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WHAT IS HUMBOLDT'S ENIGMA AND WHAT DOES IT MEAN FOR INDIA?

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A view from one of the Shola Sky Islands. | Photo Credit: Prasenjeet Yadav/www.skyisland.in (special arrangement)

Where is biodiversity concentrated?

Explorers and naturalists have been asking this question for centuries. Many have also been curious why some areas are more biodiverse than others.

One of them was Alexander von Humboldt (1769-1859) – a polymath who recorded observations on various natural phenomena across the fields known today as geography, geology, meteorology, and biology.

Once, when exploring South America, he recorded the distribution of plants on a mountain. He also noted how climates were similar across various mountains in different parts of the world – but where specific features occurred on a mountain varied with elevation.

From his various studies, Humboldt suggested there was a relationship between temperature, altitude, and humidity on one hand and the occurrence patterns of species – or their biodiversity – on the other. His example of choice was the Chimborazo mountain in Ecuador, which has today become an important illustration of mountain diversity.

Two centuries later, a group of biogeographers – scientists who explore the relationship of diversity with geography – used modern tools to take another look at the drivers of biodiversity.

Based on their findings, they proposed their own version of the link between biodiversity and mountains and called it Humboldt's enigma.

The world's tropical areas receive more energy from the Sun because of the earth's angle of inclination. So the tropics have greater primary productivity, which then facilitates greater diversity: more ecological niches become available, creating more complex ecosystems and greater biological diversity.

The proponents of Humboldt's enigma have held that the earth's tropical areas by themselves don't contain all the biodiverse regions, that many areas outside the tropics are highly

biodiverse. These places are mountains.

Indeed, while we expect diversity to *decrease* away from the tropics, mountains have been an important exception. This is the essence of Humboldt's enigma. But scientific evidence has been hard to acquire, requiring the use of complex analytical methods and large datasets of various taxonomic groups – and even then remains an incomplete exercise.

A simple way to think of Humboldt's enigma in India is to consider the biodiversity in our tropical areas, south of the Tropic of Cancer passing through Madhya Pradesh and Chhattisgarh. These areas are supposed to be the most diverse in the country. The Western Ghats plus Sri Lanka biodiversity hotspot lies in this zone.

However, the eastern Himalaya are much more diverse. Some scientists have even suggested this part of the mountain range is the second-most diverse area of perching birds in the world. For river birds, the eastern Himalaya may be *the* most diverse.

To understand how this might be possible, let's turn to the modern understanding of Humboldt's enigma.

The history of the earth, its geography, and the climate are the main drivers of mountain diversity. And different biodiversity at different locations is the result of changes in how these factors have intermingled over time and space.

We know mountains host two processes that generate biodiversity. First: geological processes, like uplifts, result in new habitats where new species arise, so the habitats are 'cradles'. Second: species on some climatologically stable mountains persist there for a long time, so these spots are 'museums' that accumulate many such species over time.

Coastal tropical sky islands (mountains surrounded by lowlands), like the Shola Sky Islands in the Western Ghats, are a good example. Here, old lineages have persisted on the mountain tops as climates and habitats fluctuated around them in the lower elevations. This is the reason some of the oldest bird species in the Western Ghats, such as the *Sholicola* and the *Montecincla*, are housed on the Shola Sky Islands.

Sometimes, the same mountain can be both cradle for some species and museum for others, depending on the species' ecologies.

The northern Andes range – including Chimborazo – is considered the most biodiverse place in the world. If we start from the foothills of the Andes and climb, we're going to encounter different temperatures and rainfall levels that support everything from tropical evergreen biomes in the lower elevation to the alpine and tundra biomes near the top. Such a large variation over short distances supports the immense biodiversity found in mountain regions – and worldwide.

Another critical force in biodiversity formation is geology. The foundations on which mountains are erected often differ from those on which low-elevation regions rest.

Scientists have found that the more heterogeneous the geological composition of mountains is, the more biodiverse they are. Around the world, all mountains with high biodiversity have high geological heterogeneity as well, especially in the tropics. Even in tropical regions, where we expect higher biodiversity, some mountains with a lower variety of rocks are relatively less biodiverse. We also know plants are influenced by the type of soil, which depends on the type of rocks in that area. So high geological heterogeneity often produces unique habitat patches on mountains within similar climate regimes, and promotes diversification.

Against this backdrop, what drives biodiversity in the eastern Himalaya? Climate dissimilarity is still one crucial factor, something Humboldt also indicated based on his observations of the Chimborazo and understood to be a paradigm. Researchers have also found some groups of birds to have evolved elsewhere and dispersed to the Himalaya, resulting in higher diversity there.

Multiple factors drive diversification and the Humboldt's enigma in different parts of the world. Then again, scientists have also advanced more than a hundred different hypotheses on how diversity varies in different parts of the world, and they contend with the enigma in different ways. This article simply presents the big picture.

An important limitation of scientists' attempts to explain biodiversity patterns is the lack of fine data on where species occur. For now, birds are the best-described group around the world, and their diversity patterns suggest mountains play a defining role.

We need more research. In India in particular, several areas are under-studied. We can't expect to understand a place's true biodiversity unless we also use modern tools like genetics. For example, why don't the Eastern Ghats have any endemic passerine birds? The most likely answer is that scientists haven't studied them for more than a century, especially with modern tools.

Some national programmes are trying to address these gaps, including the National Mission on Himalayan Studies, the National Mission for Sustaining the Himalayan Ecosystem, and the National Mission on Biodiversity and Human Wellbeing. They need to be strengthened, bolstered by the will to support basic research on diversity.

Humboldt's enigma is perhaps one of many puzzles of mountain biodiversity – and our backyards are excellent places to study them, to find answers to global problems of climate and landscape change.

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