The crime

Recently, Midge’s owners Kit and Steven were serving as hosts for a favorite singer/songwriter, an old acquaintance who was in town for a local concert. Things went well until the door to the guest bedroom was left ajar. Under normal circumstances the open door would not have been a problem, but for lovable Midge, it was a doorway to opportunity. There, on the bedside table was $180 in cash and a check. So tempting! Not to mention delicious!

When the break-in was finally discovered, all that was left was a few shreds of the check. No sign of the $180 cash. Thus, the wait began. For Kit and Steven, walking the dog took on an entirely new purpose. Picking up after Midge required an additional close inspection to see if any of the bills made it through her digestive system intact. The project gave “money laundering” a whole new meaning. Gross? Definitely. But luckily, there was some good chemistry working in favor of retrieving the cash.

The chemistry of digestion

At the most fundamental level, the biological processes of digestion and metabolism are all about the breaking and making of chemical bonds.

Basically, digestion consists of breaking food down into molecules small enough to diffuse through the thin walls of blood ves-
Food is primarily composed of large biomolecules such as proteins, fats, and carbohydrates. The “breaking down” of food is the breaking of chemical bonds that hold the molecules of the food together. After the molecules of food are broken down into small enough pieces for cells to absorb them, they are either consumed completely for fuel or reassembled into new polymers and other molecules, according to the body’s own blueprint.

The process of breaking bonds in food includes a number of key steps. Except for animals like pythons who swallow their food whole, the process of digestion usually begins with a physical phase. Chewing breaks the food into smaller pieces, thereby exposing more surface area, which accelerates the process of digestion.

Next, most animals have some sort of specialized sac or pouch, such as a stomach, where serious digestion gets under way. In humans, a strong acid secreted by the stomach helps break down tough connective tissues and activates a set of biological catalysts called enzymes. Like all catalysts, enzymes greatly accelerate the rate of chemical reactions without being used up in the process. A single enzyme molecule can catalyze a reaction thousands of times. But that is not to say that an enzyme is able to catalyze thousands of different reactions. In fact, most enzymes catalyze single specific reactions.

Enzymes lower the activation energy, the energy required to start the reaction, by securing the reactants in a geometrically favorable position. Held this way, the molecules react with little initial energy—less than if they had to rely on random collisions to bring them together. Once bonded, they are released, and the enzyme is free to act again.

Enzymes can also work to break bonds. In this case a single molecule fits with the enzyme in such a way that one particular bond is stressed. This stress lowers the energy requirement for breaking the bond.

Because the interactions between the enzyme and the substrate molecules are totally dependent on shapes, each reaction requires its own enzyme. Virtually all of the chemical reactions that occur in living cells rely on one or more enzymes to allow them to occur at a useful rate. Just like each lock requires a key with just the right shape, each chemical reaction requires an enzyme with the right shape.

And all of this explains why Kit and Steven were optimistic about seeing their $180 again, even after it had been subject to Midge’s digestive process and the accompanying onslaught of enzymes.

The only difference between starch top and cellulose bottom is the way the ring-shaped glucose molecules are connected (blue-colored bonds).
Cellulose—defying digestion

The enzymes found in humans and other animals allow them to digest and metabolize many, but not all, biomolecules. Cellulose is one example of a molecule that defies digestion in many animals. This is an interesting exception because cellulose, a structural material found in plant cell walls, is made up of the same glucose subunits as digestible starch. Glucose is a simple sugar that provides fuel for most organisms. But the slight difference in the way the glucose molecules are hooked together in starch, compared with how they are hooked together in cellulose makes a big difference in their digestibility. Humans and many other higher animals have the enzyme required to break the bonds in starch, releasing glucose. But because the shape of the linkage is different in cellulose, the same enzyme will not work. In fact, where cellulose is concerned, humans do not have an enzyme that will work. Neither do dogs. Which brings us back to Midge.

Paper money is made of cellulose in the form of very high-quality cotton and linen fibers. This cellulose not only resists the chemical processes that are a part of digestion, but also withstands the mechanical breakdown—chewing and shredding—that is part of the digestive process.

As it turns out, most humans eat a fair amount of cellulose in the form of fruits and vegetables. Although we cannot digest it, the cellulose serves as roughage or fiber that gives food bulk and keeps it moving through the digestive system. In the end, all of the undigested material ends up being eliminated as feces.

Glucose is fuel for most organisms and the building block for both starch and cellulose. Humans (and dogs) can break down starch into glucose but not cellulose.

The end ...

And so it was that Kit and Steven, with patience and endurance, were at last able to recover their $180. Midge, like the goose that laid the golden egg, eventually passed all of the well-chewed bills in her feces. Maybe you are wondering how animals such as cattle, sheep, deer, and goats thrive on a diet of grass or other cellulose-rich food. Can they digest cellulose when humans cannot? The answer is no. None of these animals have the enzymes required to digest cellulose. Instead they rely on colonies of microorganisms living in their digestive systems. These simple microorganisms have the correct enzymes to digest the cellulose and to reassemble the products into starches and proteins. From these products, grazing animals acquire their nutrients. The special relationship between these animals and their resident microbes is called symbiosis—two organisms living with each other to the benefit of both.

As for Midge, it was a happy ending for all concerned. With the cash recovered, Midge eventually got out of the doghouse, and the songwriter was even inspired to write a new song to commemorate the entire affair.

So what are the chances—in the extremely rare case that a dog really DID eat your homework—that it might show up again undigested on the front lawn? Not good. The chemical processes that break down cellulose in the paper-making industry leaves a weaker form of cellulose in the product—so weak that there is little likelihood of it making its way through a dog’s digestive system.

Better idea? Save to disk! Avoid magnets. But that’s another story …

Photomicrograph of cellulose fibers shows their linear nature.

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