Example: Rowing (taken from T. McMahon "Rowing: A similarity analysis" Science $\underline{173}$ p 349 (1971))

The question is: how does the speed ~~of~~ of a boat depend on the number of rowers?

- Assume all rowers excert same effort, measured by their power P_0. Hence N rowers will supply a total power $P = NP_0$.

- The rowers are working against (water) drag force.

$$F_{drag} \sim A v^2 \rho$$

A is the cross section (submerged) of the boat

v is its speed, ρ is the density of water.

- The rowers must supply a rate of work, or power

$$p = F_{drag} v \quad , \text{i.e. } P \geq p$$

to just match it, $p \approx P = F_{drag} v \sim A \rho v^3$

- By Archimedes' law, the displaced volume increases linearly with the number of rowers $\Rightarrow V \propto N$ or $V \sim N$

(assuming boat has ~~neglible~~ negligible mass. This is the case in a rowing racing boat)

So the Subnerged area $A \sim N^{2/3}$

$$\text{So} \quad N P_0 \sim (N)^{2/3} \rho v^3 \quad (\ddagger)$$

If we ask how much does the speed increase with the number of rowers? We solve for v interms of N in $(\ddagger)$:

$$\boxed{v = K N^{1/9}}$$

This result appears to be well supported by ~~Olympi~~ Olympic Rowing times.