town-police understood his duty, noted down the two herrings who had lost their souls, kept the cheeses, the butter, and the glass splinters in his head, added the woman and the sausage, put them in brackets, transported them to the town-scales, where one was found too heavy and the other one too light, and subtraction was inevitable. The sausage was subtracted for the exchequer. The remainder for contempt of court was three times three crosswise cancelled in ink, and the brave town-policeman on the very same day was, by the infinitely great mayor of the town, raised to the third power. There were before the treasurer several other cases attended to with the same promptitude."

The town contains beautiful parks and orchards full of golden percentages, and the dividends go up and down on paper ladders. Some of them were seen dropping to the ground, and they stroked their bruised parts and limped drearily home.

There is also enough grief and misery displayed on all corners of the streets. One can see fractured numbers, swollen numerators who carry small denominators upon their backs. How pitiful they look! "But," adds Edward, "I remained cool. I had no money with me, and if I had had some I would not have given them anything. I had changed my character. For wherever there is need of it I do not mind a few pennies; that you know, my friends."

Edward now came among the points, a buoyant people who were just practising sharp-shooting. "The smaller these folks," he tells us, "the greater is their pleasure. They were crawling and squirming like

merry infusoria in an old barrel of rain-water. Like mosquitoes, the thinking-points were dancing with their beloved little ideas, and I myself engaged one, and waltzed a few times round. Still nimbler and windier in the terpsichorean art than they were the purely mathematical points, but they were so bashful that they became smaller and smaller the more one looked at them. One of them disappeared entirely when I looked at him very closely. Queer fellows, this sort of points. Old Brennecke, my mathematical professor, used to say: 'Whoever cannot think a point is simply too lazy.' I have often since tried, but just when I think I have it, I have—nothing. And we have the same experience with all things; as soon as we look at them more closely, when we are about to seize them with the tenderest comprehension, they secretly withdraw into the corner of the incomprehensible and disappear without leaving anything behind, like the enchanted rabbit whom the hunter can never hit. There were also some critical points making mischievous faces and impeding every one wherever they went. One of them, an impudent fellow, stepped upon the train of a beautiful, young idea and at the same time upon the corn of her partner, the thinking-point; this insolent behavior interrupted all his arguments, and he began to scream. That was the signal for a lively scandal, for all the points of dispute and the points of honor interfered, to the delight of all present."

Continuing his journey, Edward came to the atoms, who were just beginning a square dance. With great assurance they danced their complex molecular figures, and when they were through, all had grown pretty warm. They are not quite so stupid as one is inclined to believe, and are quite interesting, as well as interested themselves, for tender love-affairs are not rare among them. One of their ladies appeared to me familiar. I must have seen her, and, really! I remember, at Leibnitz's! It was the old monad, and she had grown quite young again. She approached me, shook hands, and held me with her unsubstantial affinities, and pressed a kiss upon my lips, saying: 'My dear friend, let us be eternally united.' But I was repulsive. With great rapidity I shot through the roof and hastened away to distant spheres. When I looked round I was not quite alone, for right near I heard a cough. It was the mathematical point whom I had tried to look at, and he said: 'At home I cannot get on; now I'll see what I can do in the geometrical plane.'"

The geometrical plane lay before our romantic traveller in the splendor of the sinking evening sun. No tree, no bush, no chimney loomed up. All was flat as a pan-cake; nay, a thousand times flatter. And they were standing at the entrance to an industrious city which lay flat on its side. The door through which they passed had only breadth, no height. "It was so low," says Edward, "that my pate was grazed, and even my tiny companion could just pass through. He got an appointment that very same evening with an able geometer who took him at once into his drawing-pen in order to transfer him to the place of his future activity. I wished him all success, but I myself went to the hotel, where the waiter appeared as a straight mathematical line. Nothing could be more slender, and I thought of what my little nephew, Peter, once said. 'Uncle Edward,' he said, 'a ghost must be real slim for one doesn't see it at all.'

"How ridiculously thin such a mathematical line is! In the room next to me there were thirty in one bed, which was not broader than a cigar-case, and yet there was plenty of space left. At first they were quarrelling, for there was a Pole among them who suffered from nightmares and was very restless until he was nailed tight by two points; then he became quiet. I tried to pronounce his name, Chr—rrr—rrrr, but at that moment I heard a voice saying, 'Edward, do not snore.' It was the voice of my wife, I awoke for a moment but soon fell asleep again."

When Edward, in his dream, awoke the next morning in the geometrical plane, he found that everybody had to crawl about on his stomach. High and low are difficult to distinguish at first sight, and if one has cause to be polite one must look out with great circumspection, for as there is no height there are no shadows, and everybody, even the most square fellow of great contents appears as a simple line. The absence of shadow makes photography impossible, and the people of this city have to forego the ornament of pictures in their rooms. But they do as well as they can. They call in the carpenter, they measure their friends, and make a proportional figure in the album, noting the real square contents together with the year and date, and the memorial is ready. Some of the inhabitants told me that a few postmen had become so thin by constantly crawling on their stomachs that in their old age they were only half as thin as possible. This seemed to me remarkable on account of congruence, for if the report was correct an actual congruence of equal figures which appeared to me at this highly depressed locality impossible, did not seem to be excluded under all circumstances. I inquired for the congruence office, an institution which is similar to the county clerk's office where marriage licences are given. As no one could give me any information. I went to the mayor and was told "We have no such nonsense; any one anxious for such experience, especially if it be a case of symmetrical congruence, must please go to the third dimension."

"As the atmosphere in the mayor's office was very

close I bade him good-bye and went through the ceiling into tri-dimensional space where stereometric liberty prevails and where spatially sympathetic couples have the licence of marriage relations. But even here no exceptions were allowed. I just saw two spherical triangles, one the exact reflected image of the other. They returned in tears from the congruence office where they had been refused. There was a pair of infinitely delicate gloves, one left one and one right one. He, the groomsman, and she the bridesmaid, comforting the unfortunate couple, saying that they were in the same predicament and if there was no other hope they could after all elope into the fourth dimension where nothing is impossible. 'Alas!' sighed the bride, 'who knows what the fourth dimension is like?' One might have pitied the poor people but we must not be too quick with our sympathy, for the inhabitants of this unsubstantial country are hollow, sun and moon shine through them, and any one who stands behind them can count easily the buttons of their vests in front. They look through one another, and yet these people who have as little contents as a cleaned-out sparrow's egg, talk about the noble aspirations of their souls and address one in the most refined phraseology. I got sick of this conceited world of empty figures and hurried away. When about to leave I was addressed in a deep, sonorous bass by a gentleman who was so round and thick that he almost took up the whole space of the exit. It was my former companion, the mathematical-point. By a clever turn in the plane he had become a circle, and on emigrating into tri-dimensional space he had, by another turn, developed into a sphere. He was now on his way to a spiritualistic medium for materialisation, intending to go as a globe to a high-school. The unimportant little fellow had become a regular snob who began to treat me condescendingly. That was too much for me. I did not mean to suffer it from a puffed-up point, for such are all these people. I turned and went through the wall where I supposed that the complete world of reality lay, but even this was only in parts." P. C.

[TO BE CONTINUED.]

ERECT VISION.

BY GUSTAV GLASER.

A good deal has been written about this problem of Erect Vision, i. e., about the question how it can be explained that we see objects in an upright position when the image on the retina shows the object reversed.

Professor Mach in his article, "Facts and Mental Symbols," published in *The Monist* (January, 1892), offers the following explanation: "The light-sensations of the separate spots on the retina are connected with sensations and locality from the very beginning, and we *name* the places that correspond to the parts down, up."

This explanation seems to presuppose that there actually exists a difference between the directions of the motions of our hands and the position of the image on the retina, though the difference is not actually present in consciousness, because upward motions have become definitely associated with downward position of the image, and *vice versa*.

The explanation given by Johannes Müller, though not paying attention to all sides of the problem, appears to me more satisfactory as far as it goes. It is as follows: "In accordance with the laws of optics, the images are depicted on the retina in an inverted position as regards the objects. . . . The question now arises whether we really see the images, as they are, inverted, or erect as in the object itself. Since the image and the affected parts of the retina mean the same thing, the question physiologically expressed is this: Are the particles of the retina perceived in vision in their natural relation to the body? The view which I take of the question, and which I propounded in my work on the *Physiology of Vision*, is that even if we do see objects inverted, the only proof we can possibly have of it is that afforded by the study of the laws of optics; and that if everything is seen inverted, the relative position of the object of course remains unchanged. . . . Even the position of our hand while used in touch is seen inverted. The position in which we see objects we call, therefore, the erect position."

This explanation is clear and satisfactory, but, as that of Professor Mach, it presupposes that the position of the image on our retina is different from the position in which we actually see things, and this, in my opinion, is not the case. I think it can be easily proved from a psychological standpoint that the image on the retina has exactly the position in which we see things, i. e., that it is what we call erect.

From optical experiments we learn that objects projected upon some surface by means of a convex lense, such as that of our eye, will be inverted. Consequently all the objects that are projected upon my retina are inverted; but instead of saying that they are *erect* outside of us, and are upside down (from our point of view) on the retina, we must assume that just the opposite is the case.

If I see an inverted picture upon the retina of an excised eye, this picture in reality, therefore, must have just the opposite position, i. e., it must be *erect* upon that retina, and therefore *exactly as we see* objects. In reality all objects may have a reversed position as compared with our idea of them, but the picture on the retina has just the position that we call erect.

[The problem of Erect Vision does not appear to us as difficult as many writers would make us believe. Considering the

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mechanism of our organ of sight, it is obvious that when we look down upon the ground at the foot of a tree, the fixed point will appear in the upper part of the eye, while when we look up to the top of the tree the fixed point will lie in a lower part of the eye, and the whole picture of the tree upon the retina will be inverted. Now the problem of erect vision may be stated in the question, How can the inverted picture of the tree appear erect before me? But he who proposes this question forgets that sight does not consist of a sensation in the retina alone, but of a very complex process comprising also the sensations of the adjustment of the muscles of the eye and a co-operation of the memory of innumerable other experiences, especially of the tactual sense, by the help of which the retina-picture is interpreted. When the foot of a tree is fixed, it is not a single spot of the upper part of the retina which is seen, but together with it a direction downwards is perceived. Again, when the top of a tree is fixed, it is not an isolated spot in the lower part of the retina which is seen, but in connexion with this sensation a number of muscles round the eye and perhaps also in the neck are felt to be innervated, which mark the line of vision to be turned upwards. In the former case as well as in the latter the judgment is made unconsciously, and there is no choice but to see the inverted picture erect. The problem accordingly, so it seems to us, arises simply by limiting our attention to the retina, and the problem disappears as soon as we take into consideration the functions of all the auxiliary organs of vision, especially of the muscles of the eye.—Ed.]

CORRESPONDENCE.

THE MEANING OF "CHRISTIANITY."

To the Editor of The Open Court:

Permit me to correct an accidental misrepresentation of my thought concerning the meaning of Christianity, which appeared in your issue of September 27. In my second contribution to *The Open Court* I took special pains to say that I should be ashamed to define Christianity myself and that I utterly repudiate the dogmatism which sets up *its own* definition of Christianity and then demands that the world shall accept it. Neither you nor I can define a religion. The Christian Church, Christian tradition and history, the New Testament, *these* alone can define Christianity. And all these unite in defining Christianity as the religion which regards Jesus as the *Lord* and *Master* of mankind, the *ultimate* authority, to go beyond which is to cease to be a Christian. So-called "Liberal Christianity" ignores the *essential* element which permits the use of the Christian name because it sets reason above all other lords and masters, even the Lordship of Jesus tho' still retaining nominal acceptance thereof in its National Conference Constitution. Everybody cannot define the term Buddhist or Christian as he pleases; at least he should not because he has no right to. I drop the name Christian because I do not accept the authoritative definition of it. He who believes in unsectarianism and in the lordship of *universal human reason governed by experience* occupies a position obviously antithetical to that represented by Christianity and he should therefore discard the name. But this by no means involves rejection of the spiritual ideals to which Jesus gave expression and which are sometimes designated Christianity by indiscriminating persons. ALFRED W. MARTIN.

NOTES.

The Annual Congress of the American Secular Union and Freethought Federation of America will be held at Madison Hall, 146 Madison street, Chicago, October, 26, 27, and 28, 1894 The demand of the Union is, that "not only in the Constitutions of the United States and of the several States, but also in the practical administration of the same, no privilege or advantage shall be conceded to Christianity or any other special religion, and whatever changes shall prove necessary to this end shall be consistently, unflinchingly and promptly made." The programme is an attractive one, and will include many well-known speakers. All are invited.

BOOK NOTICES.

We acknowledge the receipt of a copy of "The Annual Literary Index" for 1893, which has taken the place of the "Co-operative Index to Periodicals," and forms the second annual supplement to "Poole's Index to Periodical Literature" and to the A. L. A. Index to general literature. The work upon this volume seems to be accurate and complete; for the library and for the searcher in periodical literature it will be indispensable. It contains an "Index to Periodicals" and an "Index to General Literature," an "Author's Index," a List of Bibliographies of the Year and a Necrology of Authors. (Price $3.50, pp 213. New York: Office of the Publishers' Weekly, 28 Elm St.)

The American Mathematical Monthly, now in its first year, is edited by B. F. Finkel and J. M. Colaw, and published at Kidder, Missouri, by the Chubbuck Brothers. In the first five or six numbers Prof. George Bruce Halsted has a series of articles on the "Non-Euclidean Geometry." The chief space of the magazine is devoted to the solutions of problems usually involving no questions of principle and in some cases very trivial. The July number prints without comments (which perhaps after all was the best) Mr. Edward J. Goodwin's "Solution of the Quadrature of the Circle." As Mr. Goodwin's solution is nearly eighteen hundred years old, and so has not even the merit of novelty, it is difficult to understand how a serious journal could be brought to publish it; if on the ground of humor, we will say that that is an intellectual quality to which Mr. Goodwin's solution cannot aspire.

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