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Scaling macroscopic aquatic locomotion MATTIA GAZZOLA, School of Engineering and Applied Sciences, Harvard University, USA, MEDERIC ARGENTINA, Universite Nice Sophia-Antipolis, Institut non lineaire de Nice, France, LAKSHMINARAYANAN MAHADEVAN, School of Engineering and Applied Sciences, Harvard University, USA — Inertial aquatic swimmers that use undulatory gaits range in length L from a few millimeters to 30 meters, across a wide array of biological taxa. Using elementary hydrodynamic arguments, we uncover a unifying mechanistic principle characterizing their locomotion by deriving a scaling relation that links swimming speed U to body kinematics (tail beat amplitude A and frequency ω) and fluid properties (kinematic viscosity ν). This principle can be simply couched as the power law $Re \sim Sw^{\alpha}$, where $Re = UL/\nu \gg 1$ and $Sw = \omega AL/\nu$, with $\alpha = 4/3$ for laminar flows, and $\alpha = 1$ for turbulent flows. Existing data from over 1000 measurements on fish, amphibians, larvae, reptiles, mammals and birds, as well as direct numerical simulations are consistent with our scaling. We interpret our results as the consequence of the convergence of aquatic gaits to the performance limits imposed by hydrodynamics.

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