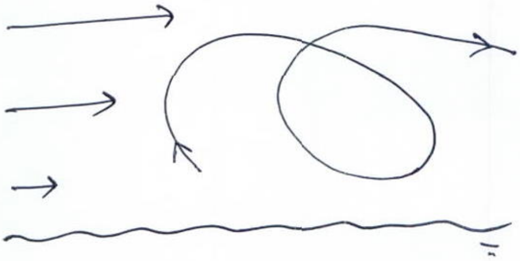
(4) Soaring

i) static soaring (upward moving air)
- slope soaring
  e.g. hang-gliders
  petrels
  albatrosses
- thermal soaring
- sea anchor soaring
  e.g. petrels ~ kite

ii) dynamic soaring
- no upward air movement
- temporal or spatial velocity gradient in wind from which an animal extracts the power necessary to stay aloft



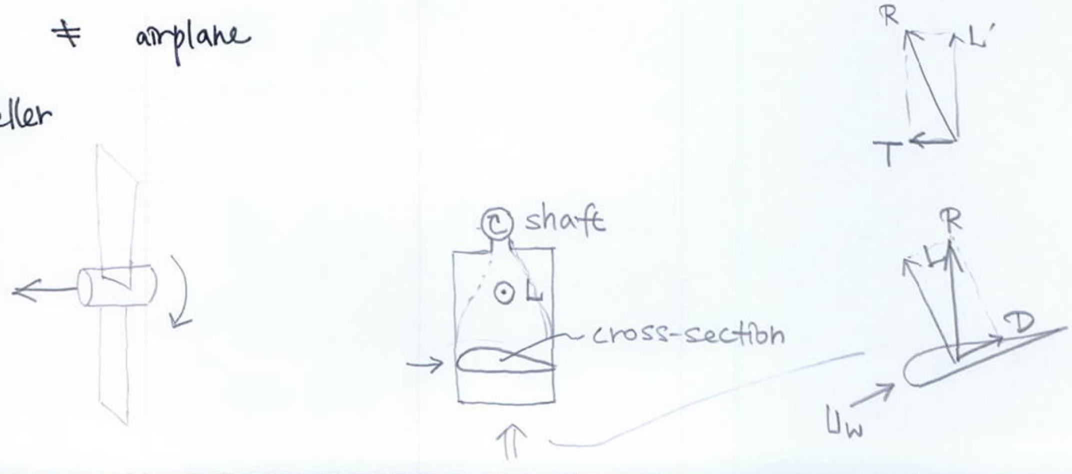
Chap. 12. The thrust of Flying and Swimming

§ Thrust from flapping

(1) The origin of thrust

birds, bats, insects with "flapping" wings
≈ helicopter
≠ airplane

· propeller



- near the base (shaft) : wind mainly due to craft's progression
- near the tip : wind mainly due to propeller rotation

→ twisted shape

~ flying organisms : nonrigid wings
- change degree of lengthwise twist

(2) The plane of flapping

- propeller

- hovering ~ stroke plane horizontal
- flight ~ " severely tilted

- hovering : the most expensive kind of flight

no component due to forward speed

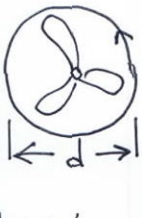
→ wind over wings slower

→ C_L must be higher : $L = \frac{1}{2}\rho U^2 S \cdot C_L$ ($U \downarrow$, $C_L \uparrow$)

to get enough L $(= W)$

(3) Advance ratio

$$J = \frac{\text{forward speed of craft}}{\text{blade speed of propeller}} = \frac{U_f}{nd}$$



airplane : $J < 4$

to increase U_f, $d \uparrow$ or $n \uparrow$

flying animals with reciprocating blades (or wings) :

$$J = \frac{U_f}{2\phi n R}$$

R : wing length

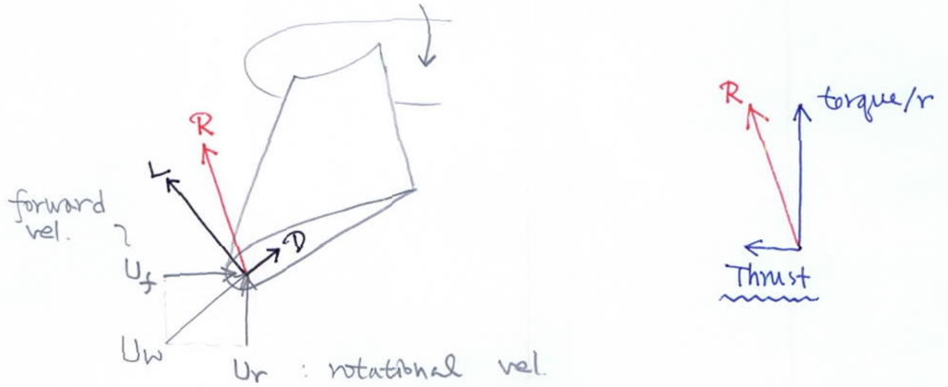
ϕ : stroke angle (amplitude)

n : wingbeat frequency

§ Four kinds of moving airfoils

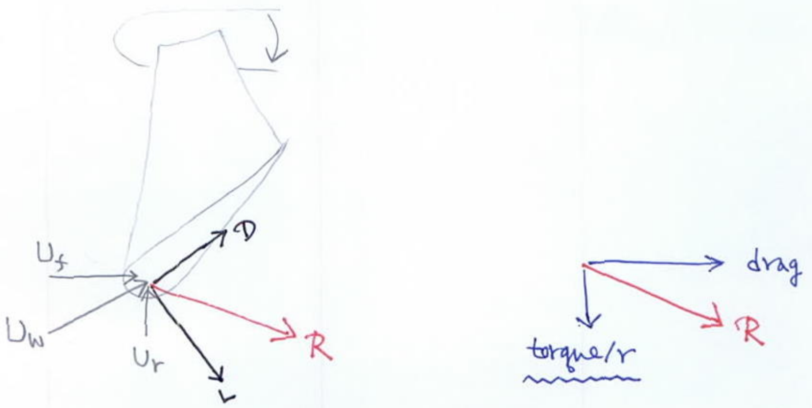
(1) propeller

~ inserts power into horizontal airstream



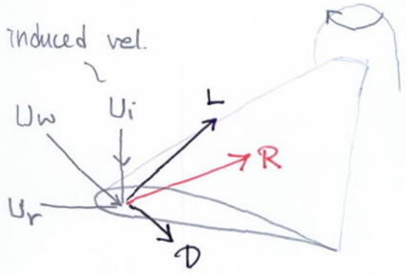
(2) windmill

~ extracts power from horizontal airstream



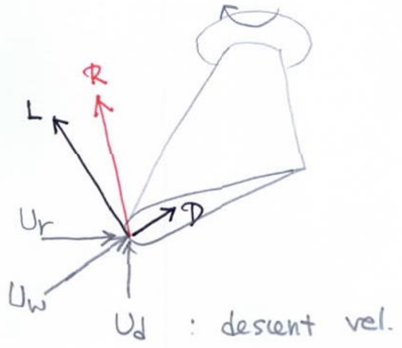
(3) helicopter

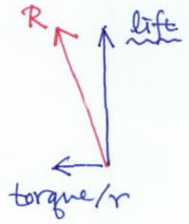
~ inserts power into airstream, taking air from above and thrusting it out below the plane of the rotor



(4) autogyro

~ extracts power from the airstream, taking air from below and retarding its passage upward through the plane of the rotor





- helicopter $\xleftrightarrow{\text{pitch change}}$ autogyro.

§ The flight of samaras (autogyro)

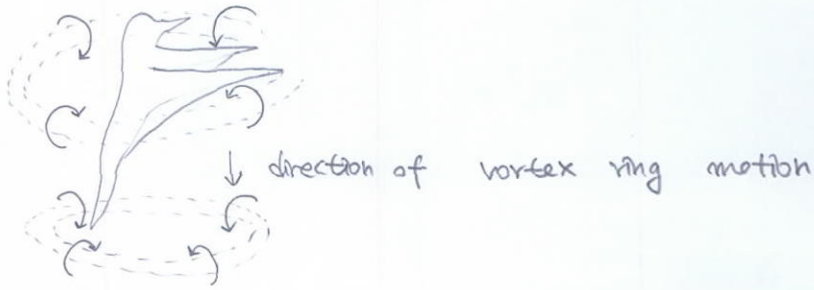
- low sinking speed desirable → low J : 0.9 ~ 1.5
- const. vel. descent : $L = W$

$L \sim U^2$

$\therefore U_{sink} \sim W^{1/2}$

§ A wake of vortices

: most powerful method to dissect the roles of nonsteady phenomena in flight (of animals)



* clap-and-fling mechanism

Fig. 12.8

§ Swimming

· diverse modes of swimming
  - common feature : generating and shedding vortices

(1) anguilliform

← eel, Anguilla

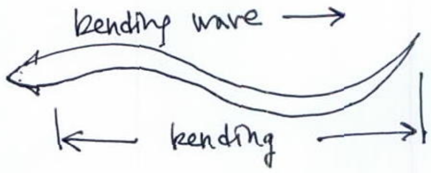
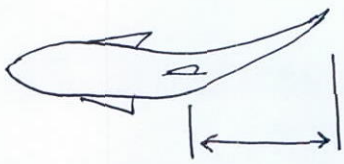


Fig. 12.9

e.g. limbless amphibians, aquatic snakes

(2) carangiform

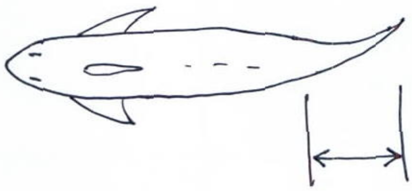
← Caranx (Jack : 전갱이 고기)



e.g. trout, perches, cichlids, mullets, ...

: ordinary mode of fish swimming
versatile in motion and control, good starting acceleration,
good maximum speed, good Froude efficiency

(3) thunniform
← tuna, Thunnus



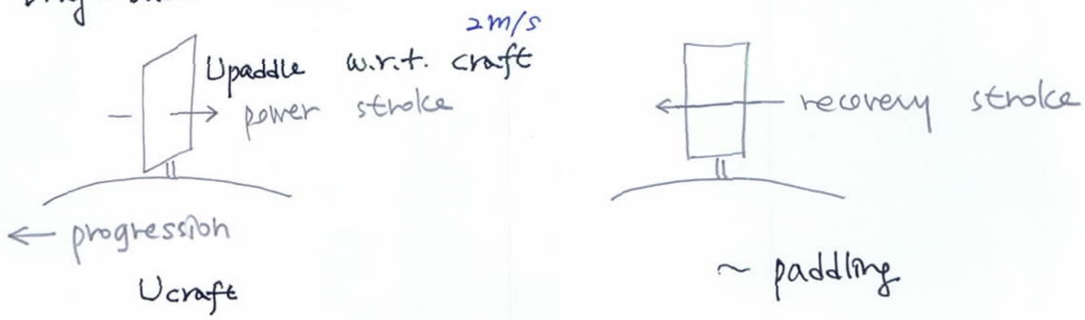
tail ≈ oscillating propeller / beating wing

e.g. mackerels, marlin, sharks, whales, dolphins

: most force- and power-efficient for high-speed swimming

§ Drag-based vs. lift-based thrust

(1) Drag-based thrust



if $U_c = 0$, $U_{p/water} = U_{p/c}$ = 2 m/s

$U_c \neq 0$ (1 cm/s) $U_{p/water} = U_{p/c} - U_c$ (= 1) in power stroke

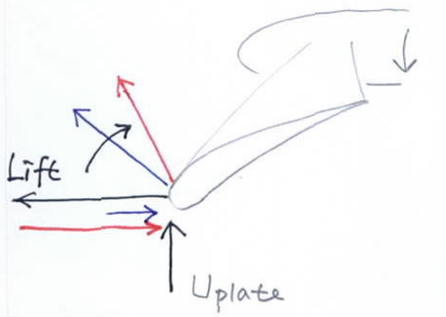
$U_{p/c} + U_c$ (= 3) in recovery stroke

if $U_c = U_p$: $U_{p/w} = 0$ in power stroke

∴ absolute speed limit exists

(2) Lift-based thrust

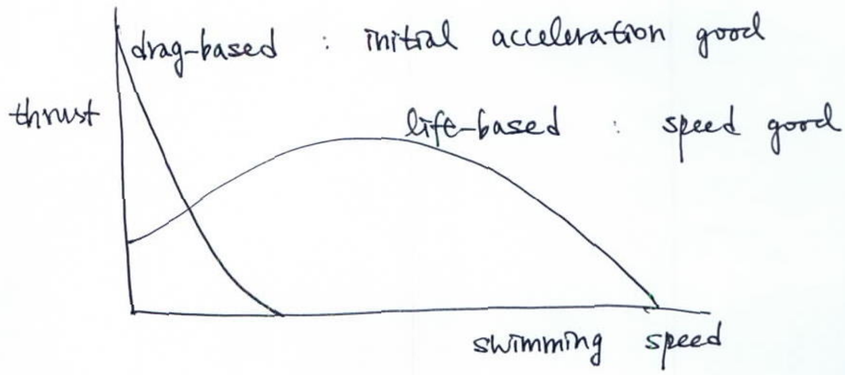
≈ wing flapping



as U_{craft} ↑ − lift ↔ not good

lift ~ U^2 good

Fig. 12.11

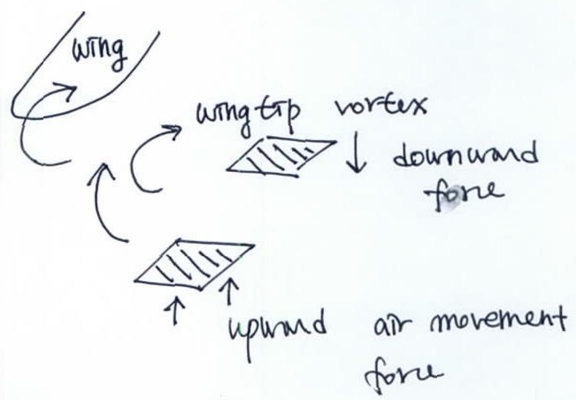


e.g drag-based : muskrats, freshwater turtles, large water beetles, angelfish
* crayfish (가재), shrimp, lobster
→ impulsive rearward motion with powerful flexing of abdomen

lift-based : penguins, sea lions, sea turtles
sea butterfly

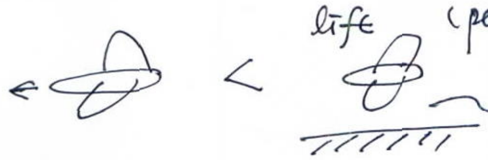
§ Fillips and flourishes in flying and swimming

(1) formation flight in birds



- fish schooling

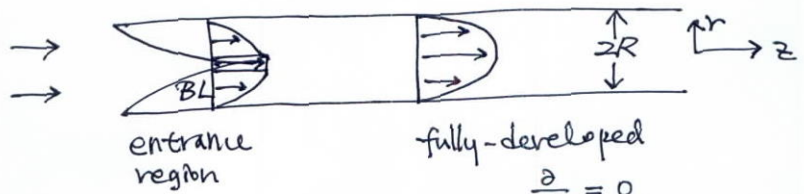
(2) Ground effect



~ increases air pressure on the lower wing surface

interrupts wingtip vortices → lower induced drag

Chap. 13. Flows within pipes and other structures



$\frac{\partial}{\partial z} = 0.$

Navier-Stokes eq (cyl. coords)

$$\rho \frac{D v_z}{Dt} = -\frac{\partial p}{\partial z} + \mu \left[\frac{1}{r}\frac{\partial}{\partial r}\left(r \frac{\partial}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2}{\partial \theta^2} + \frac{\partial^2}{\partial z^2} \right] v_z$$

$$\rightarrow \quad 0 = -\frac{dp}{dz} + \mu \frac{1}{r}\frac{d}{dr}\left(r \frac{d}{dr}\right) u$$

B.C. $\quad u(r=R) = 0$

$\frac{du}{dr}(r=0) = 0.$

$$u = \left(-\frac{dp}{dz}\right) \frac{1}{4\mu} (R^2 - r^2)$$

$$-\frac{dp}{dz} = \frac{\Delta p}{L}$$