

3 Lift

Forces of Flight

Four forces push and pull an airplane in flight. The force of **gravity** pulls the airplane downward. The airplane's wings produce an upward force called **lift** that counteracts gravity. A force called **drag**, caused by air resistance, slows the airplane down. To fight drag, the airplane uses a propeller or jet engine to produce a forward force called **thrust**.

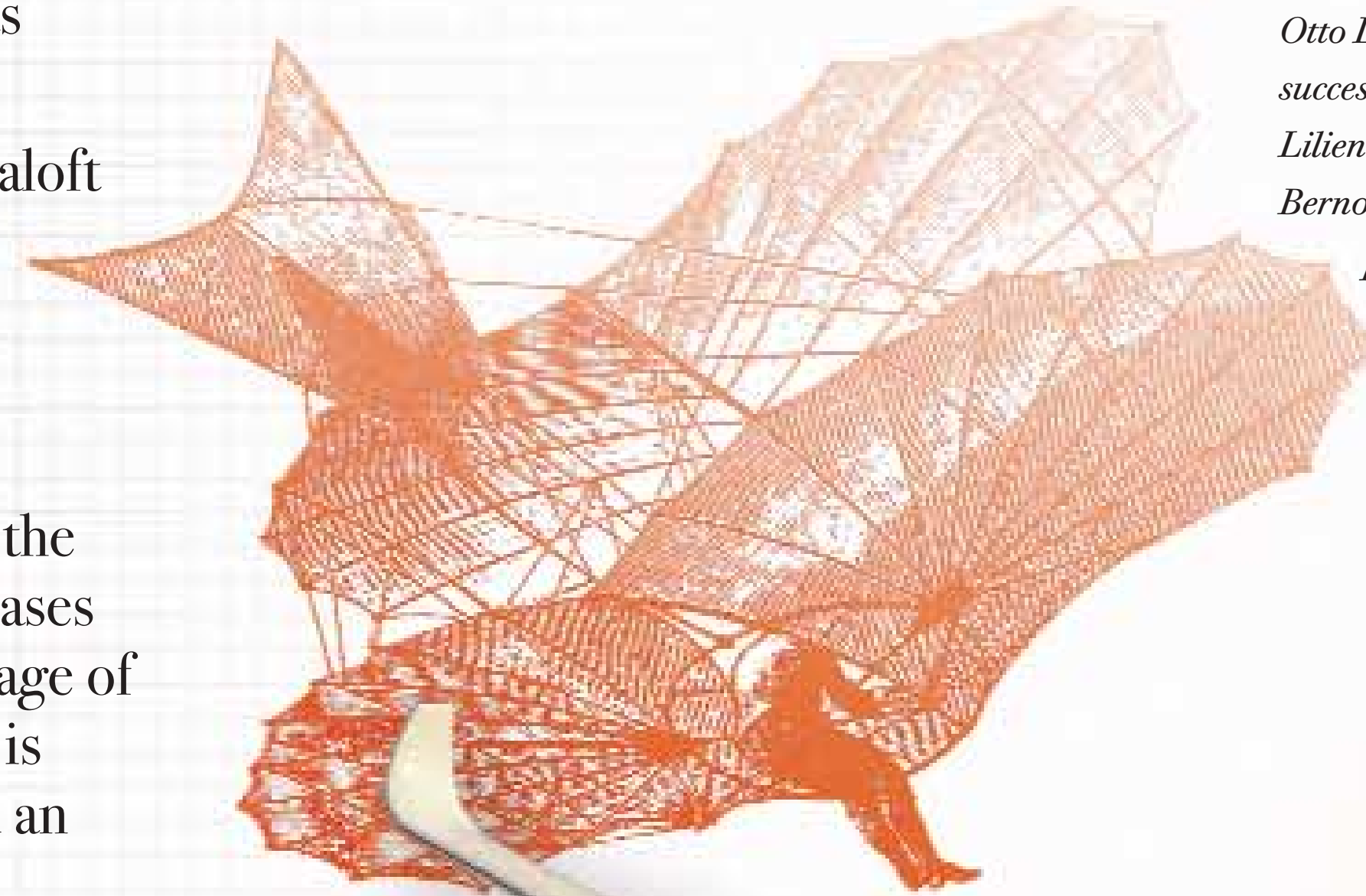
The Basics

Lift is the upward force that counteracts gravity and enables airplanes to fly.

Lift keeps birds, gliders, and airplanes aloft as they move forward through the air. Lift is also generated by the spinning blades of a helicopter.

Aerodynamic lift is based on Daniel Bernoulli's Principle, which states that the pressure of a flowing fluid or gas decreases as its velocity increases. To take advantage of this, an airplane wing, like a bird wing, is designed with a distinctive shape called an airfoil. This shape creates the greatest possible lift for the airplane.

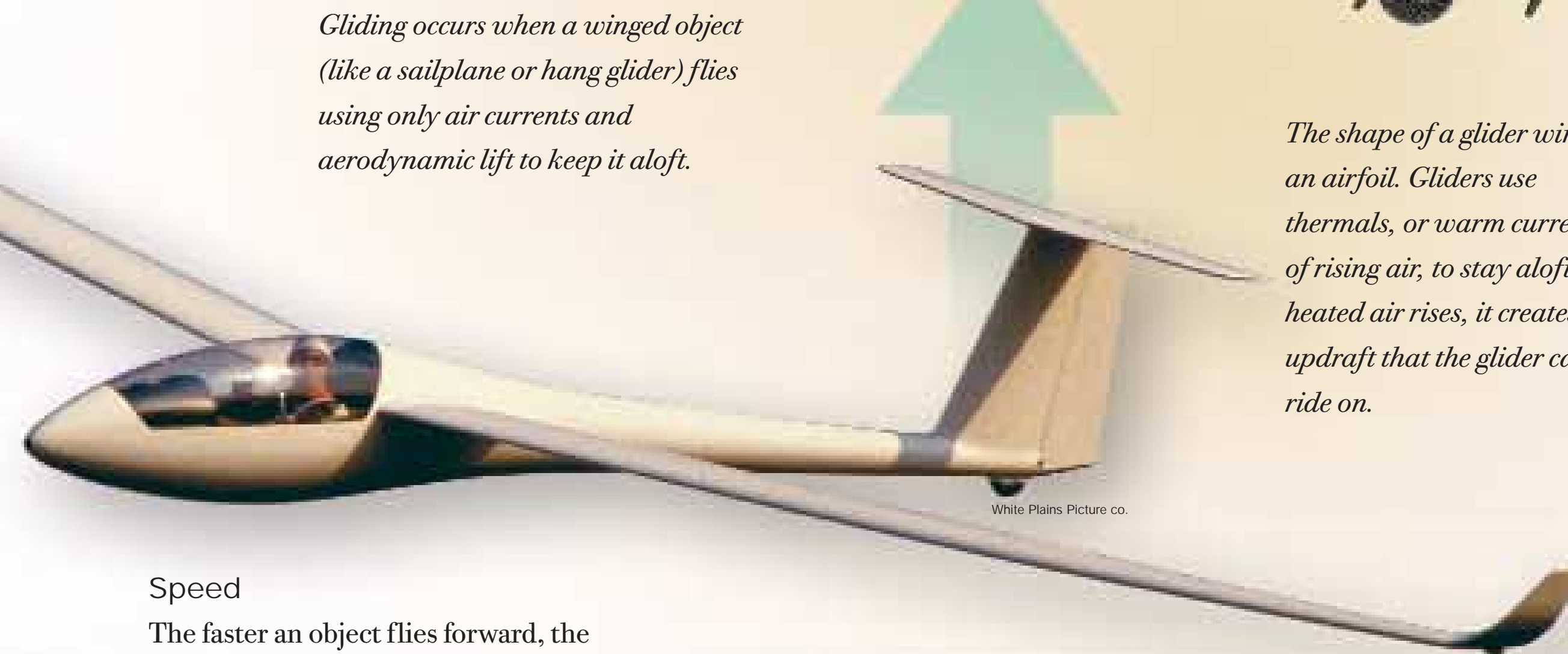
The shape of an airplane wing, the angle at which the wing meets the airflow, and the speed of the airplane all affect the lift.



A German engineer named Otto Lilienthal made the first successful glider flights. Lilienthal's success validated Bernoulli's Principle and proved that the airfoil is the most efficient way to generate lift.



Helicopters fly using horizontal propellers called rotors that create lift. A helicopter travels in the direction the rotor is tilted. Because the helicopter will tend to spin in the opposite direction from the main rotor, a tail rotor is added to this AH-64D Apache helicopter to counteract the spin and hold the helicopter straight.



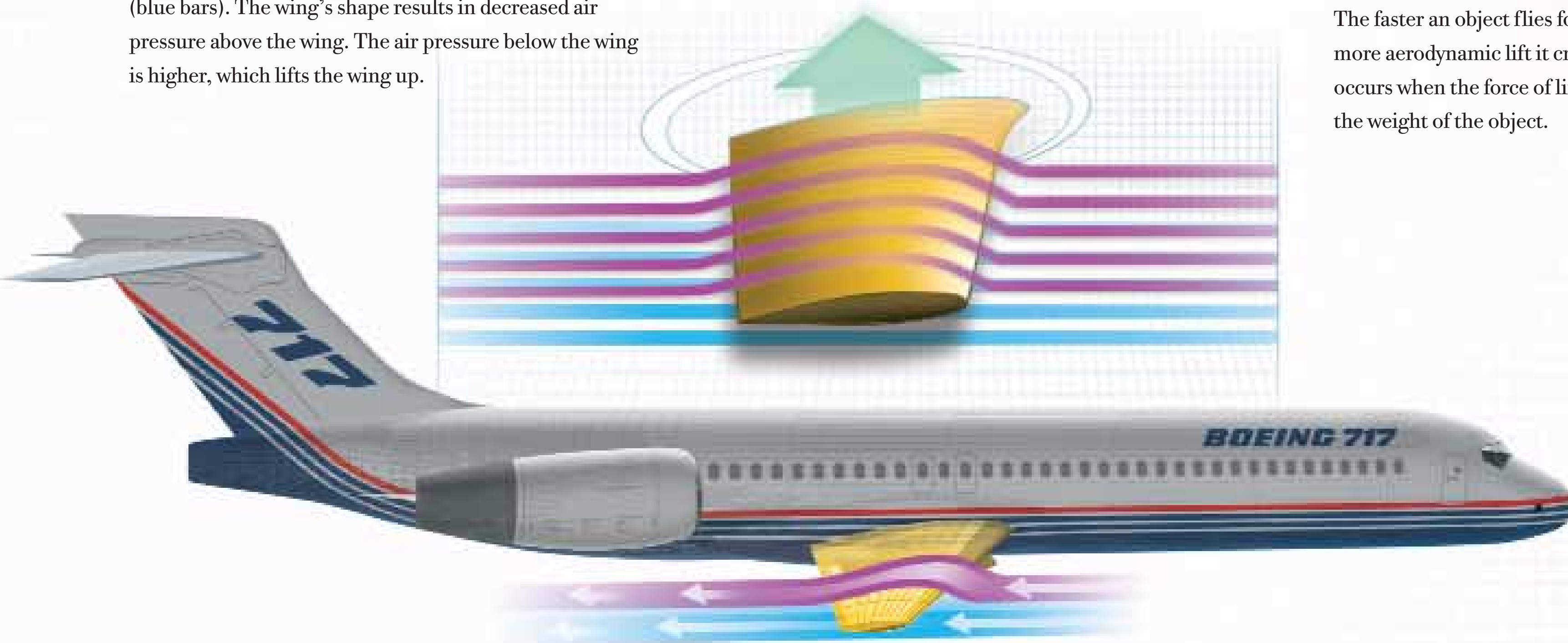
Gliding occurs when a winged object (like a sailplane or hang glider) flies using only air currents and aerodynamic lift to keep it aloft.



The shape of a glider wing is an airfoil. Gliders use thermals, or warm currents of rising air, to stay aloft. As heated air rises, it creates an updraft that the glider can ride on.

Angle of Attack
Angle of attack is the angle at which a wing meets the airflow. As angle of attack changes, a wing generates more or less lift. This can result in a stall. Stalling occurs when the angle of the wing becomes too steep and disrupts the flow, causing a chaotic pattern that eliminates lift.

Wing Shape
As an aircraft wing moves through the air, some of the air passes above the wing (purple bars) and some below (blue bars). The wing's shape results in decreased air pressure above the wing. The air pressure below the wing is higher, which lifts the wing up.



Speed
The faster an object flies forward, the more aerodynamic lift it creates. Flight occurs when the force of lift exceeds the weight of the object.

Daniel Bernoulli, 1700–1782
Swiss mathematician whose work studying the movement of fluids forms the foundation for the study of aerodynamics today.

Otto Lilienthal, 1848–1896
German civil engineer who learned about flight mechanics by studying birds in flight; he designed gliders based on his findings and completed more than 2,500 controlled glides.

$\frac{1}{2} \rho v^2 + p = \text{constant}$
Bernoulli's Equation

