General Relativity: Past, Present and Future[§]

*Syed Arif Kamal**

Gold Medalist; PhD (Neuroscience); MA, Johns Hopkins, United States; MS, Indiana, Bloomington, United States

Professor of Mathematics and Dean, Faculties of Science and Engineering

University of Karachi, Karachi, Pakistan; profdrakamal@gmail.com

The pathway to general relativity emerged for Albert Einstein after he struggled for seven years with many things, consisting of strong hunches about what the theory should say physically, vivid though experiments to support the hunched, lengthy explorations into new mathematics, errors and confusions, which tended to derail him and a final insight rescued him from exhaustion and desperation. The theory was developed by Einstein between 1907 and 1915, with contributions from many others afterwards. It was immediately recognized as both 'beautiful' and 'deep'. Within a short span of time after its formulation, some the main predictions were confirmed, viz. light-bending prediction during the 1919 total-solar-eclipse expedition and the mathematical calculation of perihelion precession of Mercury accounted for. However, one must realize that the contact of general relativity with experiment and observation is, mostly, limited to solar-system tests, *e. g.*, gravitational-red shift and the gravitational-time delay. Finding of the exact solutions, like the Schwarzschild solution, enabled researchers to investigate strong-field phenomena, predicted by general relativity. General relativity has developed into an essential tool for astrophysics and cosmology, in particular, the current understanding of black holes. However, when attempts are made to combine it with quantum mechanics and quantum-field theory, one realizes that general relativity is a tensorial theory, whereas quantum theories are linear (based on superposition principle and expansion postulate). Hence, this problem needs to be resolved before a mathematically consistent theory of quantum gravity is formulated, either by linearizing general relativity or by generalizing quantum mechanics to make it a tensorial theory. Further, general relativity is based on medium strong principle of equivalence and an experimental verification of this principle needs to be provided. The covariant approach has evolved through higher derivative gravity theories (which resolve non-renormalizability, but introduce new serious problems), supergravity theories (which yield finite scattering amplitudes to higher loop order in perturbation theory than ordinary general relativity) and on to superstring theory. The last one has the achievement of providing theorists with a finite theory of gravity. There are two distinct groups of researchers investigating the formulation of quantum gravity — particle physicists (taking the covariant approach) and general relativists (taking the canonical approach). It is too early to predict how far down the road, the theorists have come towards obtaining quantum theory of gravitation.

*Keywords***:** Albert Einstein • Curvature of space-time • Differential geometry • Geometrodynamics • Riemannian manifold

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[§]Main ideas are taken from**:**
https://sites.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/general_relativity_pathway/index.html

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*Senior-most professor among the entire faculty of University of Karachi