The Physics of Thermals: Invisible Elevator to the Sky

Have you ever watched a hawk spiral ever higher into the sky without flapping its outstretched wings?

Until about 1870, the physics behind the ability of birds to gain altitude on unmoving, outstretched wings was a mystery. One explanation was that they flew with a slow flapping motion that could not be seen (Ákos et al. 2010). Thanks to the likes of Sir George Cayley, Jean Marie LeBris, and Otto Lilienthal, who studied bird flight in order to pioneer human aviation, the mystery was eventually solved. Today, we understand that birds are able to accomplish this feat by taking advantage of two common atmospheric conditions, one called *thermal columns* (or thermals) and another called *deflective air currents* (or updrafts).

A hawk soaring on an updraft (photo courtesy of John Beller).

Thermal Columns

Thermals are columns of air that are warmer than the surrounding air. They are created when sunlight warms patches of dark-colored ground (for example, highways and freshly plowed fields) that are next to cooler areas (for example, leafy areas and rivers). These warm patches heat the air above them. The warmer air then rises faster than the surrounding air. Thermals also frequently form above mountains in the afternoons, when the sun warms a mountainside unevenly (Annenberg Learner 2012).

Deflective Air Currents

Deflective lift is produced when wind or a breeze hits the vertical surface of a hill or mountain ridge. Because the air can't go through the hill or mountain, it has to go up, creating updrafts. Air deflected in this way allows birds to ride effortlessly on the updraft. The most powerful updrafts are produced on windy, turbulent days.

How Birds (and Others) Travel Using Thermals and Updrafts

In order remain airborne when not flapping its wings, a bird must be moving forward. And in order to move forward while remaining over a thermal or an updraft, a bird must move in a circle. At the same time, the rising air carries the bird upward. This makes the bird's overall movement a spiral (Annenberg Learner 2012).

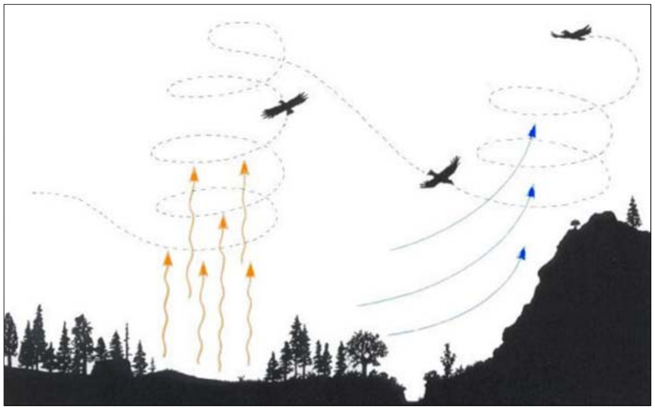

Diagram of a bird using a thermal (left) to gain altitude, exiting the thermal, losing altitude, and then regaining altitude by taking advantage of an updraft (right).

But the warm rising air of a thermal eventually cools to the same temperature as the surrounding air, so the bird ultimately loses lift. Likewise, air rising in an updraft slows little by little until it dies out. Regardless of whether the bird has been using a thermal or an updraft, the bird has now gained altitude. So when lift is lost, the bird simply abandons its spiral flight pattern and glides off toward its destination. Of course, altitude will be lost upon exiting the thermal or updraft. But the bird then finds another in a chain of thermals and updrafts en route to its destination, and the bird will repeat the process of spiraling upward, exiting the thermal or uplift, and then heading in the direction it wants to go once again. Repeating this process over and over allows birds to travel hundreds of miles a day while using only a little energy. For example, on extremely windy days that produce optimal updrafts, hawks can cover a distance of more than 200 miles (Drennan 1981).

Birds aren't the only ones who take advantage of thermals and updrafts. According to the Annenberg Learner website, "Birds, butterflies, and dragonflies all take advantage of rising currents to migrate . . . All these animals are so light for their large wings that even gently rising air can push them up when their wings are spread" (Annenberg Lerner 1997).

A para-glider glides on a thermal.

Glider, hang-glider, and para-glider pilots also use thermals and updrafts to stay aloft during flights that can last many hours and cover hundreds of miles. A documentary film called *Never Ending Thermal* about para-gliders who travel the world in search of the best para-gliding places says this about using thermals to fly: "Flying into this magic phenomenon is like taking an elevator into the sky" (Outside Television, Inc. 2004).

Demonstration: How a Thermal and Updraft Hold Up a Feather

CAUTION: *Due to the use of a hot plate or stove during this demonstration, it must be conducted under the supervision of an adult, and caution must be used to avoid being burned or starting a fire.*

Materials Needed:

- Some feathers (colorful chicken and goose feathers are often sold at craft stores)
- Thread or string
- An electric stove or hot plate burner
- Small electric or battery operated fan
- Baking sheet or large surface to deflect the air from a fan

Directions:

First, let's demonstrate how a thermal works:

1. Tie the feathers with thread or light string to a pencil, ruler, or something else (you can make them into a "dreamcatcher" if you'd like to).
2. Turn on a front stove burner, and wait until it gets hot.
3. Hold the pencil or dreamcatcher so the feathers dangle <u>at least 8 inches</u> from the burner.
BE CAREFUL!
4. Think about these questions: Does the rising heat make the feathers move? Does it hold them up? Would other kinds of feathers work better or worse?
5. Try the experiment again with feathers of other sizes.

These feathers are hanging above a cold stove.

These feathers are hanging above a hot stove.

Now let's create a deflective air current using an electric fan to simulate the wind:

1. Place the baking sheet in front of the fan at an angle. Almost any angle between 25 and 70° will work. The precise angle isn't important. We're trying to simulate a mountain blocking the wind current.
2. Imagine that the air from the fan is the wind moving into the surface of a hill or mountain (i.e., the baking sheet) and is then deflected upward.
3. Hold the feathers in the middle of the baking sheet.
4. Watch which way the feathers travel. They will follow the air currents up and over the baking sheet. This is the same mechanism we talked about above.

Fun Fact

Do you know the highest recorded altitude for a bird in flight?

A Rüppell's griffon vulture, which has a wingspan of about 10 ft, was recorded flying at an altitude of 37,000 ft (Audubon 2000). That's more than half a mile above the summit of Mt. Everest. At that height, a human without supplemental oxygen would die.

References

Audubon, 2000, *The High Life*, http://archive.audubonmagazine.org/birds/birds0011.html.

Ákos, Zsuzsa, Máté Nagy, Severin Leven, and Tamás Vicsek, 2010, "Thermal soaring flight of birds and UAVs," *Bioinspiration & Biomimetics*, Vol. 5, No. 045003.

Annenberg Learner, 2012, *Up, Up and Away: Thermals and Updrafts*, http://www.learner.org/jnorth/tm/monarch/thermal_lesson.html.

Drennan, Susan Roney, 1981, *Where to Find Birds in New York State*, New York: Syracuse University Press.

Outside Television, Inc. 2004, *Never Ending Thermal*, http://www.youtube.com/watch?v=mbIw9IqkGug.