In a 1950 Scientific American article, Einstein outlined his unified theory of physics. Too bad it was wrong  

By George Musser

When Albert Einstein started his efforts to develop a unified theory of physics in the early 1920s, it was such a hopeful enterprise. Existing theories, including both relativity and the emerging quantum mechanics, raised as many questions as they answered, so most physicists agreed on the need for a grander framework. Ideas poured forth from figures such as Hermann Weyl, Arthur Stanley Eddington and Theodor Kaluza. Although these pioneering efforts fell short of achieving unification, they introduced theorists to such fruitful concepts as gauge symmetry and extra dimensions.

Thirty years later Einstein stood alone. He had published and retracted a string of unified theories. Other scientists saw his approach as a dead end—an assessment that has been borne out by the progress of physics since his death in 1955. Whereas Einstein sought to base a unified theory on general relativity, quantum mechanics has proved the best starting point.

Toward the end of 1949, Einstein published what he called the definitive formulation of his unified theory, and the editors of Scientific American invited him to prepare a nontechnical account. Appearing in the April 1950 issue, it was the second-to-last article he ever wrote on science for the general public. Einstein scribbled it in longhand in German (the original survives in the Einstein Archives Online at alberteinstein.info), and the published version is a nearly unedited translation. It is a challenging read. Dry and methodical, it lacks the vivid thought experiments—trains, light beams, elevators—that animated Einstein’s earlier writings, and its description of the details of the unified theory is so vague as to be nearly incomprehensible. Dennis Flanagan, the magazine’s editor at the time, remarks: “The article was considerably more difficult than those we normally published, and we proposed some editorial changes to Dr. Einstein. He felt the article should be published without change.”

That said, the article rewards multiple readings, especially if one thinks of it as a discussion not of science but of the philosophy of science. The abstractness of the article, though a stumbling block for the nonphysicist, is actually one of its most important features, showing how Einstein’s goals had shifted over his career. His main research interest was no longer to explain observed phenomena. The general theory of relativity had taken care of gravitation, and Maxwell’s equations handled the other prominent force of nature, electromagnetism. Instead Einstein was trying to unite those two theories out of an urge to solve their conceptual riddles.

Thus, the abstract structure of these theories was precisely what concerned him. In the article, he wrote:

New theories are first of all necessary when we encounter new facts which cannot be “explained” by existing theories. But this motivation for setting up new theories is, so to speak, trivial, imposed from without. There is another, more subtle motive of no less importance. This is the striving toward unification and simplification of the premises of the theory as a whole.

Because physicists had already plucked the low-hanging fruit—they had come up with the laws that described our direct experiences—the next step was inevitably going to be harder:

A theory has an important advantage if its basic concepts and fundamental hypotheses are “close to experience,” and greater confidence in such a theory is certainly justified. There is less danger of going completely astray, particularly since it takes so much less time and effort to disprove such theories by experience. Yet more and more, as the depth of our knowledge increases, we must give up this advantage in our quest for logical simplicity and uniformity in the foundations of physical theory.

These comments remain pertinent even today. Many people have complained that string theory, in particular, has drift-
IN TRYING TO DEVELOP a unified theory, Einstein worked closely with Peter Bergmann (left) and Valentine Bargmann (right), two young German-born physicists who also had fled the Nazis and who went on to become renowned scientists in their own right. Bargmann’s wife, Sonja, was the one who translated Einstein’s Scientific American article (and many other manuscripts) into English. This picture was taken in 1940.

ed so far from the moorings of experiment that it has ceased to be a science. But any theory worthy of being called fundamental is going to seem remote and inaccessible, at least initially. You can’t just make some observations, follow a set of rules and arrive at an explanation. You have to come up with an idea, work it through and only then figure out how to test it experimentally. In that sense, science is an art. Einstein wrote:

The theoretical idea … does not arise apart from and independent of experience; nor can it be derived from experience by a purely logical procedure. It is produced by a creative act.

In Einstein’s theories, the creative spark was the idea of symmetry. A symmetric object remains the same even if it is transformed: reflected, rotated, distorted. Mathematically, a transformation is like typing the relevant equation into a word processor and doing a search-and-replace operation. If the equation has a particular kind of symmetry, the corresponding search-and-replace operation will have no effect on it. An example is the equation for a simple hyperbola, \(xy = 1\). If you replace \(x\) by \(y\) and \(y\) by \(x\), the equation does not change. That is an abstract way of saying that the two arms of a hyperbola are mirror images.

The goal that Einstein laid out was to formulate equations that stay the same for as many different search-and-replace operations as possible. The idea is that the more symmetrical the equations are, the more phenomena they encapsulate.

In the case of special relativity, you can replace every instance of \(x\), \(y\), \(z\) and \(t\)—the coordinates that specify the position and time—with a certain mathematical function of \(x\), \(y\), \(z\) and \(t\). Only a certain function will do; that is why it is called “special” relativity. This symmetry unites space with time. To calculate the distance between points, you cannot use the usual Pythagorean theorem containing \(x\), \(y\) and \(z\). You need a four-dimensional version of the theorem that also includes \(t\).

The general theory of relativity broadens the type of search-and-replace operation you can perform. Instead of a certain operation of \(x\), \(y\), \(z\) and \(t\), you can use nearly any function of these coordinates. For the equations of physics to remain the same, a force must enter into play, and this force is none other than gravitation. The distance between points is given by a more complicated rule—the “metric”—than the Pythagorean theorem. The metric can be represented by a four-by-four matrix of numbers. Because the distance from point A to point B is the same as from B to A, this matrix is symmetrical about the diagonal centerline, so it contains 10 unique numbers; the other six are repeats.

Einstein reasoned: Why stop there? Why not allow any matrix whatsoever? To the symmetric matrix (with 10 unique numbers) would be added a so-called antisymmetric matrix (another six). As it happens, Maxwell’s equations can be written using an antisymmetric matrix. So it is natural to hope that this approach unites gravitation with electromagnetism.

Unfortunately, what is natural is not necessarily right. Einstein ran into trouble trying to force-fit the two matrices together. It was not a transitory problem, as he thought, but a deep mismatch. Despite the outward similarities between gravitation and electromagnetism, physicists have found that the two are profoundly dissimilar. Moreover, during the three decades over which Einstein pursued his unified theory, researchers identified new forces that did not fit into his scheme: the weak and strong nuclear forces. Electromagnetism is more closely related to those forces than it is to gravitation. Although Einstein’s basic instincts about symmetry were right, he was applying them to the wrong entities. In the article, he wrote:

I do not see any reason to assume that the heuristic significance of the principle of general relativity is restricted to gravitation and that the rest of physics can be dealt with separately…. The comparative smallness of what we know today as gravitational effects is not a conclusive reason for ignoring the principle of general relativity in theoretical investigations of a fundamental character. In other words, I do not believe that it is justifiable to ask: What would physics look like without gravitation?

The opposite turned out to be true. Quantum mechanics without gravitation explains electromagnetism, the nuclear forces and the structure of matter with exquisite precision. Gravitation has actually been the hardest piece of physics to unify with the rest; physicists still struggle with it. Rather like Einstein himself at the end of his life, it stands apart.

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