Alfred Korzybski Memorial Lecture

INVARIANCE AS A CRITERION OF REALITY*

Henry Margenau
Professor Emeritus Physics and Natural Philosophy, Yale University

Introduction by Robert U. Redpath, Jr.

I must acknowledge what an honor it is to introduce Professor Margenau in any circumstance, but particularly so in this room. I'd like to point out that Professor Margenau is the third of our Korzybski speakers from our university, Yale University. The first speaker was Filmer S. C. Northrop, his associate in the philosophy faculty, and his associate on Main Currents in Modern Thought. I think both men were founders of that fine publication. Very soon after that was founded they worked together with Harold Cassidy, our speaker in 1962. He is also a Yale professor who knows and cherishes Henry Margenau as we do. So the idea of this dinner has made special sense to me, the continuity and form it has taken, and the idea that you don't have to have any special allegiance to, or knowledge of, Korzybski's work in particular. You perhaps have to have an orientation towards organisms-as-a-whole-in-environments that are constantly changing, and an optimism based on that realistic viewpoint. We have identified the guest speaker tonight in those terms.

I had the privilege of being at M.I.T. with my wife Nancy on a weekend in 1958. There was a symposium formed by Pitirim Sorokin on something to do with values. It was a two-day symposium where people like Henry Margenau, Erich Fromm, and sixteen other scholars were attending. We went to bed on Friday night of the two-day session, and Saturday we were awakened by shaking of the ground around the M.I.T. campus. Sputnik had just taken off over Russia. The whole academic and civic community of Boston was startled, as was everyone else. We drove down from Boston to New Haven with Professor Margenau and had a very interesting afternoon talking about the possibilities that were coming from that event. Everybody was in a state of shock, of course. They hadn't expected that news.

I can just touch a few of the facts of Professor Margenau's interesting and engrossing, and still active life. There is a statement at Yale, if not at other universities, that you must publish or perish. This man has published at least two hundred papers, a number of books, and is obviously anything but perished. He is a very vigorous, active person after seventy years of life, and we hope with many years to come.

He was born in Germany in 1901, and attended Teachers College there. Coming over here, he wound up in Nebraska working as a farmhand. From there he went to Midland College, where he took his B.A. He received his Master's degree at Nebraska University in 1926. The year I got out of Yale, 1928, he became a member of the Yale faculty and took his Ph.D. in physics. Since then he has had incredibly varied experiences in the two disciplines of physics and philosophy.

I wish I had time to read to you some of the topics on which he has written. For instance, 'Uncertainty Principle and Free Will' in 1931. He has written on the role of definitions in physical science with remarks on the frequency definition of probability in 1942. He has had a number of others, such as 'The Logic of Non-communicability of Quantum Mechanical Operators and Its Empirical Consequences.' He is a physicist-philosopher, which of course is a fine relationship for us who believe in the hyphen and look forward to this idea of relatedness. He has had a Guggenheim Fellowship and a Fulbright Grant. He has also been on the staff of the Institute for Advanced Study at Princeton. In all that time he has lived a very full life, always in contact with his students and colleagues. His students include two Nobel Prize winners. He has had a rich life and maintained a happy family. He

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is a great student of human nature and the natural world. It is a great privilege and pleasure to introduce him tonight to you--Henry Margenau.

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Henry Margenau: How sweet it is to be introduced by a friend who couples generosity with such a measure of eloquence.

Ladies and gentlemen, my acquaintance with Alfred Korzybski dates back to the 1940's. I met him first when he delivered a seminar at my college, Silliman College, Yale, then again on January 31, 1949, when he was the honored guest at a Yale Faculty luncheon. On this occasion I had the distinction and the pleasure of sitting next to him. I shall relate to you in a moment a part of the conversation that took place.

But first, I owe you an explanation for my choice of title, 'Invariance As a Criterion of Reality.' You remember Korzybski's theory of time-binding? Everybody knows all about it: one generation binds knowledge and hands it on to the next. In the document which was composed as a result of Korzybski's lecture in 1949 and now reposes in the archives of the Yale Library housing Memorabilia, there appears the following sentence: 'Man is making structural patterns ready for application to actual human life.' I sensed one of these patterns he had in mind was invariance. What I would like to do tonight is to elucidate the meaning of this term and to sketch for you the meaning of its application to modern science and modern philosophy--to continue, in a way, the discussion which was initially launched by Count Korzybski on that day.

I promised to tell you a little of the bantering chat that took place. It happens that early in my teaching career, when I was conducting a seminar in general physics, I sprang upon my unsuspecting class a ten minute quiz. I happened to have covered the laws of mechanics, as one usually does in the beginning of an elementary course in that science. I asked my class to define for me the term 'mechanical advantage', suggesting to them that they might use the example of a long pump handle to illustrate their answers. I got a variety of answers, three of which I remembered and preserved.

Now the mechanical advantage, defined in physics terms, is of course the ratio of the force output of a machine to the force input. The greater that ratio, the greater is the mechanical advantage. My class consisted of roughly three types of students. There were the straight-laced majors in physics, who were going hell-bent for election through research and some of them toward the Nobel Prize. Then there was a large sprinkling of philosophers, people interested, in general, in the humanities. And finally there were a few engineers, budding engineers, people who later became men of affairs--executives like our friend Exton.

I brought an answer to this question from one of each of these groups. The budding physicist simply said, 'The mechanical advantage of a long pump handle is equal to the ratio of the lever arms--the long lever (the length of the handle) divided by the short lever (the distance between fulcrum and plunger).' Now that answer was absolutely correct. It was wholly uninspired, and it drew an 'A', of course. I couldn't help myself, but I wasn't very much impressed by it.

A philosopher in this group wrote as follows: 'Mechanical advantage provides a systematic amelioration of an unfortunate situation involving too much work (short pump handle).' The sentence goes on, as most philosophical sentences do, 'achieved by a categorical application of general mechanical principles' and, heavily underscored, 'A Triumph of Mind Over Matter.' The paper was very literary. It was equipped with footnotes to the original literature, including one to Archimedes, which said, "Δοσ μοι που στησομαι, και το παν κινησω" -'Give me one firm spot where I may stand, and I shall move the universe.' It was edifying, scholarly, even poetic, and it drew an 'A'. I couldn't help it. The guy didn't know what he was talking about, but he said it so well.

But finally the applied scientist, who now works for the Bell Telephone Company, wrote as follows: 'The mechanical advantage of a long pump handle lies in the fact that you can get two people to pump.' Now this is the story I told to Alfred Korzybski. He laughed and said, 'I like that third guy.'

When I formed the idea that I would probably do maximum honor to Korzybski by discussing a theme close to his heart, I looked through his writings and found the following comments on invariance, most of them in his Science and Sanity. At one place he quotes Professor Shaw saying:

> We find in the invariants of mathematics a source of objective truth. So far as the creations of the mathematician fit the objects of nature, just so far must the inherent invariants point to objective reality. Indeed, much of the value of mathematics in its applications lies in the fact that its invariants have an objective meaning. (page 285)

You may not comprehend fully the significance of these remarks. I am making them by way of preface, and I promise to go into them more deeply and tell you what I think they mean.

At another place in Science and Sanity I read:

> If a characteristic appears in all formulations, it is a sign that this characteristic is intrinsic, belongs to the subject of our analysis, and is not accidental and irrelevant, belonging only to the accidental structure of the language we use. Once these invariant, intrinsic characteristics are discovered . . . we then know that we have discovered invariant relations, which survive transformation of different forms of representations, and so realize that we are dealing with something genuinely important, independent from the structure of the language we use. (page 148)

'The structure of the human nervous system,' Korzybski says, 'is such that it abstracts or generalizes, or integrates, etc. in higher orders, and so finds similarities, discovering often invariant . . . relations.' At another point he says:

> It seems that relations, because of the possibility of discovering them and their invariance in both worlds [and by both worlds, Korzybski means the world of objects and the world of the mind] are, in a way, more objective than so-called objects. We may have a science of "invariance of relations," but we could not have a science of permanence of things; and the older doctrines of the permanence of our institutions must also be revised. Under modern conditions, which change rather rapidly nowadays, obviously, some relations between humans alter, and so the institutions must be revised. If we want their invariance, we must build them on such invariant relations between humans as are not altered by the transformations. This present work, indeed, is concerned with investigating such relations, and they are found in the mechanism of time-binding, which, once stated, becomes quite obvious after reflection. (page 285)

After the day of Korzybski, the principle of invariance--I say this again merely as a superficial comment upon the general significance of the idea of invariance--has created several new scientific disciplines. Einstein was intrigued by concerns about invariance. His chief fame rests on his application of that principle to one part of physics. Eugene Wigner (whose departure from Princeton we are going to celebrate a week from today) received a Nobel Prize for having applied the idea of invariance to the quantum theory. These are simply two significant historical facts. They bespeak the importance of the subject; however, I shall not dwell here upon its history.

Invariance can be applied in the sciences, and the first part of my discourse this evening will attempt to sketch for you how this works. A little later I shall extend the scope of my talk to two other disciplines--esthetics and ethics. Our western culture has developed under it a trinity of stars--the true, the good, and the beautiful--ideals which are incorporated in three disciplines: science, ethics and esthetics. I shall try to show in a general way how the principle of invariance bridges all three of them, but first I wish to speak of science.

One doesn't have to go very far in science in order to recognize the great importance of invariance. Let me illustrate that by a simple example. The table that I have before me has a shape. From where I stand, it has the appearance of a trapezoid. Yet nobody regards the surface of this table to be trapezoidal. We say it is a rectangle, but from where you sit it doesn't look like a rectangle at all. Appearances are deceptive. Why then, do we call the surface a rectangle? Simply because, within the confusion of shapes that this object offers as I move about it, one stands out. If you measure the opposite sides of this table, you find them to be equal in length, although they don't look it. An ideal structure which has parallel sides, equal in length, is called a rectangle. It is the invariance property of this appearance which you do not see from where you stand, which however we regard as significant for our definition of the 'reality' of the object. Invariance typifies what we regard as true about the table. Now let me proceed to some slightly more scientific examples.

Invariance, in popular language, means constancy; invariant things are constant in some respects. We speak of an invariant climate, invariant behavior, invariant toil, meaning thereby that these are conditions, actions, which prevail without cessation and without change. Once we inspect the meanings of these words more closely we see at once that invariance, constancy, is not generally absolute. I may say a clock runs invariantly, its rate of running is constant, and I do not specify the conditions under which this statement is true. Certainly it is not true under all conditions. I could smash that clock with a hammer and can do other things to it which will make it stop. As a scientist I must therefore state with care and circumspection those conditions under which invariance, constancy, is meant to hold. The clock runs constantly in spite of changes in the magnetic field in which it is placed, in spite of the humidity changes which may occur in its environment. It is not invariant under all conditions, but under certain conditions only.

A tune, a melody, may be said to be invariant with respect to transposition to other scales. Well, that is not an absolute statement either. If I were to transpose a tune written for a major key to a minor key, it would lose its beauty and change its structure. So, what I have to say is: the tune is invariant only with respect to a certain kind of transposition. This now brings me to the crux of the matter of invariance. In general, invariance refers to some entity--a clock, the weather, a tune--under specified changes. An invariant idea entrains at once the idea of changes--permitted changes--with respect to which invariance is claimed to hold.

Now I want to make a little table of instances for which scientific invariance becomes important. I will list here the entities that are said to be invariant, and over here the permitted changes. Two examples from everyday life have already been mentioned. I spoke of the clock. Permitted changes are temperature, humidity, magnetic field, and perhaps a few others. A tune is invariant with respect to transposition to all major keys, and so forth. One could cite many examples from everyday life which, however, are not very interesting from a scientific point of view.

Let me now turn to a very elementary science, geometry, the science with the most ancient and most illustrious past. There is first of all the circle--that is our 'entity'. If you draw a circle and then turn it about an axis through its center, the circle remains a circle. It does not alter its shape, nor its visible position. In fact, you could not tell the circle had been rotated through any angle. We therefore call the circle a figure that is invariant with respect to all rotations (about an axis through its center and perpendicular to its plane).

Another regular figure is a square. If you perform the same operation with a square--rotate it through an angle about its center--let us say through forty-five degrees--you can tell it has been rotated. It has altered its position in the world. But if you make the rotation ninety degrees, the original square, the shape, is restored. The same thing is true about one hundred and eighty degrees. In fact, the square is invariant with respect to rotations of ninety degrees and multiples thereof.

Let's take some other polygon, say a hexagon; it is invariant, not with respect to all rotations but only with respect to rotations through 60°, 120°, and multiples of 60°. In fact, you can classify all polygons, regular polygons, in terms of the invariances which these polygons satisfy. This was already done in the days of Plato. The Greeks called the circle the perfect figure because it is invariant with respect to all rotations. The square and the other polygons are less perfect because their range of invariance is limited.

From geometry we go to algebra. There invariance takes a new form. In algebra you deal with equations. I hope you will forgive me if I write down the equation for a circle, $a^2 = x^2 + y^2$. What I previously called an entity now becomes an equation. A similar change is required in the conditions of invariance if the idea is to be applied to algebra: permitted rotations become permitted transformations, and these also take the form of equations. Thus, for instance, the algebraic version of a rotation through an angle θ is the pair of relations

$$x = x' \cos\theta - y' \sin\theta$$
$$y = x' \sin\theta + y' \cos\theta$$

They are known to mathematicians as orthogonal transformations. If you substitute them into the equation for the circle the result is $a^2 = x'^2 + y'^2$. In other words, the equation is the same in primed and unprimed coordinates, regardless of the value of θ; it is invariant with respect to all rotations.

On the other hand, were I to write the equation (or set of equations) representing a square, it would retain its form (remain invariant) under the transformation above only if θ is a multiple of 90°. The equations for a hexagon remain invariant only if θ is a multiple of 60°, and so on. Thus algebra mirrors, in a more abstract way, what our intuition conveys in geometry.

Now we have reached the stage of modern science. Invariance, which in the simplest cases referred to objects and figures, is now applied to equations, and equations which describe the behavior of nature are called 'Laws of Nature'. Thus our previous entities have now become laws of nature, or simply 'laws'. The permitted changes, which are also written in terms of equations, are called transformations. A transformation is a generalized statement of permitted changes. A law is a generalized entity that remains invariant.

What are the most fundamental laws of the universe? I am going to pass now from algebra to physics. One of the most basic laws is Newton's Law--force equals mass times acceleration. This law has a range of invariances. That is, it remains invariant under a certain set of transformations which are very simple. The first of these is called 'space displacement'. You apply the law (Newton's Law of Motion) at a certain point of space, and you find it works. The formula, $F = M \times \frac{d^2X}{dt^2}$, is true at a given place in the universe. But you can also apply the law at another point of space. For this transposition, this passage from one point of space to another point of space, the scientist has a name--he calls it <u>space displacement</u>. Space displacement simply means replacement of X in the formula by X', which is defined as X plus a constant. It turns out, purely algebraically, that if you make this replacement of X by X', i.e. if you write for X, X plus a constant, the law remains unchanged. We speak of this as invariance with respect to space displacement. It entrains a most important philosophical consequence. All laws of nature which are invariant with respect to space displacement are 'universal'. They are true for every point of space in our universe.

Newton's Law has a further invariance: it is invariant with respect to another transformation, namely, the replacement of the time for which it is written by another time, which is the old time plus a constant. Well, purely analytically it turns out that if you make this replacement of T by T' in the law itself, the law does not change. It remains invariant. Laws that have this property of invariance with respect to time displacement are said to be 'causal' laws. The philosophical idea of causality is an immediate consequence of invariance with respect to time.

Now there are other invariances, some quite interesting, some not. For instance, it turns out that Newton's Law is also invariant when you make the replacement of T by -T. The law is insensitive to that substitution. This is described by the scientist as 'reversibility', or by the statement 'time is reversible'. Most basic laws of nature would remain the same if time flowed not forward, but backwards. This has given rise to a great number of philosophical speculations which I will not enter into tonight. The point is that the laws are in fact invariant with respect to this substitution, this transformation. They are reversible--time reversible.

Of all the possible transformations, the era of Sputnik has brought one into particular prominence. That transformation is called the Lorentz Transformation. Please do not faint, I'm not going to become highbrow here. The Lorentz Transformation is the following sort of thing: You replace the coordinate system in which the law is known to hold by another system, like Sputnik, which travels relative to the first system with a constant velocity. Now it might be that the laws of nature are different on Sputnik than on Earth. The laws of nature might indeed be different on a moving train, on an automobile, on some other planet, than they are on Earth. The Lorentz Transformation is merely an expression of the passage from one system, like Earth, to another system, like the Moon or Sputnik, or from a point at rest on the Earth's surface to a vehicle moving with constant velocity. One can write that down in analytic form, a very simple form--the Lorentz Transformation. If you make the replacements specified by the Lorentz Transformations in Newton's Law, they don't work.

I'll first talk about the so-called Galilean Transformation, which has a certain very simple form. The Galilean Transformation also portends to tell you what happens when you go from one system of reference to another that moves with constant velocity relative to the first. If you plug them into Newton's Law you find that it does not alter its form. It is invariant with respect to changes in the system of reference, so long as these systems are inertial systems that move with constant velocity relative to one another. This has a profound effect. It means you don't have to learn a new kind of physics, chemistry, psychology or what not, when you go on a spaceship or on a Sputnik. The laws of nature remain unchanged and so we have become almost convinced that the laws of nature shall have this desirable, elegant, beautiful property of invariance with respect to certain important transformations. We are always shocked when a law of nature is discovered which does not have this property of invariance with respect to many different transformations.

Now, something terrible happened about eighty years ago. It concerns the so-called 'ether'. Hence I will go back and tell you a little of the story of the ether. It seems to be quite unconnected with anything I've said so far, but I promise to return to this point in five or ten minutes. At various times in the history of science scholars thought the world was filled with very tenuous material medium called 'ether'. The idea of an ether is really quite old. It arose with Aristotle, was featured by the Stoics, became dormant, but sprang back to life some two hundred years ago. This came about as follows:

Faraday discovered the forces between positive and negative electrical charges--attraction between unlike charges, repulsions between like charges. It was tempting to believe that one charge could act upon another only through some rather sophisticated medium that pervades the space between them. And so Faraday remembered the Stoics and he remembered Aristotle. He said there must be some stuff in this world, material stuff, which fills it completely, and forces are merely manifestations of tensions or compressions within this universal stuff, within the world 'ether'.

A few decades later came Maxwell, who proved that light is nothing more than an electromagnetic disturbance, like Faraday's forces. Light passes through space as a combination of electromagnetic fields; in fact, it is a wave. Now a wave must have a medium to travel in. A wave wiggles, and it's got to have something to wiggle in. Therefore Maxwell fell back on the old notion of the ether, conceiving it as the medium, the elastic medium, in which light must travel.

In the latter part of the nineteenth century every physicist believed in the literal existence of this ether as a material medium, very light, very tenuous indeed, which fills the world, enabling light to travel through it. Then people became curious. They wanted to know the physical properties of this stuff. First of all they asked the question: What is its density? After all, we have very light gases, hydrogen and so forth. We can measure their density. So they said: Let's try to measure the density of the ether. No one succeeded in doing it. One had to guess, and the first guess was based on a formula which you learn in elementary physics courses. The formula tells you how fast a wave will travel through an elastic medium. For instance, a seismic wave has a certain speed with which it passes through the crust of the earth. An acoustic wave has a speed which is determined by the properties of the air through which it passes. Now if light is a wave within this elastic ether, the formula for the velocity of waves in an elastic medium must hold. That formula has the following form: The velocity is equal to the square root of the elasticity of the stuff divided by its density.

That formula, however, did not help much. It could not be tested because, while we knew the speed at which light travels (186,000 miles per second) we had no idea of the elasticity or the rigidity of the ether, nor of its density. One could make a guess and suppose that the density is so small that nobody can measure it. Suppose it is about one hundred times smaller than the density of hydrogen. You can then insert this value for the density into the formula for the speed of light and compute the rigidity of the ether. The answer you get is baffling: It turns out that ether has a far greater rigidity than steel! Now your intuition is caught in a vice. It's almost unthinkable to have this world pervaded by a medium that has a rigidity like steel. Thus physics reached an impasse.

It was soon joined by another. People began to wonder about the state of motion of the ether. After all, the whole world was supposedly filled with it. It must be either stationary or it must be moving. Now these alternatives can be tested. If it moves, if for instance every heavenly body, every planet, every star drags its own private portion of this ether along with it, there must be a streaming of the ether within space. In that case the Earth takes along its ether and the sun takes along its ether. Earth and sun don't travel at the same speed, so there must be relative motion between the ether near the sun and the ether near the Earth. This should give rise to strange aberrations in light rays passing from the sun to the Earth. These aberrations should be observable. People looked for them and found them absent. Well, that left us with the only alternative that the ether is stationary. The heavenly bodies pass through it without disturbing it.

Thus, the following argument arose. Our earth moves around the sun with a known speed, let us say 'V'. If it passes through a stationary ether, an observer on the earth must somehow experience an 'ether wind'. The earth moves in one direction, the ether passes it in an opposite direction if it is stationary in space. This means that a light ray traveling in that direction would have to go more slowly than a light ray going in the opposite direction. This prediction was checked by two men, Michelson and Morley, in 1876 in a very famous experiment which gave the lie to the prediction. May I say, incidentally, that the most important experiments in science are the ones that contradict one's expectations. They shock you and bring about new theories. Michelson and Morley discovered that there was no difference in the speed of a light ray going along with the earth's motion and the velocity of one going against it. That was a stunning surprise.

People would have lived with this, they would have taken it, had it not been an infraction of the principle of invariance. That came about as follows: Einstein said: Let us make a thought experiment. We shall take the results of Michelson and Morley as true. (The experiment had been repeated many, many times and there could be no doubt about its correctness.) We write down the equation of light which is emitted on Earth. Its wavefront has the form of a sphere. This sphere has the algebraic equation: $x^2 + y^2 + z^2 = a^2$. If the light velocity is 'c', then the radius of the sphere is ct. So $a^2 = c^2t^2$. We are writing the equation we encountered before, but we now have three dimensions. Now suppose that Michelson and Morley are right. If I now write down the Galilean Transformation, which takes me from one system of reference to another, I experience a disappointment: One can easily see that if one writes for X, X' - VT where V is the velocity of the Earth, and hence the relative velocity of the ether, the equation changes its form! The equation of light propagation, $x^2 + y^2 + z^2 = c^2t^2$, one of the most fundamental laws of modern physics, fails to be invariant with respect to the equally important transformation from one system of reference to another, from one inertial system to another. To summarize: the equation of light propagation is not invariant with respect to the Galilean Transformation.

Albert Einstein resolved the dilemma in a striking way. Most physicists of the early century said: either there must be something wrong with the Michelson-Morley experiment, or else the basic equation does not satisfy our craving for invariance. That was the pedestrian attitude. Einstein contradicted it and said in effect he was unwilling to surrender invariance. He knew the law was right. If it is not invariant with respect to the Galilean Transformation, he was going to find a transformation, similar to but not identical with the Galilean one, with respect to which its invariance is preserved. In this way he established in a wholly new and very general context the equations called the Lorentz Transformations. Lorentz had discovered them for a more limited purpose.

Einstein said: 'I'm going to stick to invariance. I want my laws of nature to be beautiful and simple, valid under all circumstances.' But the new transformations entailed extremely strange and initially incredible consequences, such as the retardation of moving clocks, the contraction of moving objects, its increase in mass and the equivalence of matter and energy. Yet all the strange consequences that flowed from the Lorentz Transformations were found to be correct. Here is an historical instance in which insistence upon one of the principles to which Korzybski was devoted, created the wholly new science--the science called 'relativity'.

Faith in invariance produced, first of all, a very unfamiliar set of equations, the Lorentz Transformations, which no one would have taken as true without further crucial evidence. But these very Transformations, which were necessitated by invariance, were verified and finally gave rise to all the important effects that are now being utilized in the construction of spaceships, accelerators, of atomic bombs. They all arise from belief in the ultimate invariance of scientific laws.

Now I may pause briefly to say that people at first tried to fix things up in less audacious ways. They said: the issue is not really invariance; the ether isn't as simple as we conceived it to be. There was for instance an Englishman named James McCullagh who, at the end of the last century, produced a theory of an ether which would explain, not the Michelson-Morley effects, but another circumstance which proved troublesome to the ether advocates. Light for whose propagation the idea of an ether was invented, is known to be a transverse wave, like the ripple on a pond. But a transverse wave can be transmitted only by a solid body, not a gas or a liquid. The inference must therefore be that the all-pervasive ether is a solid. However, even if our imagination is stretched sufficiently to accept this intuitive atrocity there remains a paradox, for a solid transmits both a transverse and a longitudinal wave like sound! And a longitudinal light wave was unknown. McCullagh's so-called theory was designed to remove this anomaly.

Here's the theory of the ether propounded by McCullagh. I shall read it to you as it is presented in a book by E. T. Whittaker, distinguished physicist and historian of science. He wants to describe the molecule of an ether that will do all proper tricks and will make invariance unnecessary. He says (and now I ask you to follow me very carefully--I hope I shall not unduly strain your imagination in reading this): 'Suppose that a structure is formed of spheres, each sphere being in the center of the tetrahedron formed by its four nearest neighbors. Let each sphere be joined to these four neighbors by rigid bars which have spherical caps at their ends so as to slide freely on the spheres.' (Are you still with me?) 'Such a structure would for small deformations behave like an incompressible perfect fluid and would transmit only transverse light waves.' In other words, it would nip the longitudinal ones in the bud as soon as they were formed. Then he goes on, 'Now attach to each bar a pair of gyroscopically-mounted flywheels rotating with equal but opposite angular velocities and having their axis in the line of the bar. A bar thus equipped will require a couple to hold it at rest in any position inclined to its original position, and the structure as a whole (conceived as a molecule of ether) would possess the kind of quasi-elasticity which is needed in order to satisfy all requirements.'

Now Einstein was up against it. He could accept this complicated, this ugly ether model and thus sacrifice invariance. But he rejected this model for the sake of invariance. And he won out. Nobody believes in the ether any longer; we don't need it anymore. The formal appeal of invariance together with the verification of its consequences is sufficient to endow that guiding principle with objective validity and to make invariance true. Well, so much for invariance in modern physics. I shall not go into the further pursuits of the topic, which has led to most interesting mathematical theories in connection with quantum mechanics.

I am about to shift gears now and talk quite briefly about esthetics. Recall these regular polygons, these perfect figures of Plato; they clearly are not without esthetic appeal. In a primitive sense they are beautiful, and their beauty arises from their invariance with respect to simple rotations. Music has a rhythm. The repetitive feature of rhythm of music is nothing more than invariance with respect to time displacement. The vertical patterns we see on the walls which appeal to us as being decorative are nothing more than invariant patterns, invariant in this case with respect to space displacement. And I could go on in this way.

You've doubtless all done this little trick. Korzybski was fond of informal demonstrations, so I decided to offer this one (forgive me, because it's really quite commonplace and sometimes used to make Christmas tree ornaments). I have a piece of paper here. I fold it in a regular way and fold it again, and then I tear out quite irregular bits from it, something like this. I do this without any premeditation. Then I unfold the pattern, and you see it has a certain esthetic appeal. Why? It's symmetrical, symmetric with respect to rotations through 45 degrees, and other simple geometric transformations. This comes from the way I folded it. Whatever esthetic appeal this has, whatever qualities of beauty it possesses, arise from its visual invariance.

Now I could multiply this example many, many times and try to convince you that a lot of music, of decorative art--in fact, a good deal of painting--depends upon certain invariances. I might remind you of the kaleidoscope, an optical device equipped with six radial mirrors, one segment of it being filled with colored bits of glass. You look through it and see one irregular pattern repeated six or eight times, and there results a mosaic, a symmetric pattern of exquisite beauty. Invariance inspires beauty in art. This is probably all that time permits me to say about esthetics.

Thus far I have dealt, very sketchily to be sure, with invariance in the domains of truth (science) and of beauty (esthetics). I announced in the beginning of my discourse that I was also going to say a few words about the good, i.e. about ethics, and what I am going to do in this context may appear as a tour de force. First, I must sketch for you, very briefly and crudely, what is called the epistemology of science.

Science proceeds as follows: It begins with certain postulates, certain theorems which are inspired by the scientist's desire for invariance and a few other very general logical and esthetic principles. From these postulates the scientist derives theorems. He then checks the validity of these theorems against the facts of observation. That, in very simple terms--simple but fundamental--is the essence of scientific procedure. It is what every science does: it tries to formulate postulates sufficiently powerful and embracive to generate theorems, which are minor propositions (minor in a logical sense), aimed at observational experience, propositions which can then be tested against the facts of observation. And if the theorems match the facts we speak of the postulates as being true. The choice of postulates is based upon a variety of principles, among which invariance is very important. There are others, like logical fertility, simplicity, and so forth, but invariance is among them. So much for science.

Now what do we do in ethics? We encounter a very similar scheme. Every living system of ethics begins with commandments: the ten commandments of the Old Testament; the Golden Rule; the Sermon on the Mount. These generate values in the group of people living in accordance with the commandments, and these values are tested against certain goals which they are designed to achieve, for instance individual or collective happiness, contentment, serenity or the Buddhist's nirvana. There is a parallelism between science and ethics. The postulates correspond to the commandments, the theorems to the values, the facts to the goals. But there is more than parallelism here. The two schemes, the two epistemologies, are invariant with respect to a certain transformation. In this case the transformation is not a mathematical or a geometrical one; it is a transformation in language. Science tells us what is or will be, it leads us to understand the facts of the world. The language of science is the indicative. Ethics wishes to exhort, to admonish, to persuade human beings, to tell you what to do. Its language is the imperative.

In science invariance rests upon mathematical transformations. In the scheme of philosophy, which embraces both science and ethics, invariance rests upon semantics, as Korzybski would say. It rests upon a change in language. If you make the postulates of science into imperatives, they become commandments. The theorems of science which result from the postulates are the factual values which are generated by the commandments, and one can show that the facts of science correspond in this way to the goals of ethics.* So again, science and ethics, the true and the good, are invariant with respect to a kind of transformation, in this case a transformation with respect to language.

And now, in concluding, let me comment on one of the somewhat curious and astonishing consequences of my analysis of invariance. We are going to find more and more invariant relations. Korzybski's hope is going to be more and more fully realized. Whenever we find more invariances, truth is going to acquire additional facets. 'Objectivity' is going to be augmented and enhanced. We are never in possession of ultimate truth, and the philosophy which follows from the premises of Korzybski, among them the principle of invariance as it is worked out and more fully developed in modern science, embraces the non-ultimacy of truth. We never have truth fully within our grasp. Truth is the light at the end of the scientific or the ethical or the esthetic road. That seems somewhat unsatisfying, doesn't it? The postulates of science are not given to us by the facts, it takes genius to inject them into the stream of history. The commandments, the imperatives of ethics, the principles of esthetics, are generated by enlightened, inspired men, and there's going to be more enlightenment and inspiration in the future.

*The parallelism so inadequately sketched here is more fully worked out in my little book: Ethics and Science, Van Nostrand, 1966.

Truth, ethical goals, beauty, all will be enhanced in time.

So I would like to conclude my talk tonight by recalling to you one of the oldest legends of Western culture. It dates back before the Libyan dynasties of Egypt many centuries before the Christian era. It relates to the town of Sais in the delta of the Nile where a great temple had been dedicated to Osiris, the god of the underworld. Its ruins are still visible today.

It is said that this temple contained a mysterious picture covered by a veil and inscribed with the tantalizing words, 'The Truth'. Mortal man was forbidden to lift the veil, and the priests of Osiris enforced this statute with careful rigor. It is also said that a youth, dedicated to the discovery of truth--perhaps a scientist, if I may use a modern term--once entered the temple and saw this covered image. He asked his guide whether he knew what was covered by the veil, but he received a horrified denial and an official account of the ancient law. The thoughtful youth left the temple that day with an irresistible thirst for knowledge--knowledge of truth--which forced him to return at night with the intention of sacrilege. In the ghostly light of the moon he entered the hall of Osiris and lifted the veil from the image. What he saw nobody knows, but the legend insists he was found near death at the foot of the picture by the attendants of the temple the next morning. Revived, he would not speak of his experience, except to regret it. His life thereafter was spiritless and he sank into an early grave.

There the legend stands at the very beginning of our history, seemingly pregnant with significance yet noncommital, sphinx-like, forboding--human agony over truth--symbolizing one of the great and noble passions of man. The story has not lacked interpretations. Some writers have made it simply the finiteness of the human mind which cannot comprehend absolute truth. The German poet Schiller has given the story moral content, claiming that truth is fatal to a sinful conscience. Others have said, only God can reveal truth and he will not be forced to it by human impetuosity.

Now I should like to suggest another resolution to this ancient riddle, one perhaps not contradictory to those I have mentioned, but more timely and more useful, and more in the spirit of Korzybski's philosophy and of modern science. I suppose that the youth of Sais as he lifted the veil might have seen engraved on the temple wall a message such as this: 'Only a fool looks for truth in a finite formula; only a knave would want to acquire it without toil and heartache. Final truth is tantamount to stagnant knowledge. There is no substitute for self-correcting, progressing, ever-searching understanding. Dismiss your quest for truth in final formulation and embrace the greatest human virtue called un-ending search for truth.' And that search is aided in no small measure by such guides as the principle of invariance.

Apparently the shock of this message destroyed a feeble soul that expected truth by easy revelation.

Thank you.

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HENRY MARGENAU, Eugene Higgins Professor Emeritus of Physics and Natural Philosophy, is well known as an author and lecturer, and honored for outstanding teaching and scholarship. He is a leading authority on the philosophical foundations of physics. He is also deeply concerned with developing and fostering a more integrative education at all levels, where man and nature are assumed to be in harmonious unity.

Professor Margenau taught for forty-one years at Yale University and made important contributions to physics. In 1970-71 he lectured at the Philosophisches Seminar der Universität at Heidelberg. He has been at the forefront of advancing knowledge not only in physics, but also in the philosophy of science.

In his writings and teaching Professor Margenau has probed into the relationships between physical theory and philosophy. Particularly he sought to bring the methods of science to bear on ethics, and to help fill the need for a methodology of the exact natural sciences. He feels that a sense of unity among various scientific disciplines arises only through a methodological approach. He has the capacity to reduce seemingly complex theories to simple terms, and seeks to show the generality and the simple, universal humanity of the scientific approach. His interests lie especially in the shift in emphasis from technical science to the philosophical problems surrounding and pervading science. Also, certain traditional philosophical problems are brought into a contemporary setting.

He is Editor of Main Currents in Modern Thought, the journal of The Center for Integrative Education, an organization of which he is a Director, and also Director of Research. He is co-editor, with Wolfgang Yourgrau, of a new journal, Foundations of Physics. He also served as Consulting Editor for the Time-Life Science Series of volumes, and co-authored The Scientist, a book which grew out of this assignment.

Among his numerous professional honors, he received eight honorary doctorates. He has been a visiting lecturer or professor at many universities in this country and in Japan, Germany and Switzerland. He also has served as National Visiting Scholar of Phi Beta Kappa and as Distinguished Visiting Professor at Pennsylvania State University.

He is a prolific writer, the author or co-author of nine books, as well as more than two hundred scientific and philosophical articles. Among his books for which he is perhaps the most widely known are: The Nature of Physical Reality; A Philosophy of Modern Physics, Open Vistas; Philosophical Perspectives of Modern Science, and Ethics and Science.