WORKING KNOWLEDGE

BASEBALL PITCHES

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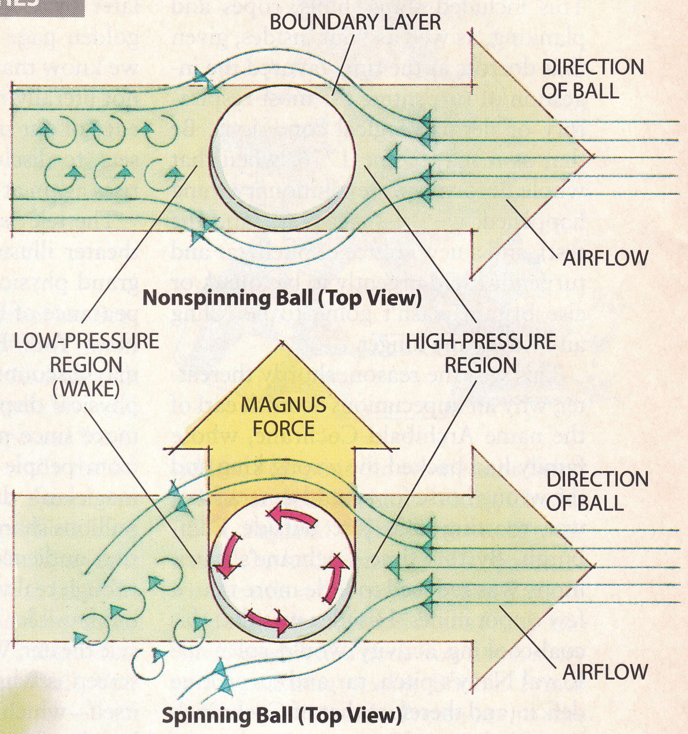
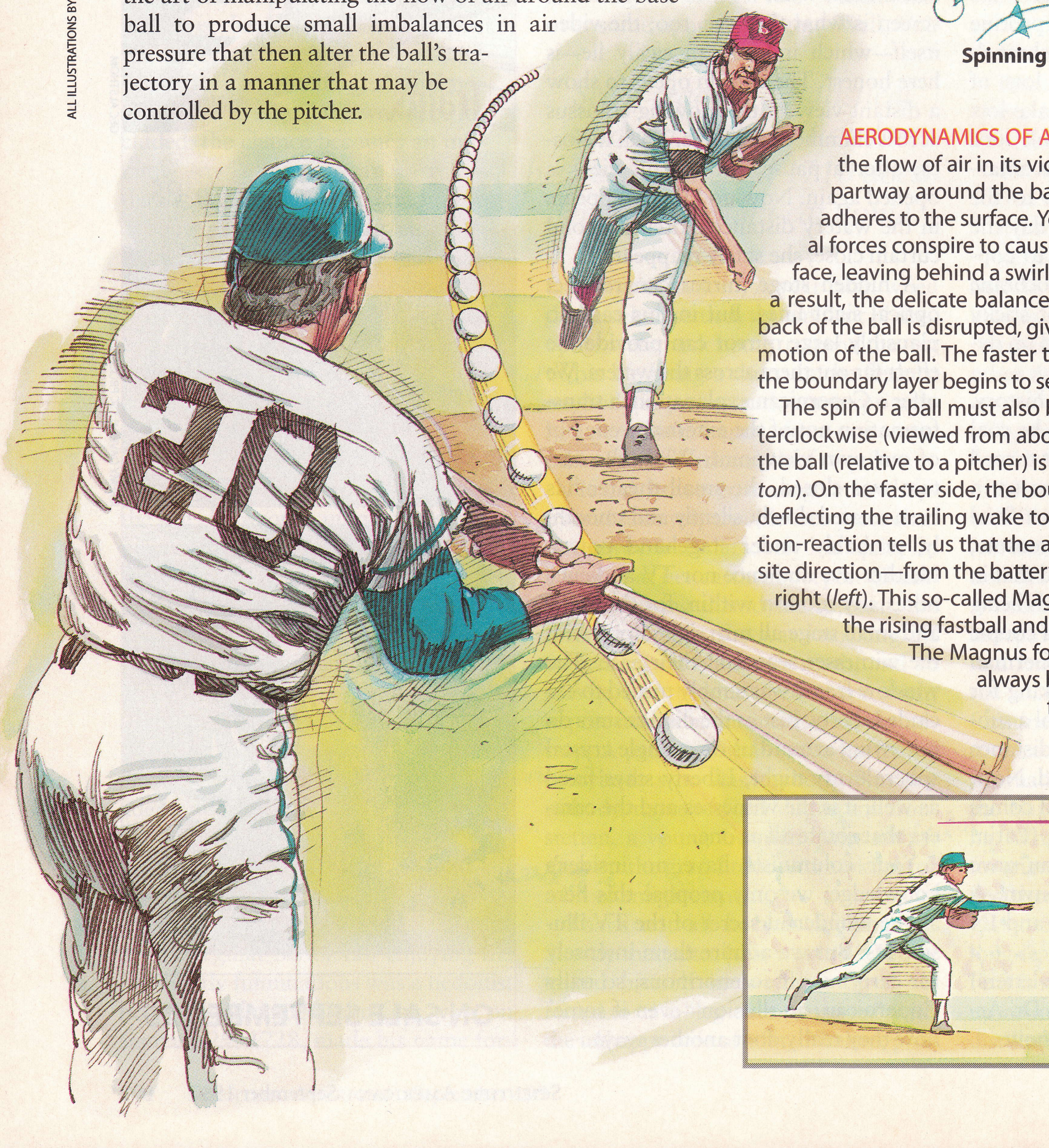
"Hitting is timing; pitching is upsetting timing." So said Warren Spahn, possibly the greatest left-handed pitcher of all time. One way that a good pitcher can upset the batter's timing is by altering the trajectory of the baseball in a manner not expected by the batter. If baseball were played in a vacuum, a pitch would be affected only by the downward tug of gravity. The resulting trajectory would be completely predictable, and no experienced batter would be fooled.

But the game runs its course in the often sweltering atmosphere of the summer ballpark. Much of the pitch's subtlety arises from the interaction between the ball and the surrounding air. Indeed, the art of pitching is largely the art of manipulating the flow of air around the baseball to produce small imbalances in air pressure that then alter the ball's trajectory in a manner that may be controlled by the pitcher.





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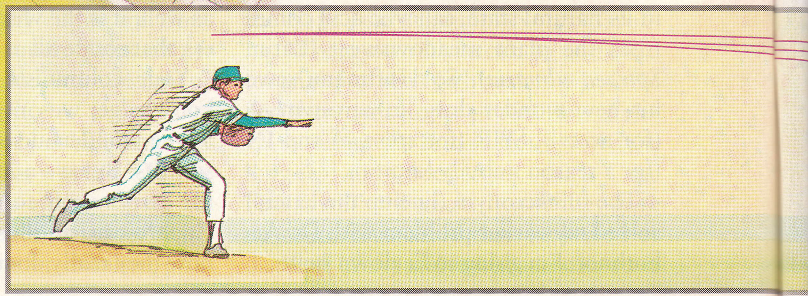
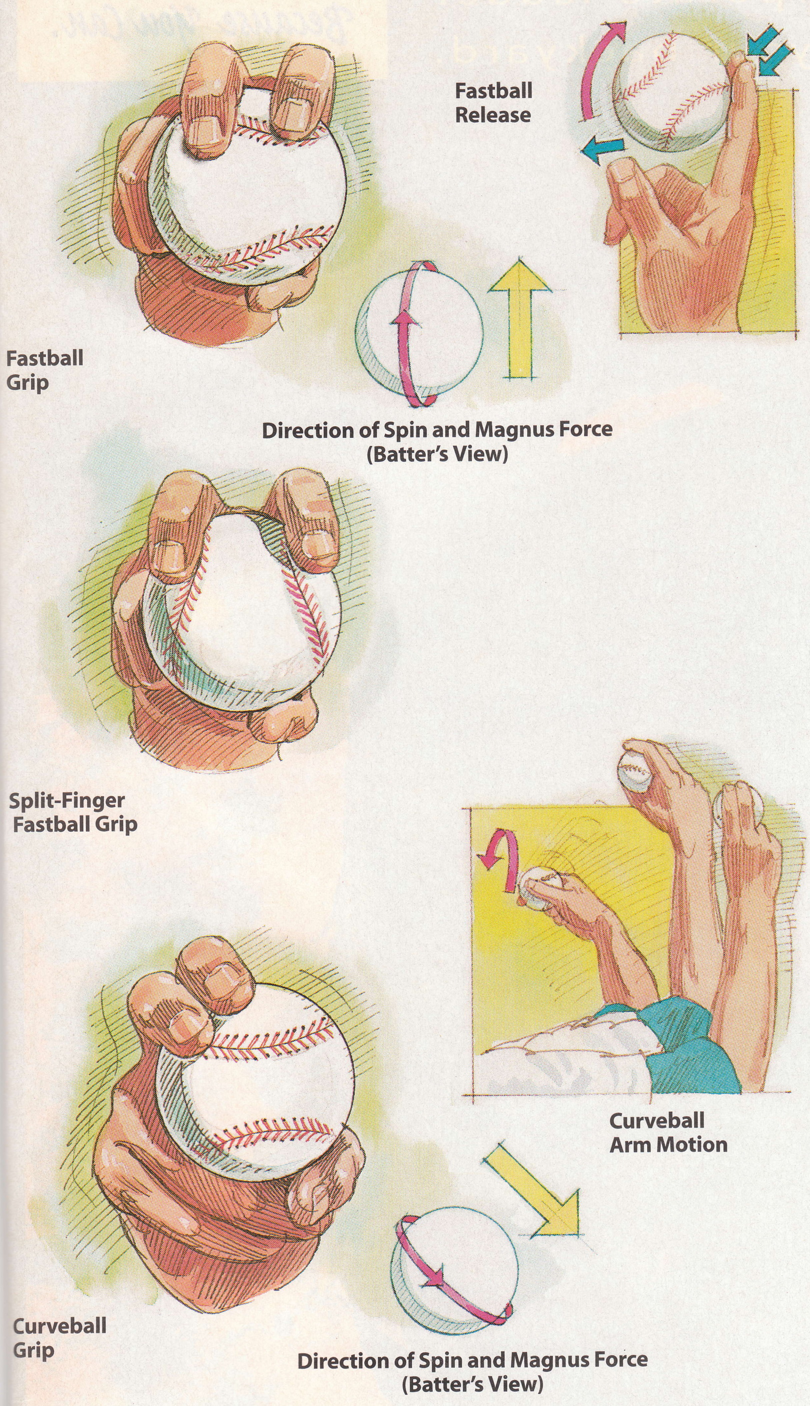
AERODYNAMICS OF A PITCH As a baseball moves, it disrupts the flow of air in its vicinity. The air follows a streamlined path partway around the ball, forming a thin "boundary layer" that adheres to the surface. Yet both the shape of the ball and frictional forces conspire to cause the boundary layer to peel off the surface, leaving behind a swirling low-pressure wake (*above at top*). As a result, the delicate balance between air pressure on the front and back of the ball is disrupted, giving rise to a drag force that opposes the motion of the ball. The faster the air is flowing, the farther to the front the boundary layer begins to separate, resulting in greater drag.

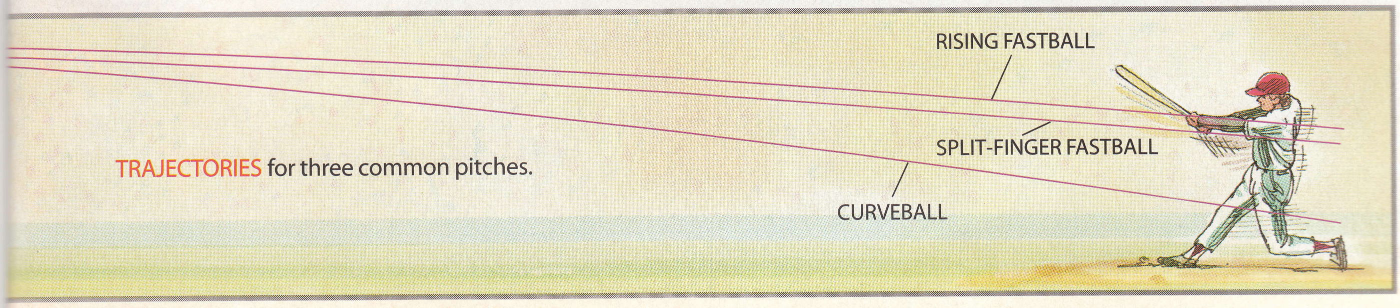
The spin of a ball must also be considered. For a ball spinning counterclockwise (viewed from above), the flow of air past the right side of the ball (relative to a pitcher) is faster than on the left side (*above at bottom*). On the faster side, the boundary layer separates farther upstream, deflecting the trailing wake toward the right side. Newton's law of action-reaction tells us that the air exerts a force on the ball in the opposite direction—from the batter's perspective, the ball breaks from left to right (*left*). This so-called Magnus force is responsible for the "hop" of the rising fastball and for the break in the curveball and slider. The Magnus force grows as rotation increases; the ball always breaks in the direction toward which the front of the ball is turning.





FASTBALL The natural way to throw a fastball is with backspin, which is induced by friction between the fingers and the ball and its stitches. Because of the backspin, the Magnus force opposes gravity, leading to what is erroneously called a rising fastball. Gravity alone would make a 90-mile-per-hour fastball fall about three feet between the pitcher's mound and home plate. With a typical spin of 1,600 revolutions per minute, the Magnus force is only about 20 percent of gravity, so the ball drops only about 2.4 feet. (For the fastball to rise, the Magnus force would have to exceed gravity, an unlikely occurrence, although a fastball that drops less than expected may appear to hop.) A clever pitcher can make the batter's job difficult by varying the rotational velocity to control the amount by which the ball drops. A popular variation is the split-finger fastball, which is thrown by gripping the ball with the fingers far apart, thereby reducing the natural tendency to put backspin on the ball. With very little spin at all and somewhat slower speed, the ball drops about six to 12 inches more than a normal fastball. If the batter's eye does not pick up the reduced spin, he is fooled into thinking the ball will cross the plate higher than it actually does, and his swing goes over the ball.

CURVEBALL The curveball is thrown with greater spin than the fastball, up to 1,900 revolutions per minute, thereby producing a larger Magnus force. It is also thrown at a slower speed, usually at about 70 to 75 miles per hour, giving the Magnus force a longer time to act and resulting in a larger deflection. Typically the rotation has both sidespin and topspin, so that the ball breaks both to the side and down by as much as 15 inches. Making matters worse for the batter, half of the deflection occurs over the last 15 feet of the 60-foot, six-inch journey to home plate, giving rise to the illusion that the ball "falls off the table." A variation is the slider, which is thrown a bit faster and with more sidespin than topspin.



TRAJECTORIES for three common pitches.