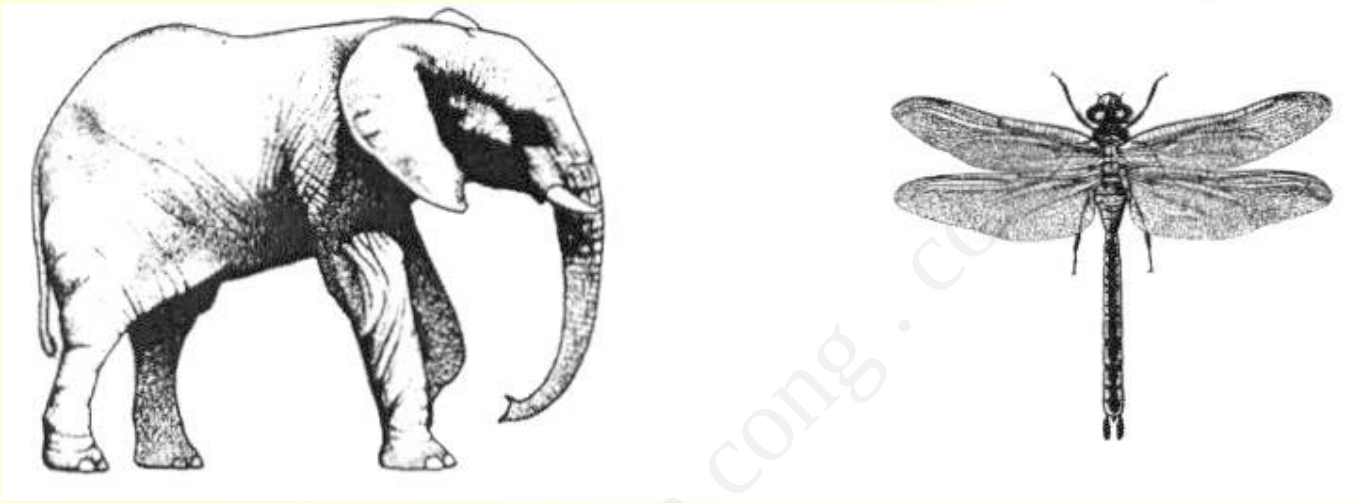
# 12. Actuators
## - Scaling

# Scaling

- If a systems is reduced isomorphically in size (I.e. scaled down with all dimensions of the system decreased uniformly), the change in length, area and volume ratios alter the relative influence of various physical effects that determine the overall operation.
- As objects shrink, the ratio of surface area to volume increases, rendering surface forces more important

- In scaling, equal reduction of surface and volume is not normally achievable
- Volume-related physical quantities: mass, heat capacity
- Surface-related physical quantities: pressure, buoyant force, heat flux



- Scaling in nature

Set s = single scale variable

Surface = $s^2$

Volume = $s^3$

S/V = $s^{-1}$

(Example)

Elephant, S/V = $10^{-4}$/mm

Dragonfly, S/V = $10^{-1}$/mm

# Scaling of mechanical systems

Trimmer's matrix formalism

Set s = single scale variable; linear scale of system

Assume all dimensions of the system are scaled down in size as s is decreased

For example,

Force law $s(F) = \begin{pmatrix} s^1 \\ s^2 \\ s^3 \\ s^4 \end{pmatrix}$ Time required $s(t) = \begin{pmatrix} s^{1.5} \\ s^1 \\ s^{0.5} \\ s^0 \end{pmatrix}$

- Scaling factor: s(Physical entity) = [$s^n$]

- Scaling of electrostatic force
- Scaling of magnetic force