

black sun

the spectacular play of starling aerobatics take place in southern Denmark two times every year when the starlings migrate to and from their breeding and winter quarters respectively.

having foraged during the day in groups of 10-15 birds they meet up at dusk to form flocks of up to 500,000 individuals before settling down to roost in the marshes.

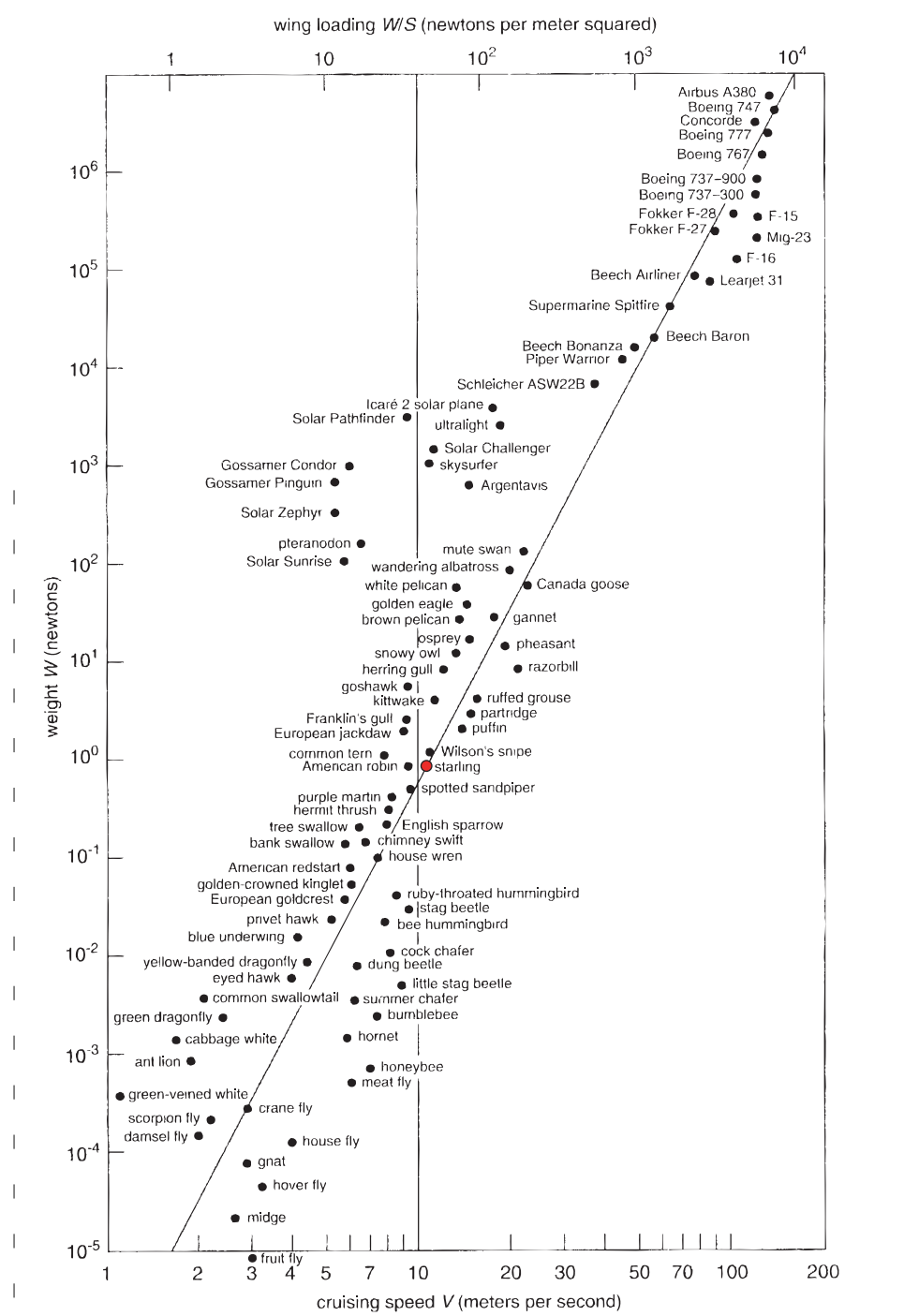
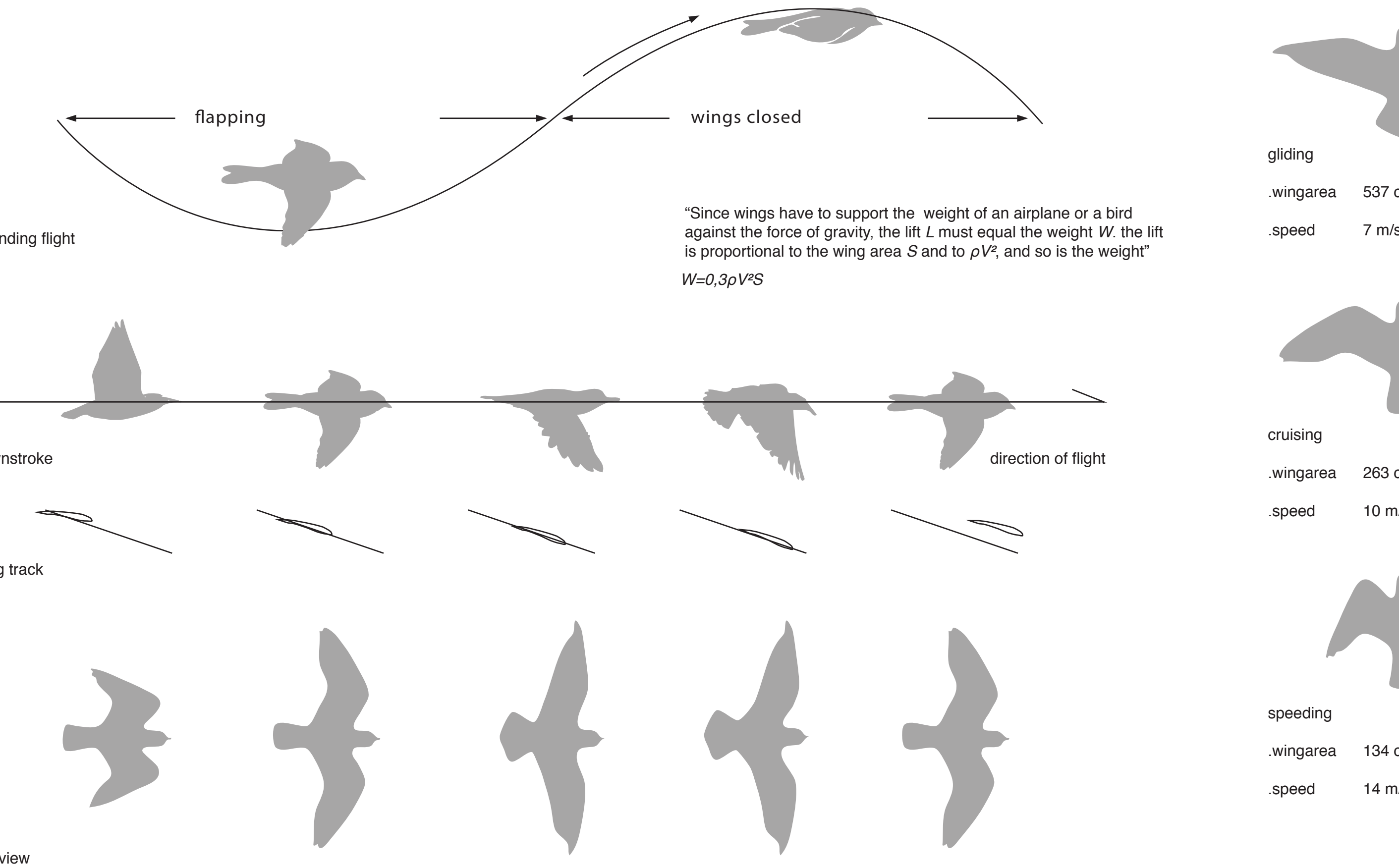
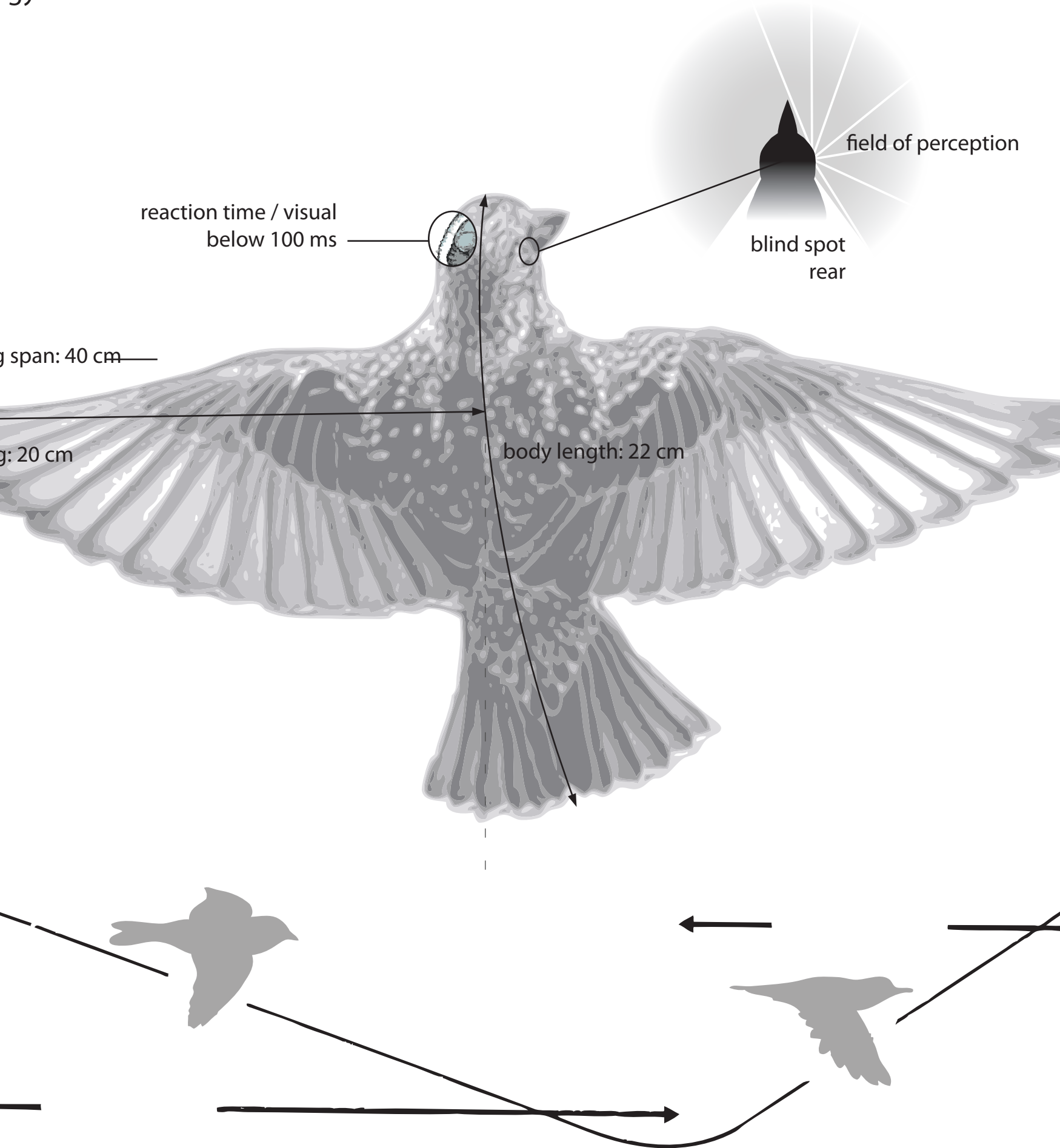


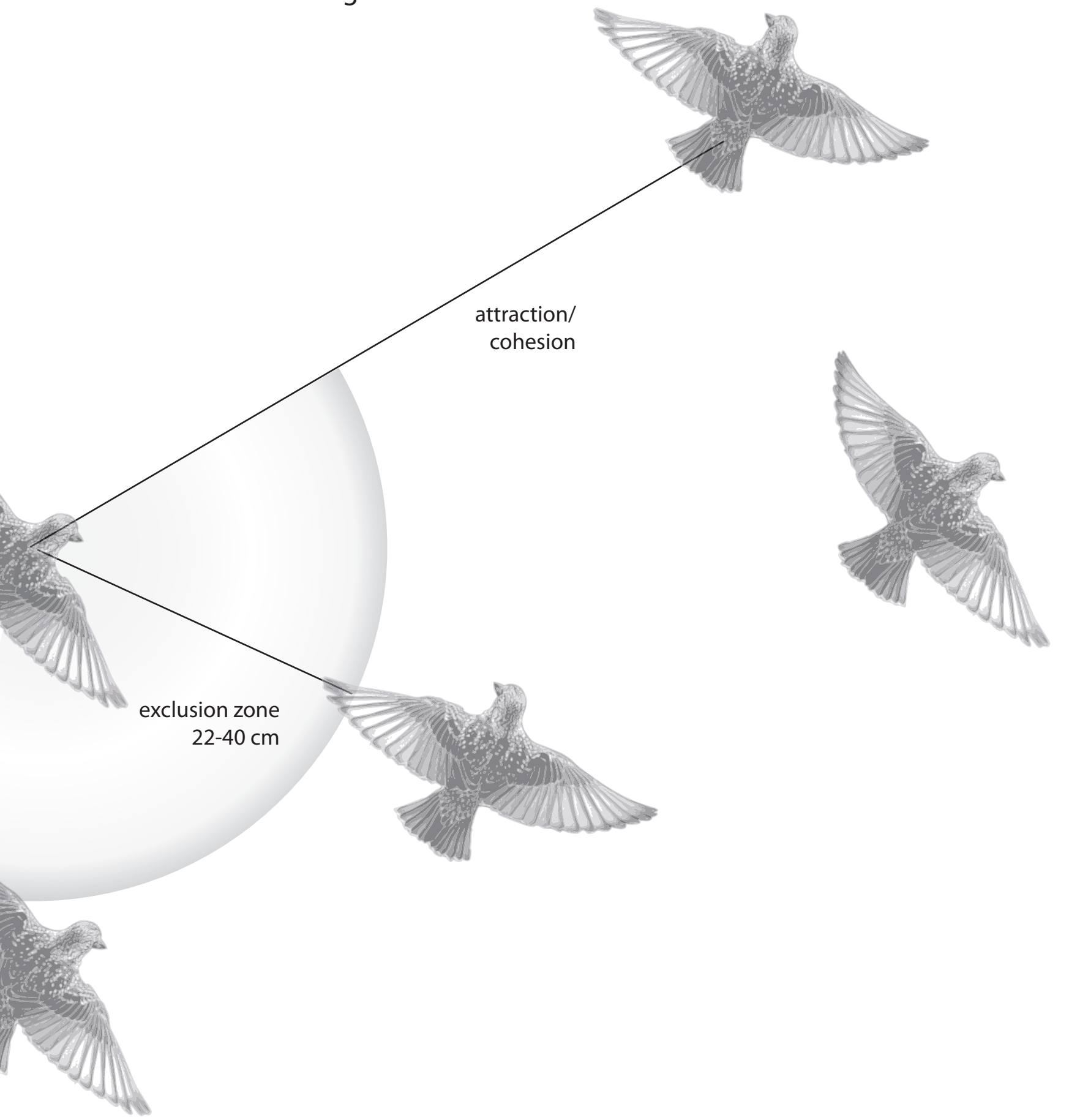
Figure 2 The Great Flight Diagram. The scale for cruising speed (horizontal axis) is based on equation 2. The vertical line represents 10 meters per second (22 miles per hour).

H. Tennekes, 'The simple science of flight - From insects to Jumbo Jets', The MIT Press 2009

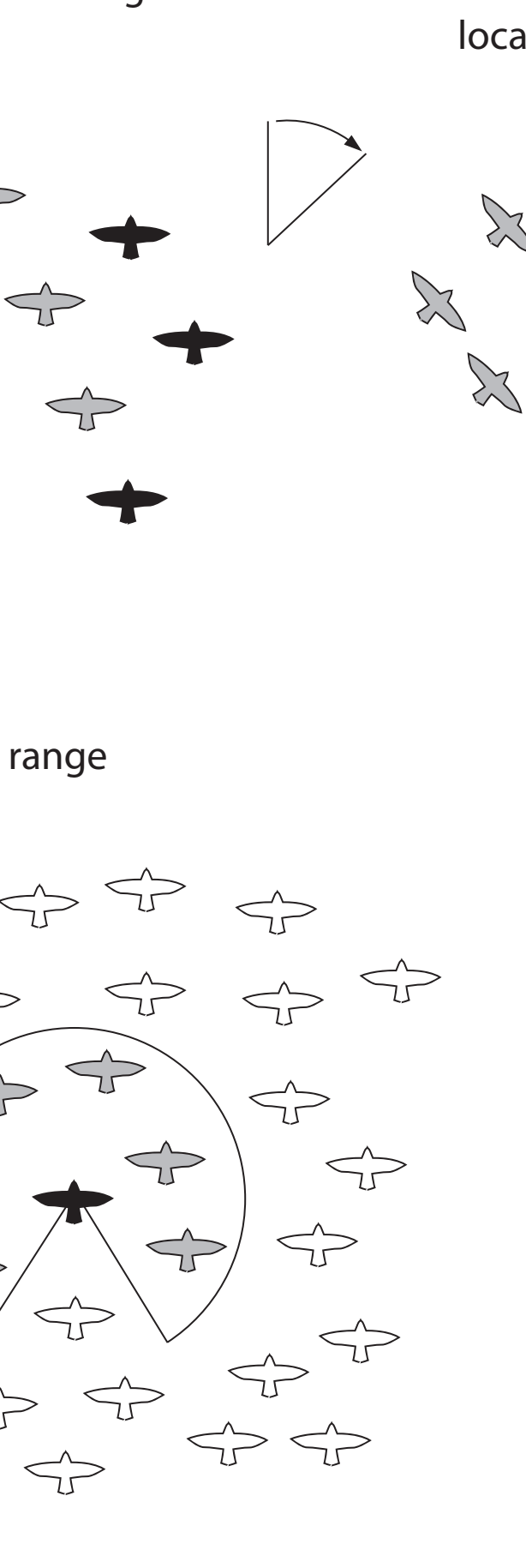
physiology



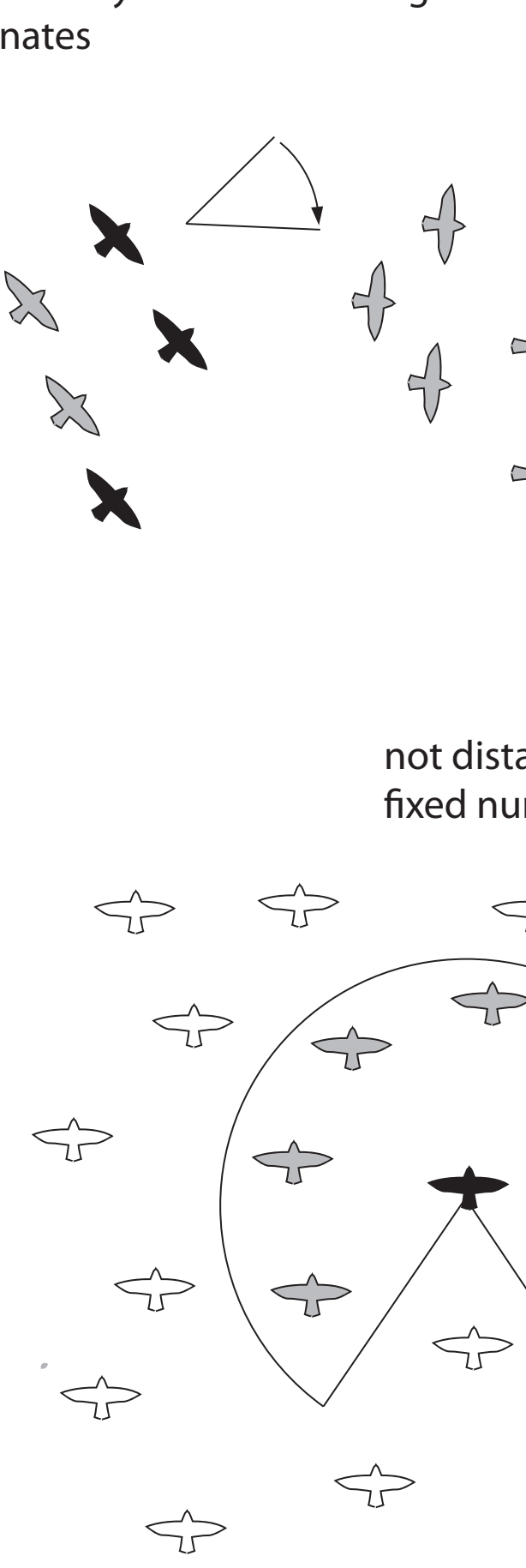
avoidance of collision and remaining close



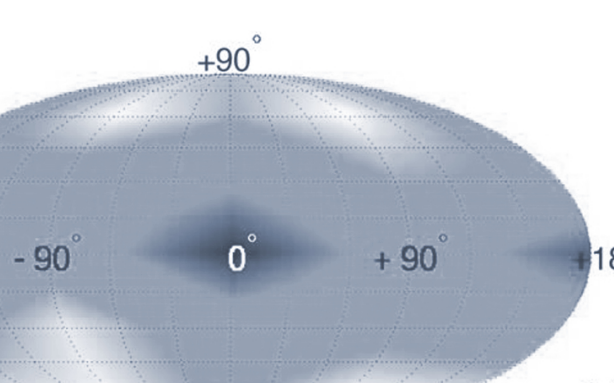
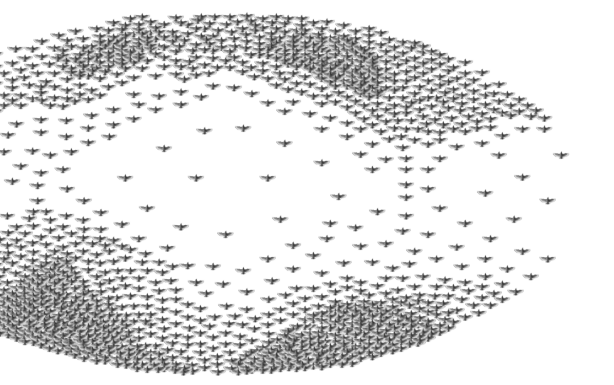
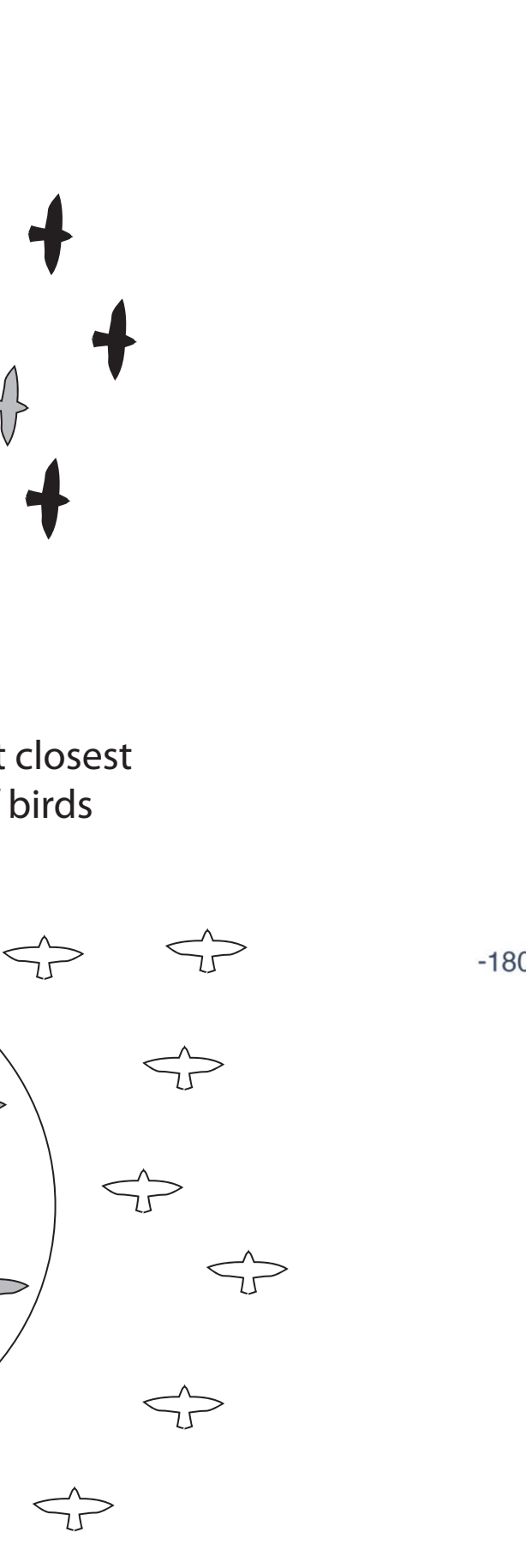
align with your neighbour



individuals bank by local coordinates



right becomes front



Parameter	Description	Default value
Δt	Integration time step	5 ms
Δu	Reaction time	50 ms
v_0	Cruise speed	10 m/s
M	Mass	80 g
C_L/C_D	Lift-drag coefficient	3.3
L_0	Default lift	0.78 N
D_0, T_0	Default drag, default thrust	0.24 N
W_{pin}	Banking control	10
W_{bank}	Banking control	1
T	Speed control	1 s
R_{max}	Max. perception radius	100 m
n_c	Topological range	6.5
S	Interpolation factor	0.1 Δu
r_h	Radius of max. separation ("hard sphere")	0.2 m
r_{sep}	Separation radius	4 m
Σ	Parameter of the Gaussian $g(x)$	1.37 m
w_s	Weighting factor separation force	1 N
w_a	Rear "blind angle" cohesion & alignment	2°45°
w_d	Weighting factor alignment force	0.5 N
w_c	Weighting factor cohesion force	1 N
C_c	Critical centrality below which an individual is assumed to be in the interior of a flock.	0.35
w_r	Weighting factor random force	0.01 N
R_{bound}	Boundary radius	150 m
W_{boundH}	Weighting factor horizontal boundary force	0.01 N/m
W_{boundV}	Weighting factor vertical boundary force	0.2 N

Table 1. Default parameter values.

H. Hildenbrandt, C. Carere, C-K. Hemelrijk - 'Self-organised complex aerial displays of thousands of starlings: a model' - (year unknown, but later than 2007)

'Empirical investigation of starling flocks: a benchmark study in collective animal behaviour'
Original Research Article: Animal Behaviour, Volume 76, Issue 1, July 2008, Pages 201-215
Michele Ballesteri, Nicola Cabibbo, Raphael Candellier, Andrea Cavagna, Evaristo Cislanti, Irene Giardinà, Alberto Orlandi, Giorgio Parisi, Andrea Procaccini, Massimiliano Viale and Vladimir Zdravkovic