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f(R) gravity - the most straightforward generalization of the Einstein gravity

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f(R) gravity where R is the Ricci scalar represents the simplest non-perturbative generally covariant generalization of the Einstein gravity where it is possible to avoid the appearance of new ghost and tachyon degrees of freedom. Thus, this theory can be considered at the same level of generality as general relativity, not in some perturbative regime only. It represents a particular case of scalar-tensor gravity in the limit of the zero Brans-Dicke parameter, but with a non-zero scalar field potential. Its most interesting applications in cosmology are related to the possibility to use it for description of both types of dark energy which have appeared during the Universe evolution: primordial dark energy driving inflation in the early Universe and present dark energy which has much smaller effective energy density. In the case of inflation, the simplest $(R + R^2)$ model proposed already in 1980 is internally consistent, has a graceful exit to the radiation-dominated FRW stage via the period of reheating in which all matter in the Universe arises as a result of gravitational particle creation, and remains in agreement with the most recent observational data. Moreover, this form of f(R) may be justified by a number of microscopic models. In particular, it describes the gravitational sector of the Higgs inflation. It is possible to construct models describing the present dark energy in f(R) gravity which satisfy all present observational tests. However, these models require a much more complicated form of f(R) and a very low energy scale, so there is no microscopic justification of them at present. More critical is that these models generically cannot reproduce the correct evolution of the Universe in the past due to formation of additional weak singularities and other problems. Thus, to construct complete cosmological models of present dark energy not destroying all previous achievements of the early Universe cosmology including the recombination, the correct BBN and inflation of any kind, one has to change the behaviour of f(R) at large positive R and to extend f(R) to the region of negative R. I describe correct ways to do it. Combined description of primordial and present dark energy using one f(R) function is possible, too, but it leads to completely different reheating after inflation during which strongly non-linear oscillations of R occur.