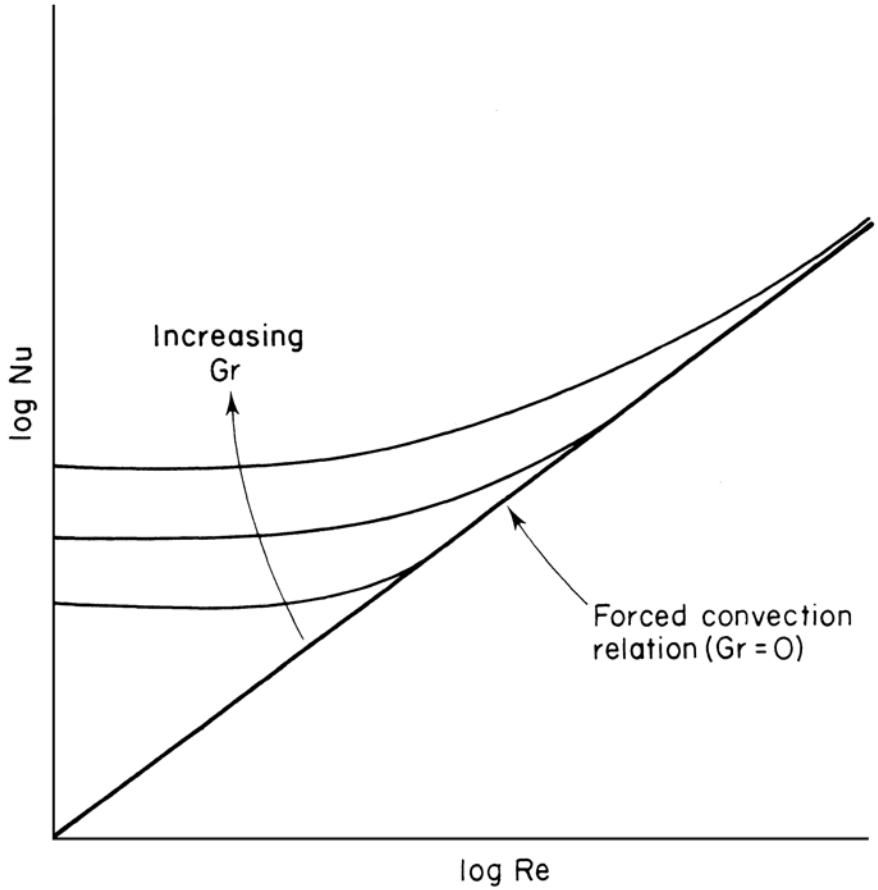

Figure 10.1 Influence of Grashof number (Gr) on the observed relation between Nusselt (Nu) and Reynolds number (Re) for a heated sphere exposed to horizontal wind. The curves represent observations at three increasing Grashof numbers; the straight line is the relation in forced convection (Gr = 0) (after Yuge, 1960).

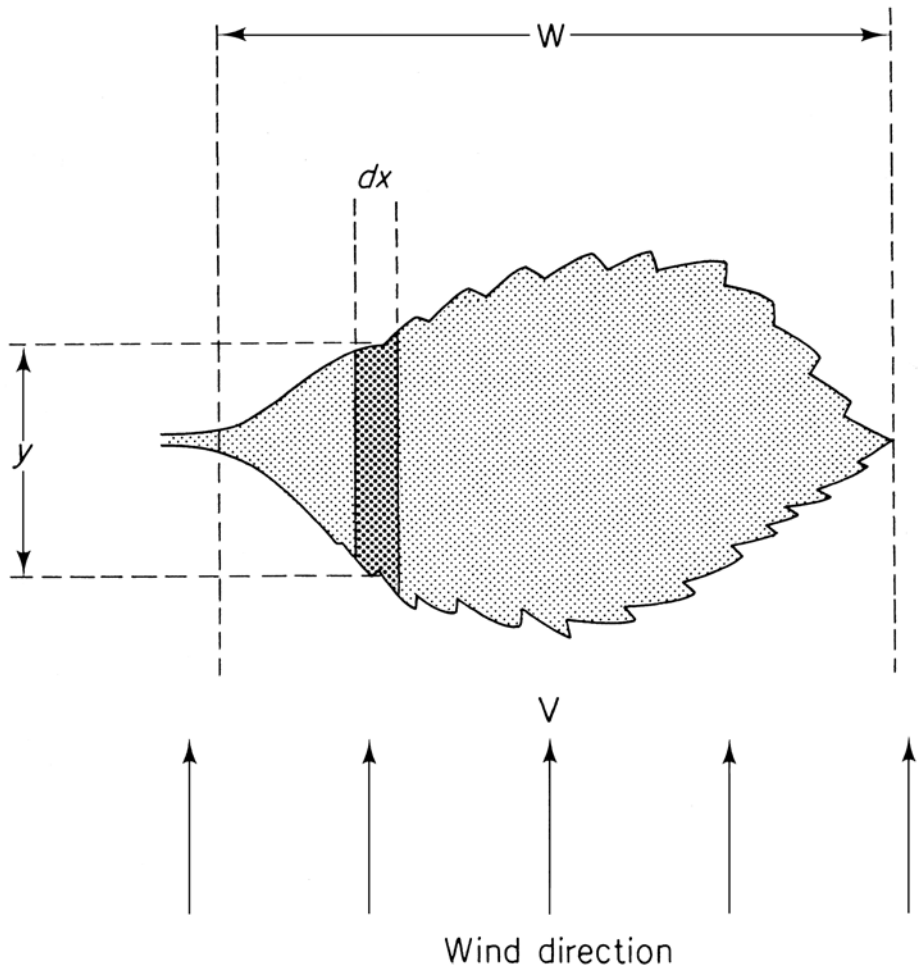

Figure 10.2 Coordinates for integrating heat loss over the surface of a leaf of irregular shape.

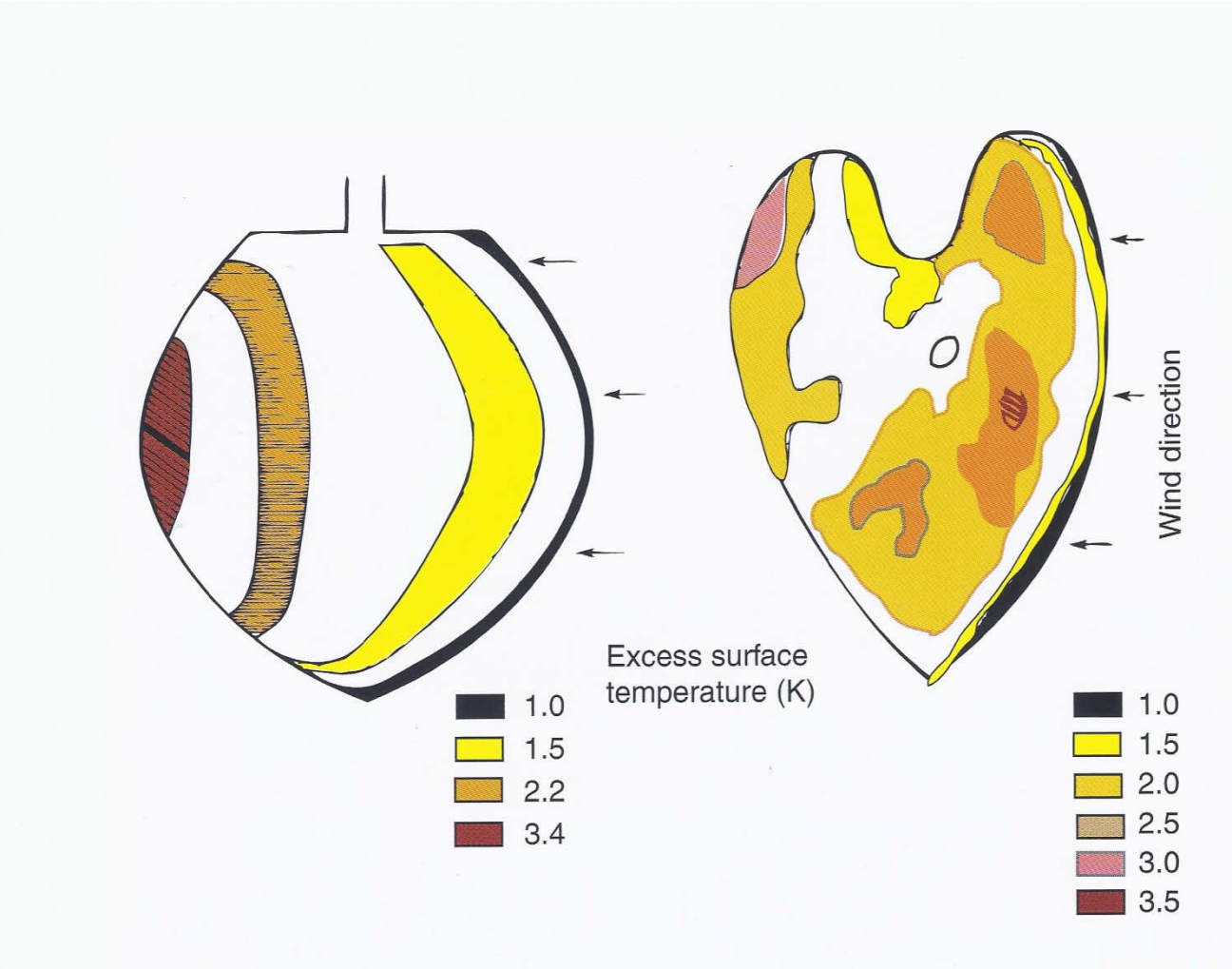

Figure 10.3 Surface temperature distribution for a model and for a real (*Phaseolus*) leaf in comparable environments measured with a thermal imaging camera. The values in the key indicate the mean temperatures of isotherm bands on the original thermograms. Narrow isotherm bands employed in measurements on the model (left of figure) result in the white areas, intermediate between the adjacent labeled temperatures (from Wigley and Clark, 1974).

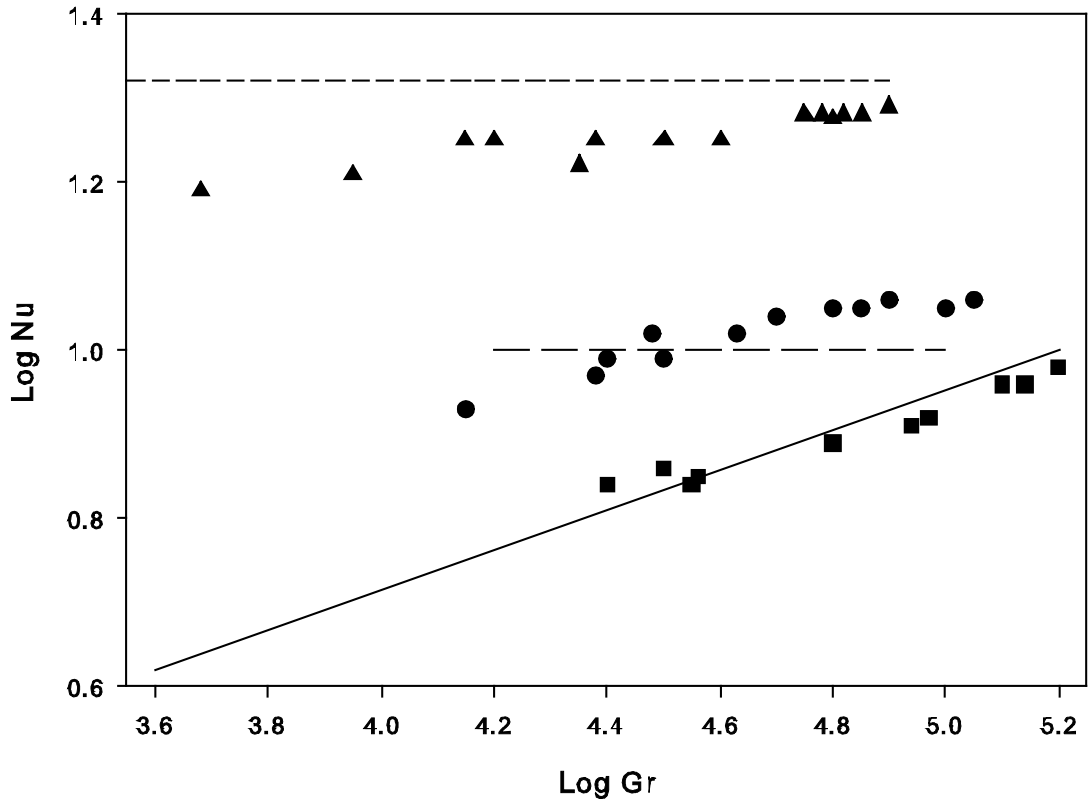

Figure 10.4 Measured values of Nusselt number (Nu) for heated artificial leaves exposed vertically, compared to values for free Eq. (10.11) and forced convection Eq. (10.7). When forced convection was applied the air flow was vertically upwards. Symbols: ■ measured at Re = 0; ● measured at Re = 296; ▲ measured at Re = 1014; —— free convection Eq. (10.11); — — —forced convection Eq. (10.7) at Re = 296; and – – – forced convection at Re = 1014 (from Bailey and Meneses, 1995).

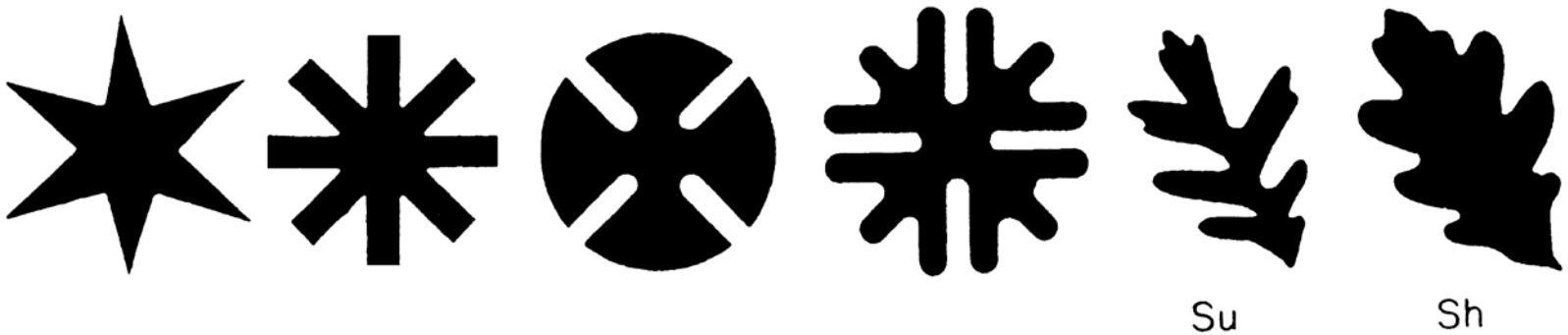

Figure 10.5 Metal replicas of leaves used byVogel (1970) to study heat losses in free convection. The shapes Su and Sh represent sun and shade leaves of white oak.

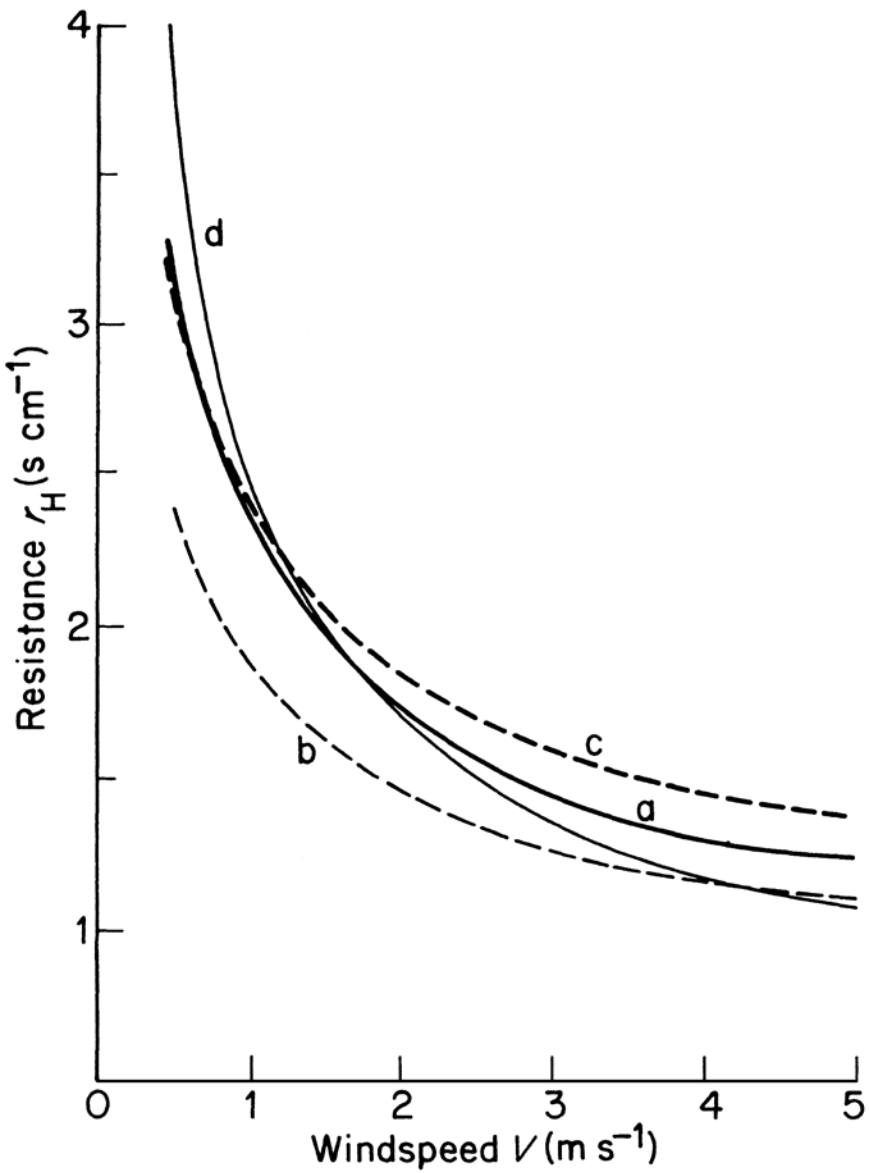

Figure 10.6 Relations between aerodynamic resistance r_H to heat transfer and windspeed V for cylindrical bodies. Line a, smooth isothermal cylinder (McAdams, 1954); line b, cattle (Wiersma andNelson, 1967); line c, sheep (Monteith, 1974); line d, sheep (McArthur and Monteith, 1980a).

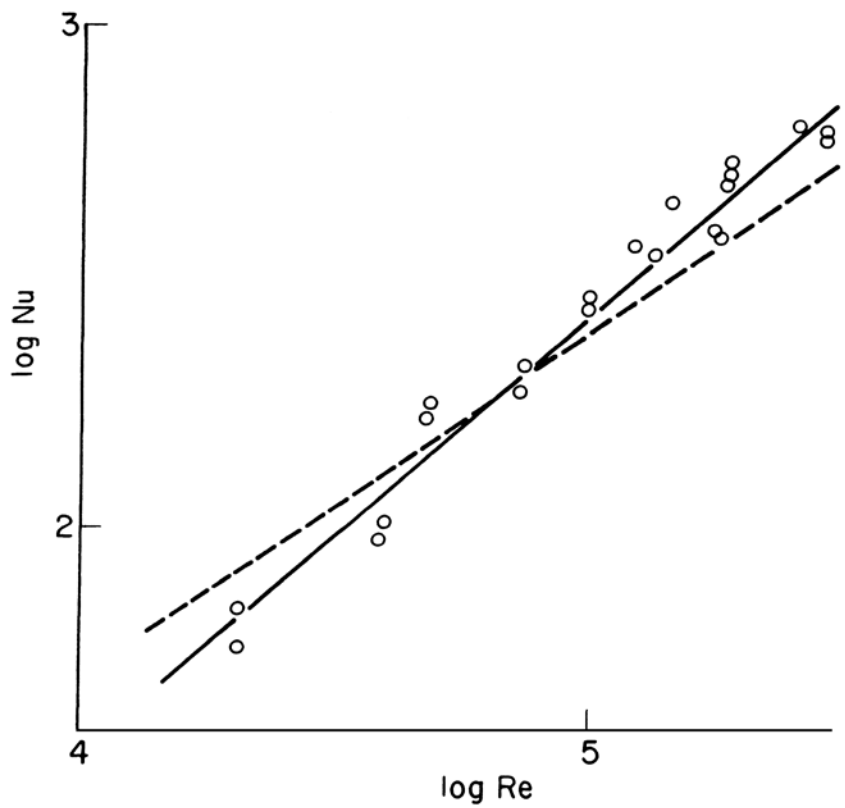

Figure 10.7 The relation between Nu and Re for model sheep without fleece (- - - -); the relation for the same model with fleece (— and points) (from McArthur and Monteith, 1980a).

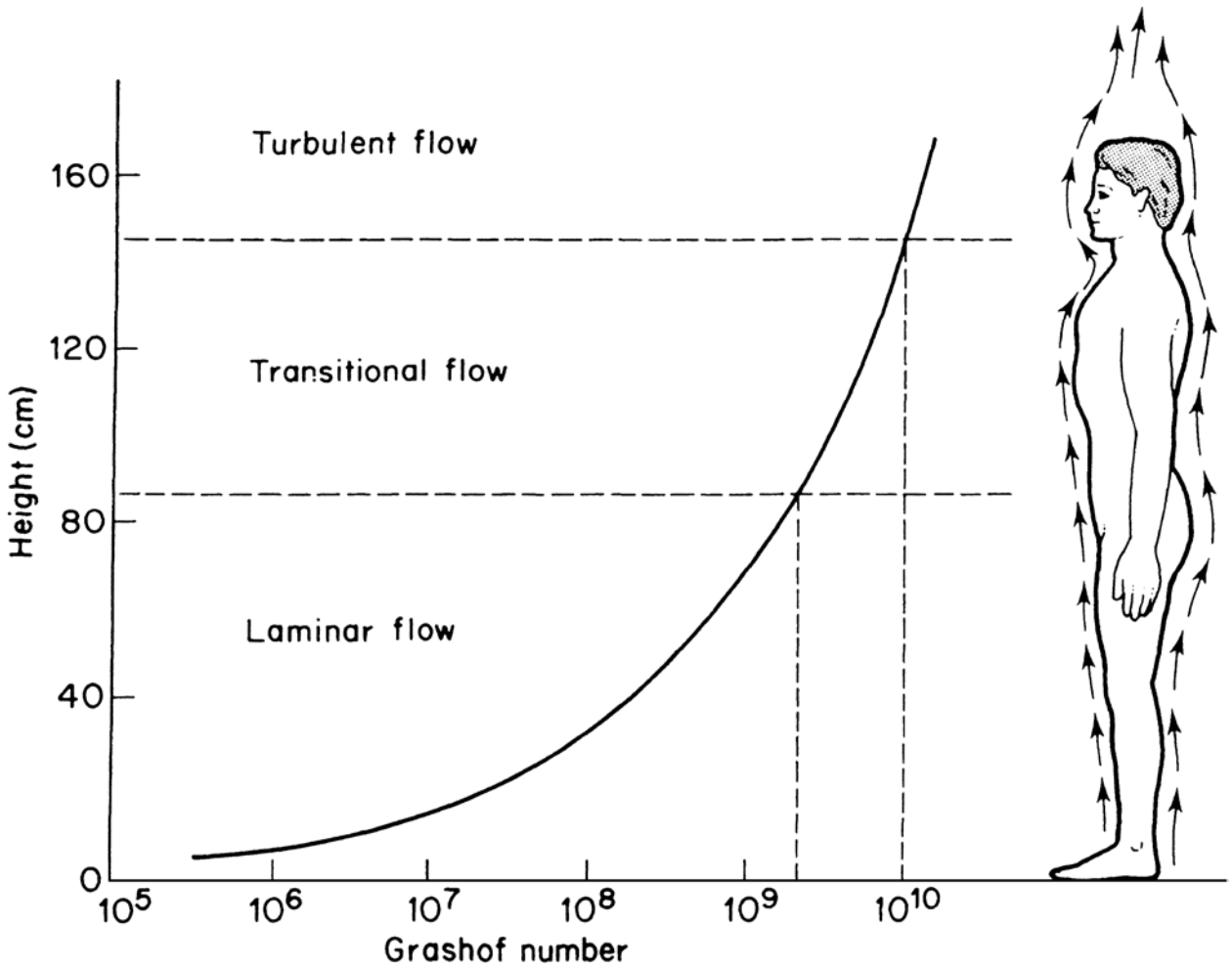

Figure 10.8 Variation of Grashof number with vertical height over the body surface for a mean skin temperature of 33 °C and an ambient temperature of 25 °C (from Clark and Toy, 1975).

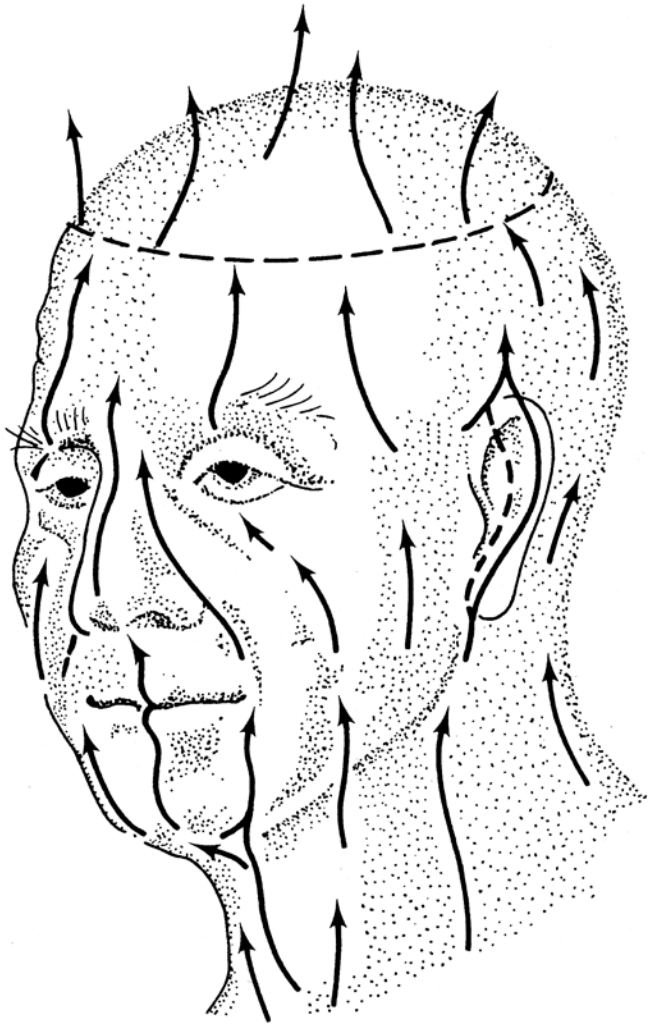

Figure 10.9 Routes taken by the flow of naturally convected air over the human head (from Schlieren photography by Lewis et al. (1969)).

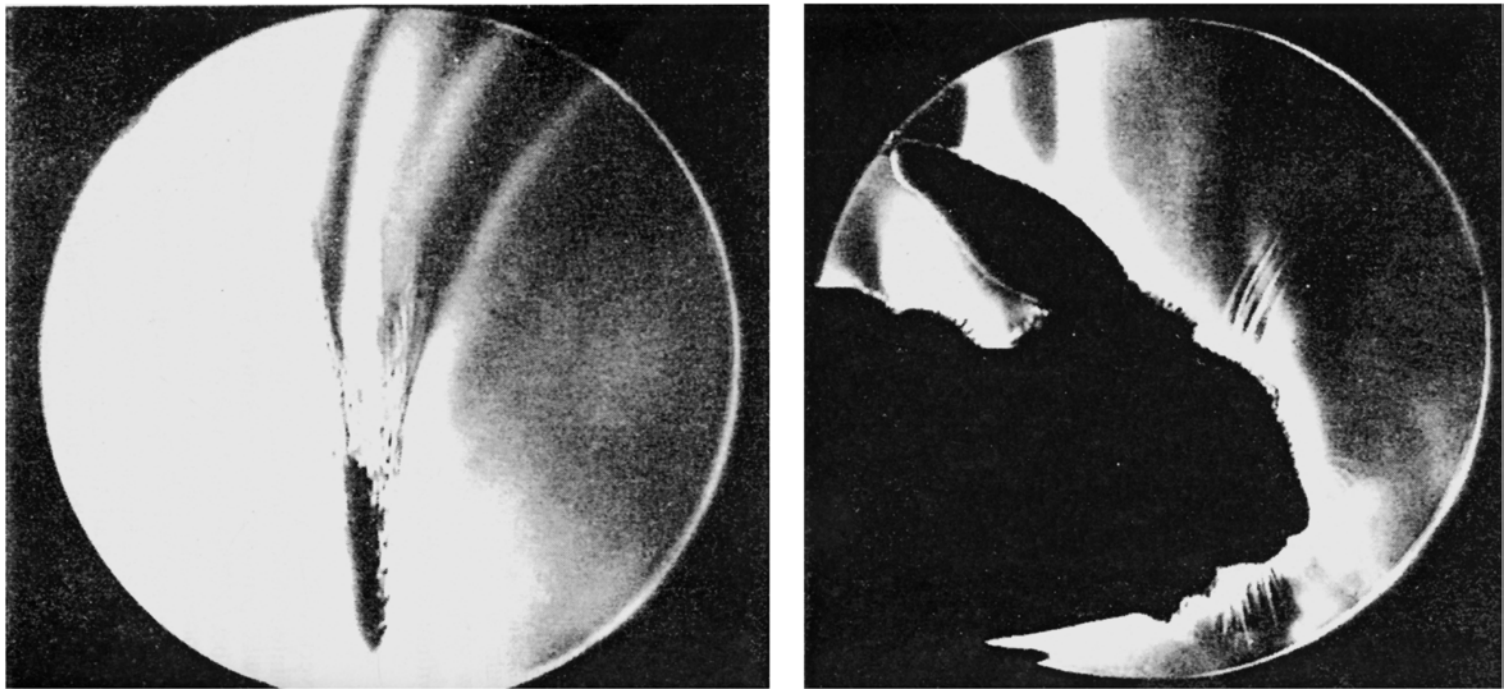

Figure 10.10 Schlieren photographs of an ear of awned wheat and a rabbit's head showing regions of relatively warm air (light) and cooler air (dark). The wheat was exposed to an incandescent light source giving about 880 W m^{-2} net radiation. Note the disturbed air round the rabbit's nostrils, the separation of rising air over the eyebrows, and the evidence of strong heating of air round the ears.

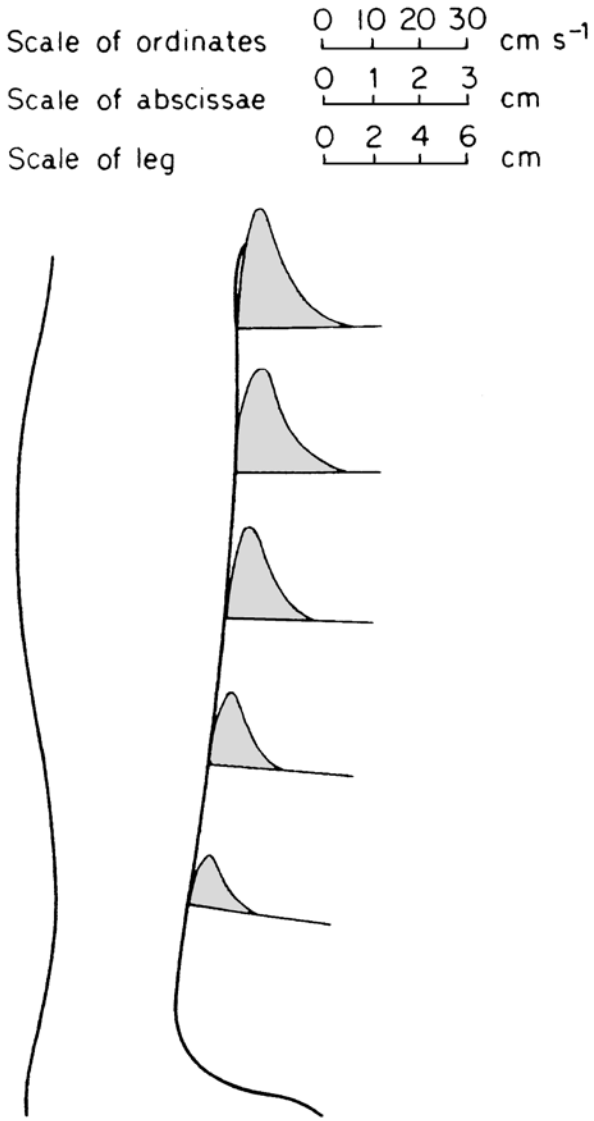

Figure 10.11 Development of velocity profiles on the front of the leg measured with a hot wire anemometer (from Lewis et al., 1969).

Table 10.1 Insulation of Still Air, Human Clothing, Sleeping Bags, and Duvets

Insulation material	**clo**	**tog**	**K m^{-2} W^{-1}**	**r (s cm^{-1})**
Still air (1 cm at 20 °C)	2.6	4.0	0.4	4.8
Naked human	0	0	0	0
Tropical clothing	0.3	0.5	0.05	0.6
Light summer clothing	0.5	0.8	0.08	1.0
Indoor winter clothing	1.0	1.6	0.16	2.0
Heavy weight business suit	1.5	2.3	0.23	2.8
Maximum insulation outdoor clothing	4.0	6.2	0.62	7.6
Summer weight sleeping bag (8–15 °C)	2–3	3–5	0.3–0.5	3.7–6.1
Winter weight sleeping bag (−3 to +10 °C)	4.5–6.5	7–10	0.7–1.0	8.5–12.2
Winter weight duvet	8.4	13	1.3	15.9

Values of resistance are based on an arbitrary value for ρc_p of 1.22×10^3 J K m^{-3}.

Table 10.2 Thermal Resistances of Animals. Peripheral Tissue, and Coats

Tissue (Blaxter, 1967)	**s cm^{-1}**	
	Vaso-constricted	***Dilated***
Steer	1.7	0.5
Man	1.2	0.3
Calf	1.1	0.6
Pig (3 months)	1.0	0.6
Down sheep	0.9	0.3
Coats (Blaxter, 1967; Hammel, 1955)	**s cm^{-1} per cm depth**	**Percent of still air**
Air	4.7	100
Red fox	3.3	70
Lynx	3.1	65
Skunk	3.0	64
Husky dog	2.9	62
Merino sheep	2.8	60
Down sheep	1.9	40
Blackfaced sheep	1.5	32
Cheviot sheep	1.5	32
Aryshire cattle		
Flat coat	1.2	26
Erect coat	0.8	17
Galloway cattle	0.9	19

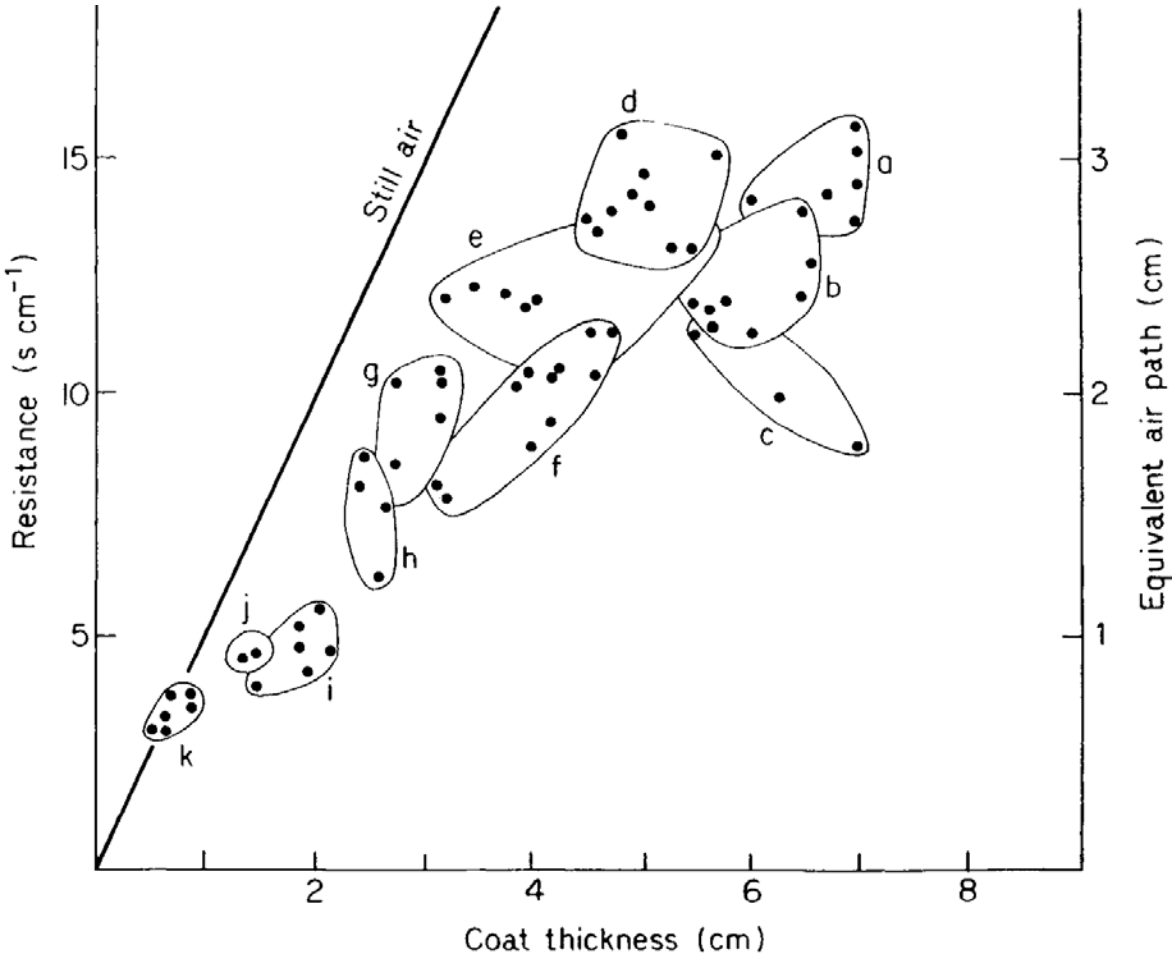

Figure 10.12 Thermal resistance of animal coats as a function of their thickness (after Scholander et al., 1950). (a) Dall sheep; (b) wolf, grizzly bear; (c) polar bear; (d) white fox; (e) reindeer, caribou; (f) fox, dog, beaver; (g) rabbit; (h) marten; (i) lemming; (j) squirrel; and (k) shrew.

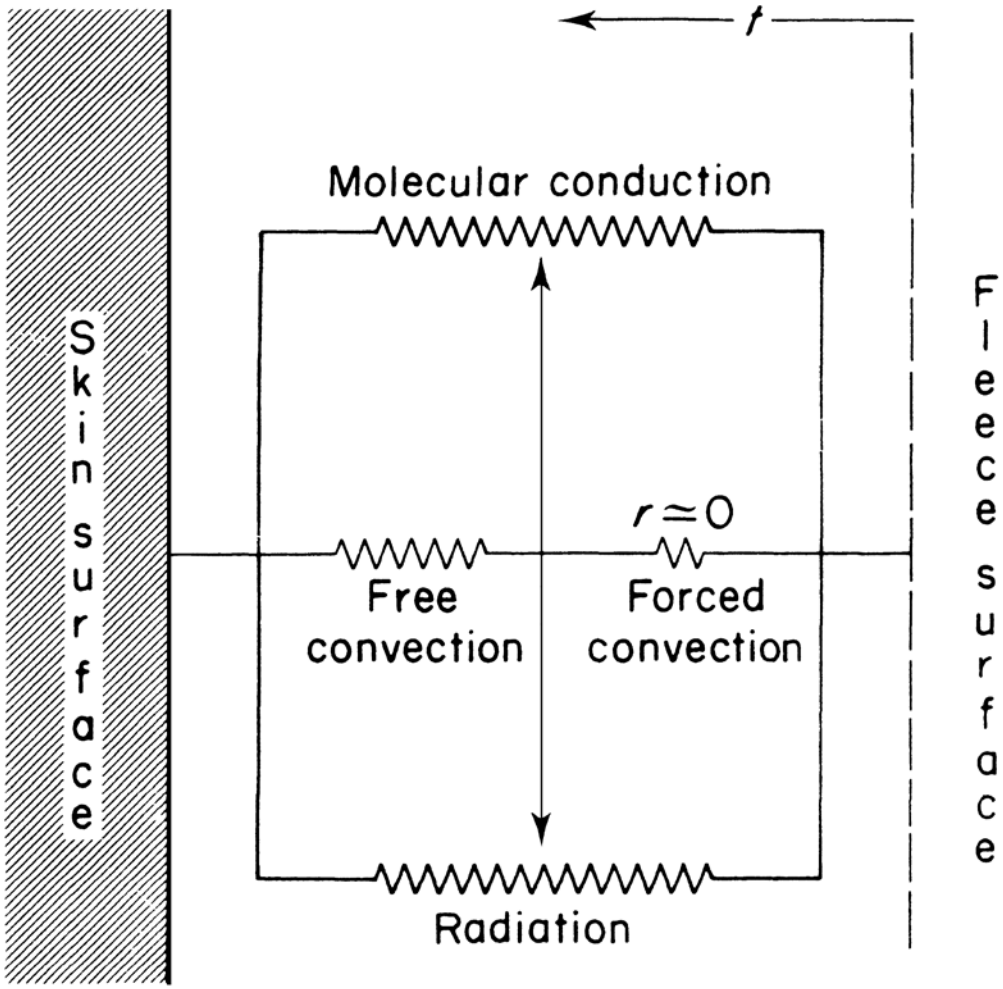

Figure 10.13 Electrical analog for heat transfer through animal coat with wind penetration to depth *t* below surface (from McArthur and Monteith, 1980b).