

HOW A BOAT SAILS

The art of sailing, one of the oldest studies in the world, has been joined by the science of sailing with its complex laws of physics and the lofty mathematics that describe them. Fortunately, along with the wind tunnels, sensing devices and computers that confront us with all of sailing's complexity has come technology that has broadened the methods and materials we use to build and to sail boats. The improvement in construction and safety of sailboats is palpable—and no less so the ability of modern sailors to take advantage of it—but both the art of sailing and the science of sailing are very much works in progress.

While sailors can take heart that the underlying physical phenomena can be used without being completely understood, it is not for nothing that sailing has been studied so assiduously for centuries. The interaction of the wind, water, hull, sails and keels—to say nothing of the involvement of sailors—is complex, often simultaneous, and indeed, at times invisible and even intuitive. But each progression in its understanding has led to easier and faster ways to sail.

Bear in mind that while the following discussion of how and why a boat sails is broken into sections so as to be intelligible, the elements that are discussed in isolation are in fact seldom isolated. On a sailboat, little happens that doesn't have an effect on everything else.

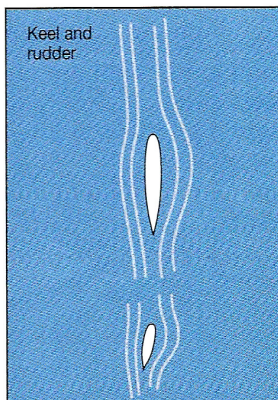
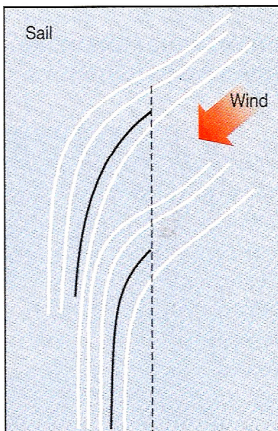
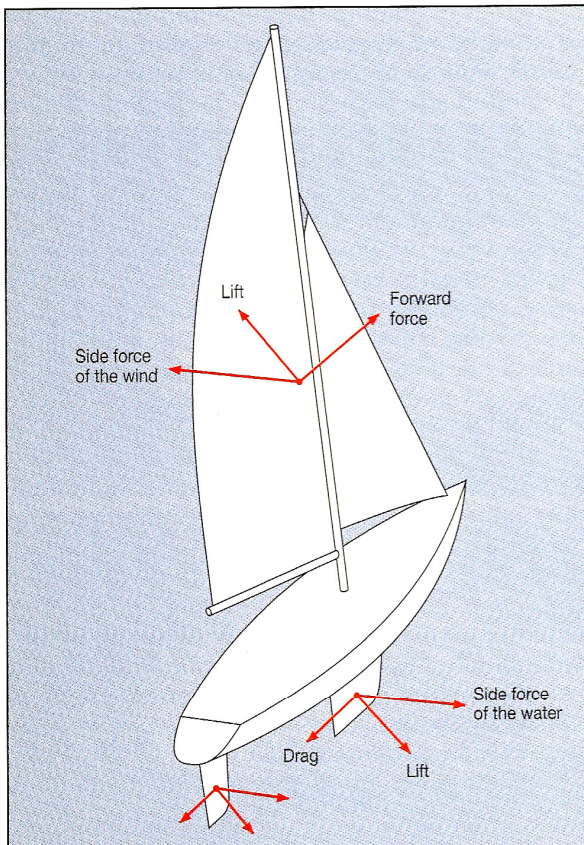
Bending the flow

Sails extract energy from the flow of air (the wind) by bending as it goes by. This is true of every kind of sail, ancient or new, and it is true whether the sail is moving across the wind, or being blown along with it. As they create a driving force from the wind, sails also create a small amount of drag—the smaller the better.

The underwater surfaces of a boat, whether they are the carefully shaped hulls and highly efficient fins of racing yachts, or old-fashioned cargo hulls, also act as foils bending the flow of water that passes around them. The interesting thing about sails ("airfoils") and keels ("hydrofoils") is that, while they are in one sense opposite, the principles that govern them are the same.

Push equals shove

A sailboat hull, driven by aerodynamic forces, accelerates until resistance from various forms of drag, both aero- and hydrodynamic, equal the driving forces. At that moment, the sailboat stops accelerating and travels at a constant speed—constant, that is, until something changes. This equalization of driving and dragging forces may be short-lived as the boat sails into a changing wind, is buffeted by waves, or when the delicate flow patterns are disturbed by its crew. Of course, if



The sails and the underwater surfaces of a boat both act as foils. The sails bend the flow of air over their surfaces, converting some of it into forward and lateral motion ("lift"), and some into drag. At the same time, water flowing past the hull and its appendages produces lift to windward, as well as drag.