Mutations in leucine-rich repeat kinase 2 (LRRK2) are the most frequent genetic lesions so far found in familial as well as sporadic forms of Parkinson’s disease (PD), a neurodegenerative disease characterized by the dysfunction and degeneration of dopaminergic and other neuronal types. The molecular and cellular mechanisms underlying LRRK2 action remain poorly defined. Synaptic dysfunction has been increasingly recognized as an early event in the pathogenesis of major neurological disorders. Using *Drosophila* as a model system, we have shown that LRRK2 controls synaptic morphogenesis. Loss of *Drosophila* LRRK2 (dLRRK) results in synaptic overgrowth at the *Drosophila* neuromuscular junction synapse, whereas overexpression of wild type dLRRK, human LRRK2 (hLRRK2), or the pathogenic hLRRK2-G2019S has the opposite effects. Alteration of LRRK2 activity also affects synaptic transmission in a complex manner. LRRK2 exerts its effects on synaptic morphology by interacting with distinct downstream effectors at the pre- and postsynaptic compartments. At the postsynapse, LRRK2 functionally interacts with the eIF4E binding protein (4E-BP) and the miRNA machinery, both of which negatively regulate protein synthesis. At the presynapse, LRRK2 phosphorylates and negatively regulates the microtubule-binding protein Futsch and functionally interacts with the mitochondrial transport machinery. These results implicate compartment-specific synaptic dysfunction caused by altered protein synthesis, cytoskeletal dynamics, and mitochondrial transport in LRRK2 pathogenesis and offer a new paradigm for understanding and ultimately treating LRRK2-related PD.