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Suppose the eigenvalue distributions of two matrices M_1 and M_2 are known. What is the eigenvalue distribution of the sum $M_1 + M_2$? This problem has a rich pure and applied math history. Free probability theory (FPT) answers this question under certain conditions. We will describe FPT and show examples of its powers for the qualitative understanding (often approximations) of physical quantities such as density of states, and gapped vs. gapless phases of quantum matter. These physical quantities are important for the understanding of quantum matter, yet are hard to compute exactly. Nevertheless, using FPT and other ideas from random matrix theory excellent approximations can be found. (Received February 18, 2018)