FROM: "LIFE IN MOVING FLUIDS" S. VOGEL 2ND ed. 1992

TABLE 5.1 A SPECTRUM OF REYNOLDS NUMBERS FOR SELF-PROPELLED ORGANISMS.

	Reynolds Number
A large whale swimming at 10 m s^{-1}	300,000,000
A tuna swimming at the same speed	30,000,000
A duck flying at 20 m s^{-1}	300,000
A large dragonfly going 7 m s^{-1}	30,000
A copepod in a speed burst of 0.2 m s^{-1}	300
Flapping wings of the smallest flying insects	30
An invertebrate larva, 0.3 mm long, at 1 mm s^{-1}	0.3
A sea urchin sperm advancing the species at 0.2 mm s^{-1}	0.03
A bacterium, swimming at 0.01 mm s^{-1}	0.00001

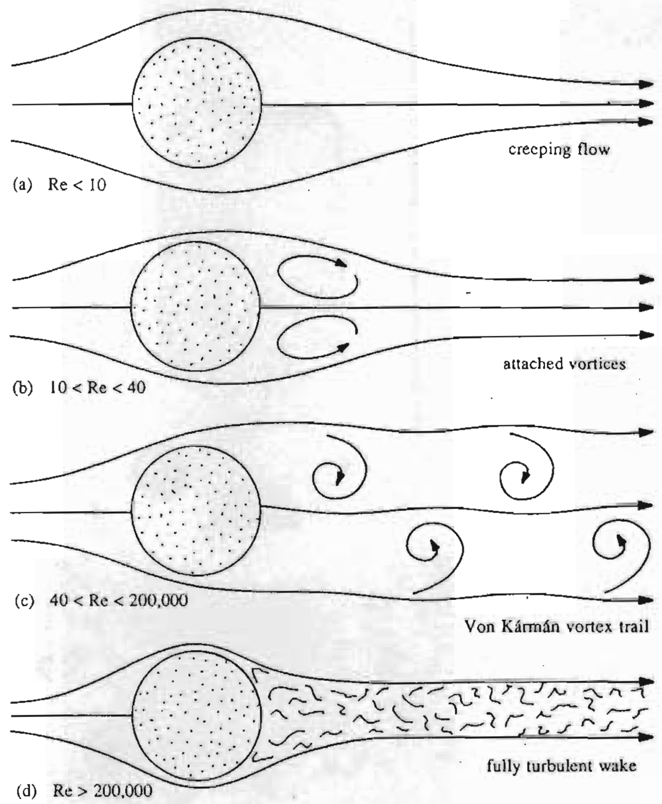

FIGURE 5.5. Patterns of flow behind a circular cylinder. Note the absence of vortices at low Reynolds numbers in (a) and the constriction of the wake between (c) and (d). This last change is concomitant with the drop in drag coefficient—the great "drag crisis"—at Reynolds numbers between about 100,000 and 250,000.

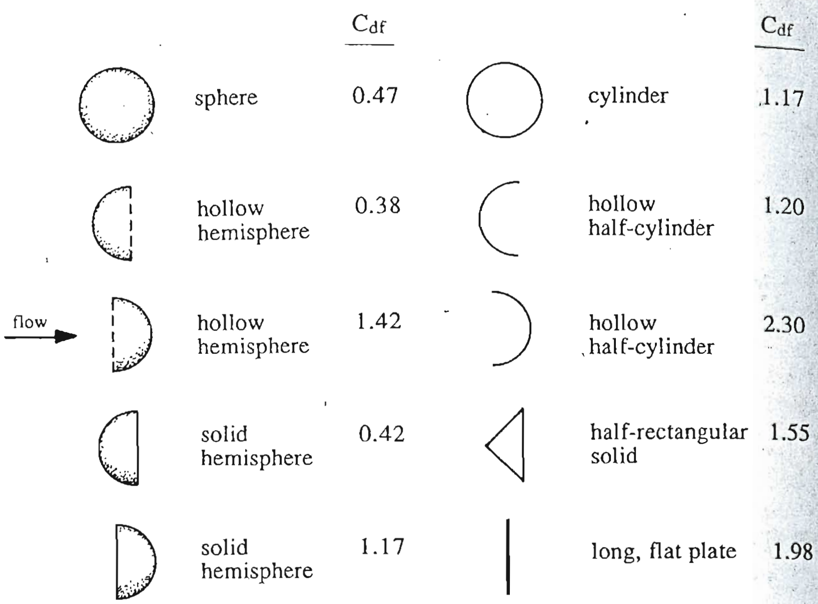

FIGURE 6.4. Drag coefficients, based on frontal area, for a variety of three-dimensional bodies and two-dimensional profiles at Reynolds numbers between 10^4 and 10^6. All the data may not be precisely comparable due to variations in the experimental conditions.

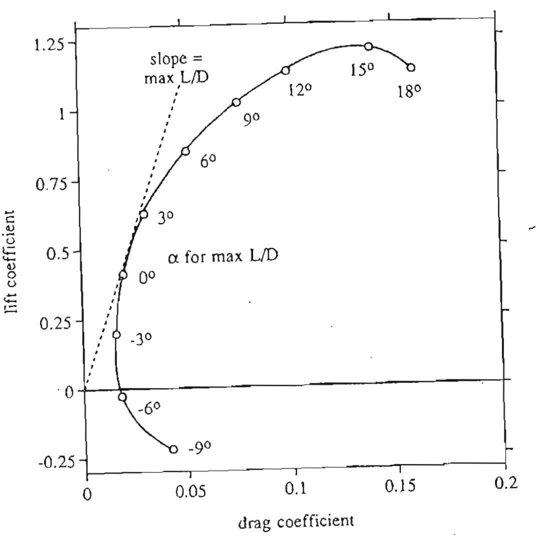

FIGURE 11.4. A polar diagram for an airplane wing. The lift coefficient is plotted against the drag coefficient, both referred to plan form area and usually with different scales, and the angles of attack are noted on the curve. Any line that passes through the origin is a line of constant lift-to-drag ratio. The one tangent to the curve gives the maximum obtainable ratio, and it touches the curve at the angle of attack that gives that maximum ratio.

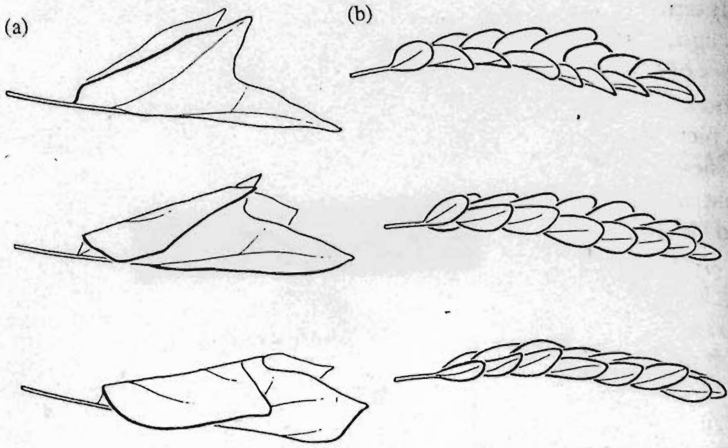

FIGURE 6.9. The reconfiguration of leaves in high winds: (a) tuliptree or yellow poplar (*Liriodendron tulipifera*); (b) black locust (*Robinia pseudoacacia*).

FIGURE 6.10. Marine macroalgae that reconfigure in flow. From left to right: *Nereocystis*, *Postelsia*, *Laminaria*, *Hedophyllum*.

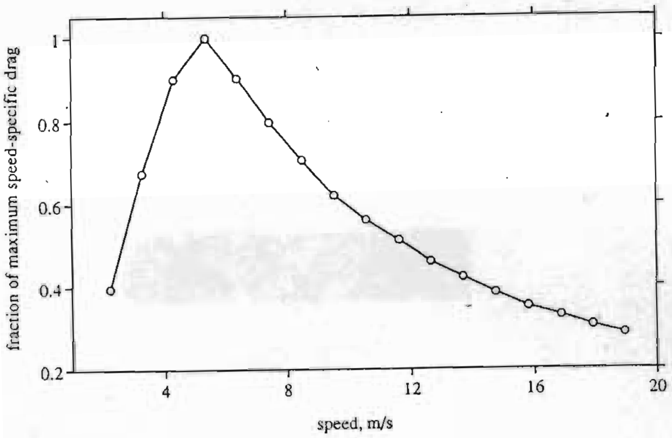

FIGURE 6.7. Speed-specific drag (fraction of maximum) versus speed for a small branch of a loblolly pine (*Pinus taeda*). For speeds above 6 m s^{-1}, $E = -1.13$.

TABLE 6.1 VALUES OF E FOR VARIOUS SYSTEMS AND SPEEDS, WHERE $U^E \propto D/U^2$.

System	*Re or Speed Range*	*E*	*Source of Data*
Bluff body	<1.0	−1.00	
Bluff body	1000–200,000	0.00	
Flat plate, parallel to flow	10–1000	−0.60	Janour 1951
Flat plate, parallel to flow	1000–500,000	−0.50	
Streamlined body, laminar flow	1000–500,000	−0.50	
Cylinder, axis normal to flow	20–120	−0.29	White 1974
Hedophyllum sessile (alga)	0.5–2.5 m/s	−1.12	Armstrong 1989
Nereocystis luetkeana (alga)	1.3–2.0 m/s	−1.07	Koehl & Alberte 1988
Sargassum filipendula (alga)	0.5–1.5 m/s	−1.47	Pentcheff (pers. comm.)
Laminaria (alga) on mussels	0.12 to 0.62 m/s	−1.40*	Witman & Suchanek 1984
Macroalgae, marine	ca. 2.5 m/s	−0.28 to −0.76	Carrington 1990
Red algae, freshwater	0.2–0.75 m/s	−0.33 to −1.27	Sheath & Hambrook 1988
Pinus sylvestris (pine)	9–38 m/s	−0.72*	Mayhead 1973
Pinus taeda, 1 m high	8–19 m/s	−1.13	Vogel 1984
Pinus taeda, branch	8–19 m/s	−1.16	"
Quercus alba (white oak), leaf	10–20 m/s	+0.97	Vogel 1989
Quercus alba, clustered leaves	10–20 m/s	−0.44	"
Other broad leaves & clusters	10–20 m/s	−0.20 to −1.18	"
Ptilosarcus gurneyi (sea pen)	0.11–0.26 m/s	−1.14	Best 1985
Pseudopterogorgia (gorgonian)	0.13–0.35 m/s	−1.66	Sponaugle & LaBarbera 1991
Abietenaria (hydroid)	0.025–0.40 m/s	−1.28*	Harvell & LaBarbera 1985
Acropora reticulata (hard coral)	1.5–3.0 m/s	+0.26*	Vosburgh 1982
Various limpet shells	0.15–0.45 m/s	0.0 to +1.2	Dudley 1985
Epeorus sylvicole (mayfly larva)	0.4–1.2 m/s	+0.28*	Weissenberger et al. 1991
Simulium vittatum (blackfly larva)	0.1–0.7 m/s	−0.64*	Eymann 1988
Locusta migratoria, antenna	20–120	−0.56	Gewicke & Heinzel 1980

NOTE: Asterisks indicate my calculations from published graphs.

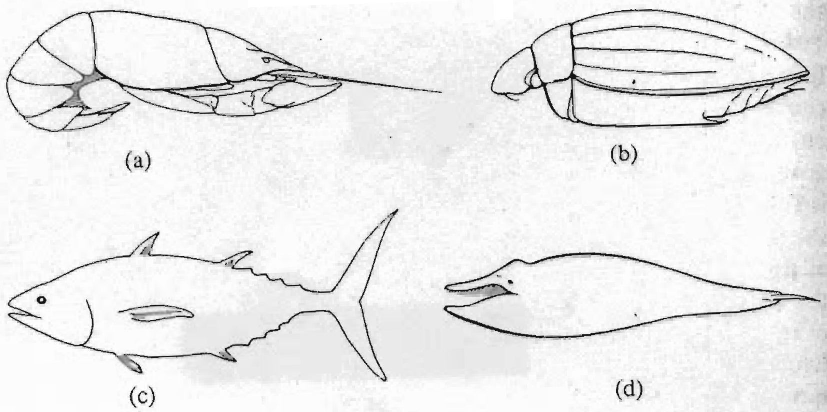

FIGURE 7.3. Streamlined organisms in a flow that goes from left to right: (a) a crayfish going rearward in a rapid escape; (b) a large aquatic beetle; (c) a pelagic fish such as a tuna; and (d) a baleen whale.

	Re	C_d	*Area*	*Source*
Fleas				
Ctenophthalamus	65–205	0.96	f	Bennet-Clark & Alder 1979
Hystricopsylla	"	1.02	f	
Fruit fly, *Drosophila virilis*	300	1.16	f	Vogel 1966
Locust, *Schistocerca gregaria*	8000	1.47	f	Weis-Fogh 1956
Marine isopods				
Idotea wosnesenskii	2700	0.08	w	Alexander & Chen 1990
Idotea resecata	5500	0.055	w	"
Dytiscid beetles				
Acilius sulcatus	8600	0.28	f	Nachtigall 1977a
Dytiscus marginalis	15,000	0.33	f	"
Tadpole, *Rana catesbiana*	1000–2500	0.36–0.74	f	Dudley et al. 1991
Frogs				
Hymenochirus boettgeri	1500–8000	0.11–0.24	w	Gal & Blake 1987
Rana pipiens	17K–40K	0.05–0.06	w	"
Crabs				
Callinectes sapidus	10,000	0.3	p	Blake 1985
Cancer productus	10,000	0.35	p	"
Ducks, various underwater	420,000	0.028	w	Lovvorn et al. 1991
Cephalopod, *Nautilus*	100,000	0.48	v	Chamberlain 1976
Falcon, *Falco peregrinus*	380,000	0.24	f	Tucker 1990a
Fish				
Trout, *Salmo gairdneri*	50K–200K	0.015	w	Webb 1975
Mackerel, *Scomber*	100,000	0.0043	w	"
"	175,000	0.0052	w	"
Saithe, *Pollachius virens*	500,000	0.005	w	Hess & Videler 1984
Penguin, *Pygoscelis papua*	1,000,000	0.0044	w	Nachtigall & Bilo 1980
Marine mammals				
Sea lion, *Zalophus californ.*	2,000,000	0.0041	w	Feldcamp 1987
Seal, *Phoca vitulina*	1,600,000	0.004	w	Williams & Kooyman 1985
Human, swimming	1,600,000	0.035	w	"

NOTE: The reference areas vary among the sources: f = frontal; w = wetted; p = plan form; v = volume$^{2/3}$.

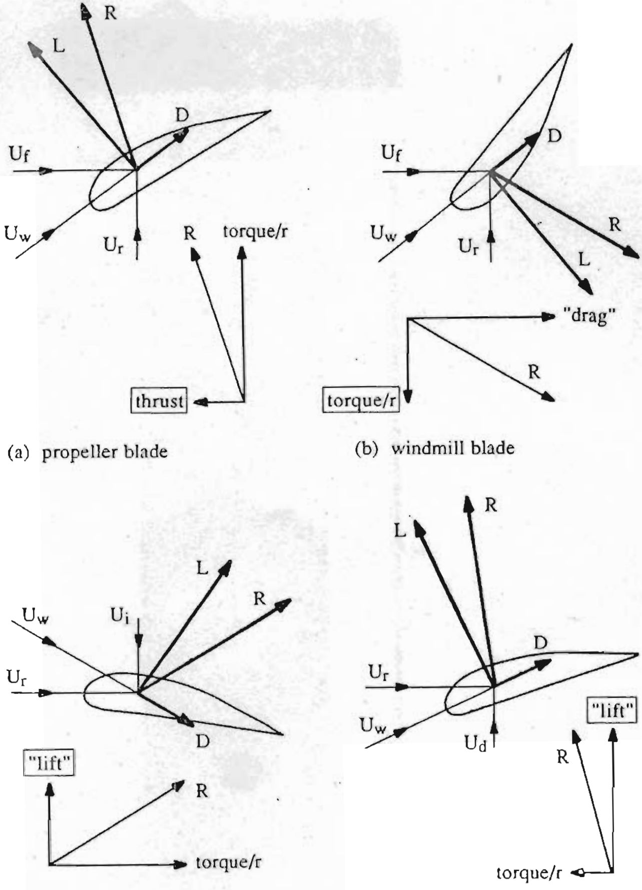

FIGURE 12.4. Four kinds of moving airfoils, analyzed as in 12.1. U_i is the wind component induced by the action of a helicopter blade as it pushes air downward; U_d is the wind component due to the descent of the autogyro. Other symbols are the same as in 12.1. Variables in quotes refer to the earth rather than the airfoil, and the desirable components of the resultants are boxed.