RIO NEGRO
AMAZON
Two Rivers that Refuse to Mix

By Genevive Bjorn

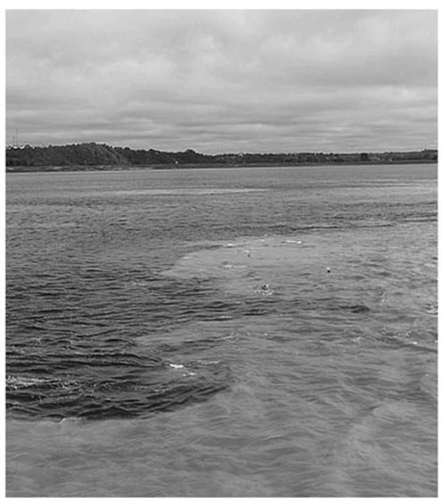
In Northern Brazil, two mighty rivers, the Amazon and the Rio Negro, meet but refuse to mix. I first learned about this place, unlike any other on Earth, while browsing online satellite maps—it's something I do when I can't sleep. The meeting of these two rivers appears as a black line across a large body of water visible from space. Intrigued by this unusual sight, I decided to travel there. What I saw was even more surprising!

Welcome to the jungle!

Aboard the double-decker riverboat, the Tropical, I peer over the wooden deck. The boat drafts low, rising only a foot or so above the Rio Negro, which runs for 550 miles in the heart of the Amazonian forest. The air is hot and sticky, swirling with diesel fumes, sunscreen, and bug spray.

I raise my binoculars and notice thousands of butterflies in shimmering colors. The butterflies are part of the millions of animal species present in the rainforest. Of all the animal and plant species on the planet, one-third is thought to be living in the Amazon. As a result, the rainforest produces a quarter of all the oxygen we breathe. That's huge! Imagine skipping every fourth breath or eliminating one in every three species. That's what life would be like without the Amazon jungle.

The captain announces that we are nearing the spot that I have come to see: the place near Manaus, Brazil, where the mighty Amazon River meets with the Rio Negro, also called the "Meeting of the Waters." But I am already leaning over the boat's bow to see up close this watery dividing line. It's spectacular! I see both rivers flowing separately, yet side by side, for miles on end. The opposing waters look like storm clouds (the Rio Negro) pushing into blue skies (the Amazon).



Meeting of the Rio Negro river (right) and the Amazon river (left)

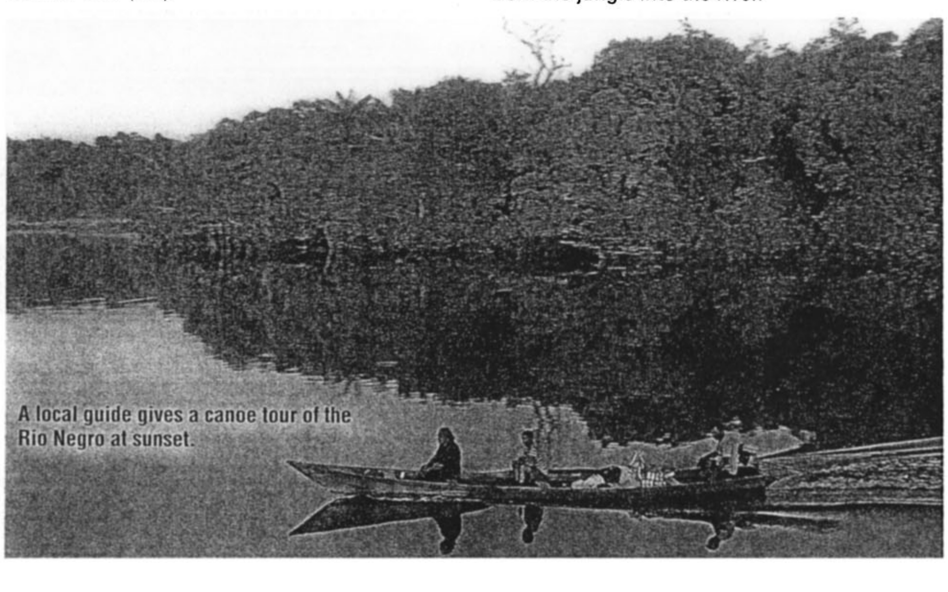
What actually happens is that on the north and west side of the line is the Rio Negro—a warm, shallow, and slow river the color of tea. On the south and east side is the Amazon River—a deep, cool, and fast blue river. The rivers eventually mix, and the Amazon dominates, but it takes about 5 miles for this to happen.

Acid and rain

Looking at the rippled edge, I wonder: Why is the Rio Negro so dark? According to Wanderli Tadei, a researcher at the Amazonian National Research Institute in Manaus, the dark color comes from plant materials decaying more slowly than usual. These plant materials consist of leaves, bark, and berries deposited by the acid-loving trees and shrubs growing around the sandy banks of the river.

"When the trees and shrubs near the river die, bacteria speed the breakdown of plant parts," Tadei says. "Then, all the rain that falls from January to July flushes these plant parts from the jungle into the river."

PHOTOS BY GENEVIVE BJORN



A local guide gives a canoe tour of the Rio Negro at sunset.

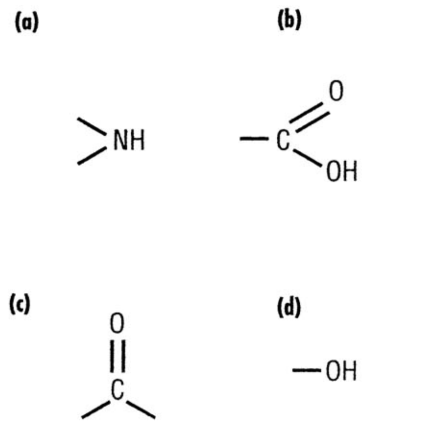


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Figure 2. Examples of functional groups present in humic acid: (a) secondary amine; (b) carboxyl; (c) carbonyl; and (d) hydroxyl. Some of these functional groups can be identified from the structure of humic acid shown in Fig. 1.

This is a serious problem because ions are essential to life. Without these free ions, many species of fish and plants cannot grow, and the soil becomes less fertile. While the dark water of the Rio Negro is rich in nutrients—especially organic nitrogen compounds from plant decay—it contains relatively low levels of these ions.

Ripple effect

How does the unique chemistry of the Rio Negro impact plants, animals, and people? Hundreds of species of fish live in the Amazon, but only a dozen or so are present in the Rio Negro. Fish cannot switch between rivers without risking death—except for a few, such as the snarl-toothed piranha. This also explains why only about 250 species of animals live along the Rio Negro, while thousands of species can be found along the Amazon.

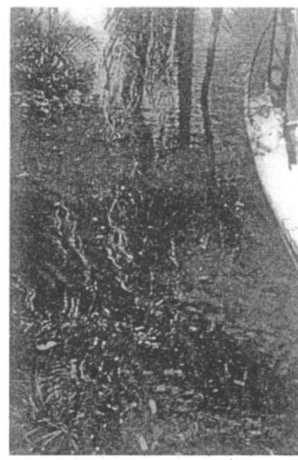
Because fewer species of fish, rodents, and birds live along the Rio Negro, people who rely on hunting and gathering for food have more limited resources than people living along the Amazon.

However, those who choose to live along the Rio Negro receive a vital health benefit: no mosquitoes or the life-threatening diseases they carry, such as malaria or dengue fever. Mosquitoes reproduce in neutral freshwater, and the Rio Negro's low pH disrupts their growth. The result is a jungle Eden, lacking the clouds of blood-sucking insects common along the Amazon—a benefit the people living along the Rio Negro have enjoyed for centuries.

Through thick and thin

So, why don't the rivers mix? Several differences between the rivers inhibit mixing: the velocity at which they flow, their temperature, their acidity level, and their density—the ratio of the river's mass over its volume.

When the plants present around the Rio Negro decay along its banks, their acidic remains build up along the bottom in the form of red, muddy sediment. Sediment builds up on the bottom, raising the Rio Negro's floor and slowing its flow by more than half that of the deeper, faster Amazon. The Rio Negro flows 1.2 miles per hour while the Amazon flows at 3 miles per hour, or about 2.5 times the Rio Negro's speed.



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Plants decay along the banks of the Rio Negro, resulting in the river's unusual properties.

Also, the shallow and slow water of the Rio Negro heats up fast under the more than 12 hours of daily blaze at the equator, raising the temperature of the Rio Negro to an average 82 °F, compared to the Amazon's 71 °F. Warmer water in the Rio Negro more readily dissolves the organic matter resulting from plant decay, further increasing the density of the river.

After the rivers have met, these differences in the rivers' flow, temperature, acidity, and density create turbulence, which eventually forces the rivers to overcome their differences and mix.

In order to feel these differences, I dip my right hand into the Rio Negro and take mental note: It's lukewarm and makes my skin appear mustardy yellow. As I trail my fingers through the water, I feel resistance—it's thicker, almost oily, and warm. Then I sink my left hand into the Amazon. It's cooler and lighter, and blue like most other rivers I have seen.

My open palm easily traces a figure "eight" pattern. Feeling both rivers at the same time, I look up, tracing their turbulent boundary with my eyes. It extends as far as I can see. But it is not a straight line. Rather, it is a rippled edge where two resolute rivers' chemistries dance for equilibrium with consequences that ripple across both rivers, impacting all life. ▲

Density

Density is the ratio of the mass of an object to its volume. A dense object, such as lead, is relatively heavy and has a small volume. For example, the volume taken up by 10 grams (g) of lead is 0.88 cubic centimeters (cm^3), so its density is 11.4 g/cm^3 (10g/0.88 cm^3). But the same mass of water would take up a larger volume (10 cm^3), so its density (1 g/cm^3) is 11.4 times smaller.

Knowing the density of a material helps determine the volume taken up by a given mass of this material. For example, if someone asks you: "Which is heavier, a pound of lead or a pound of feathers?" The answer is that they weigh the same, but a pound of feathers takes up a significantly larger volume than a pound of lead.

Changes in temperature can affect the density of a material. The volume of most substances increases as the temperature increases, but their mass remains the same. Density is the ratio of mass over volume, so if the volume changes, then the density must also change. The density of a substance generally decreases as its temperature increases.

SELECTED REFERENCES

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Satellite map showing the Rio Negro (black, left) and the Amazon (blue, right). These rivers refuse to mix for at least 5 miles, a phenomenon not seen anywhere else on Earth!

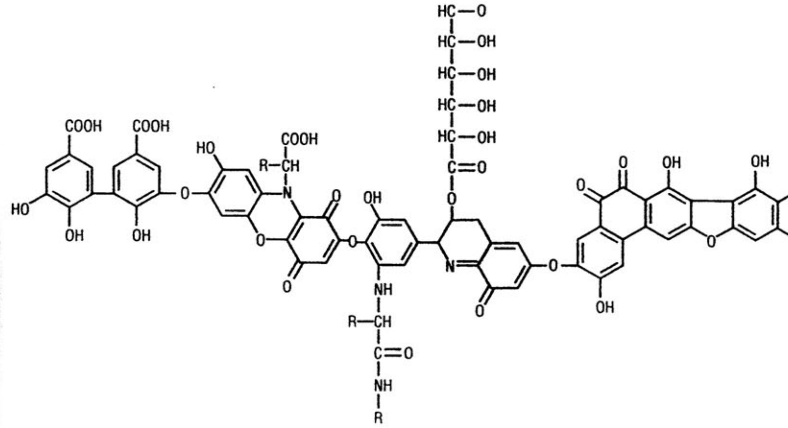

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Figure 1. One of the molecular structures of humic acid

This organic decay produces humic acid (Fig. 1), a major component of the sandy soil along the Rio Negro. When humic and other acids mix into the river, the Rio Negro becomes acidic.

To measure the acidity of a substance, chemists use a quantity called potential Hydrogen (pH). A solution is acidic if its pH is between 0 and 7 and alkaline if its pH is between 7 and 14. The Rio Negro's pH is 3.5. In contrast, the pH of the Amazon River is close to 7, making it neutral.

Humic acid is a complex mixture of carbon-based molecules with the average formula $C_{187}H_{186}O_{89}N_9S$ structured generally as long chains of carbon and hydrogen atoms with attached functional groups—groups of atoms that give physical and chemical properties to the molecules that contain them.

Hydroxyl (–OH) is a common functional group. Another common functional group is carboxyl (–COOH). Examples of other functional groups found in humic acid are shown in Fig. 2.

The abundance of humic acid in the tropical soil and sediments along the banks of the Rio Negro prevents some types of fish and plants from growing in it. Humic acid binds free ions, such as calcium (Ca^{2+}) and magnesium (Mg^{2+}), making the Rio Negro inhospitable to fish and other aquatic life.

Acids and Bases

Acids are substances that give foods a tart or sour taste. Examples of acids are acetic acid (CH_3COOH), which gives a tart taste to vinegar, and carbonic acid (H_2CO_3), which is present in soft drinks.

Bases are substances present in many commercial products, such as soaps and household cleaning agents. Examples of bases include sodium hydroxide (NaOH), which is used to make soaps and paper, and calcium hydroxide ($Ca(OH)_2$), which is a component of mortar, paints, and hard rubber products.

When an acid dissolves in water, it easily gives up a hydrogen ion (H^+). When a base dissolves in water, it readily accepts a hydrogen ion. So, the presence of an acid in water results in an increase in the number of hydrogen ions present in the solution, and the presence of a base in water leads to a decrease in the number of hydrogen ions in the solution.

A common way to determine the acidity of a solution is to measure the concentration of hydrogen ions in the solution. If the hydrogen ion concentration is high, the solution is acidic (but not very basic); if it is low, the solution is not very acidic (but is strongly basic).

Water itself already contains H^+ ions. They are produced when random collisions between water molecules break them apart: $H_2O \rightarrow H^+ + OH^-$. In pure water, the concentration of H^+ and OH^- ions is the same: 10^{-7}.

A solution is acidic if its concentration of hydrogen ions is greater than the concentration of hydrogen ions in pure water (10^{-7}); it is basic if the concentration of hydrogen ions is lower than 10^{-7}. Scientists use a quantity called pH (potential Hydrogen), such that the concentration of hydrogen ions in a solution is 10^{-pH}.

The pH of a solution ranges from 0 to 14—pH=0 means the solution is very acidic and pH=14 means the solution is strongly basic. For example, an acidic solution with pH=4 contains 10^{-4} moles of hydrogen ions, meaning it has 10^3 or 1,000 times as many hydrogen ions as pure water, making it a relatively acidic solution. A solution with pH=6 has only 10 times more hydrogen ions than pure water, so it is mildly acidic. On the other hand, a solution with pH=10 has 10^{-3} or one-thousandth (1/1,000) the number of hydrogen ions present in pure water, so it is basic.

	pH value	Examples
Acidic	pH = 0	Battery acid
	pH = 1	Sulfuric acid
	pH = 2	Lemon juice, vinegar
	pH = 3	Orange juice, soda
	pH = 4	Acid rain (4.2-4.4) Acidic lake (4.5)
	pH = 5	Bananas (5.0-5.3) Clean rain (5.6)
	pH = 6	Healthy lake (6.5) Milk (6.5-6.8)
Neutral	pH = 7	Pure water
	pH = 8	Seawater, eggs
	pH = 9	Baking soda
	pH = 10	Milk of magnesia
	pH = 11	Ammonia
	pH = 12	Soapy water
	pH = 13	Bleach
Basic	pH = 14	Liquid drain cleaner