Magnetic structures are investigated by means of neutron diffraction to shine a light on the intricate details that are believed to be key to understanding the magnetoelectric effect in LiCoPO₄. At zero field, a spontaneous spin canting of $\phi = 7(1)^\circ$ is found. The spins tilt away from the easy $b$-axis toward $c$. Symmetry considerations lead to the magnetic point group $m'_z$, which is consistent with the previously observed magnetoelectric tensorform and weak ferromagnetic moment along $b$. For magnetic fields applied along $a$, the induced ferromagnetic moment couples via the Dzyaloshinskii-Moriya interaction to yield an additional field-induced spin canting. An upper limit to the size of the interaction is estimated from the canting angle.