New study clarifies relationships between temperature and animals' sizes

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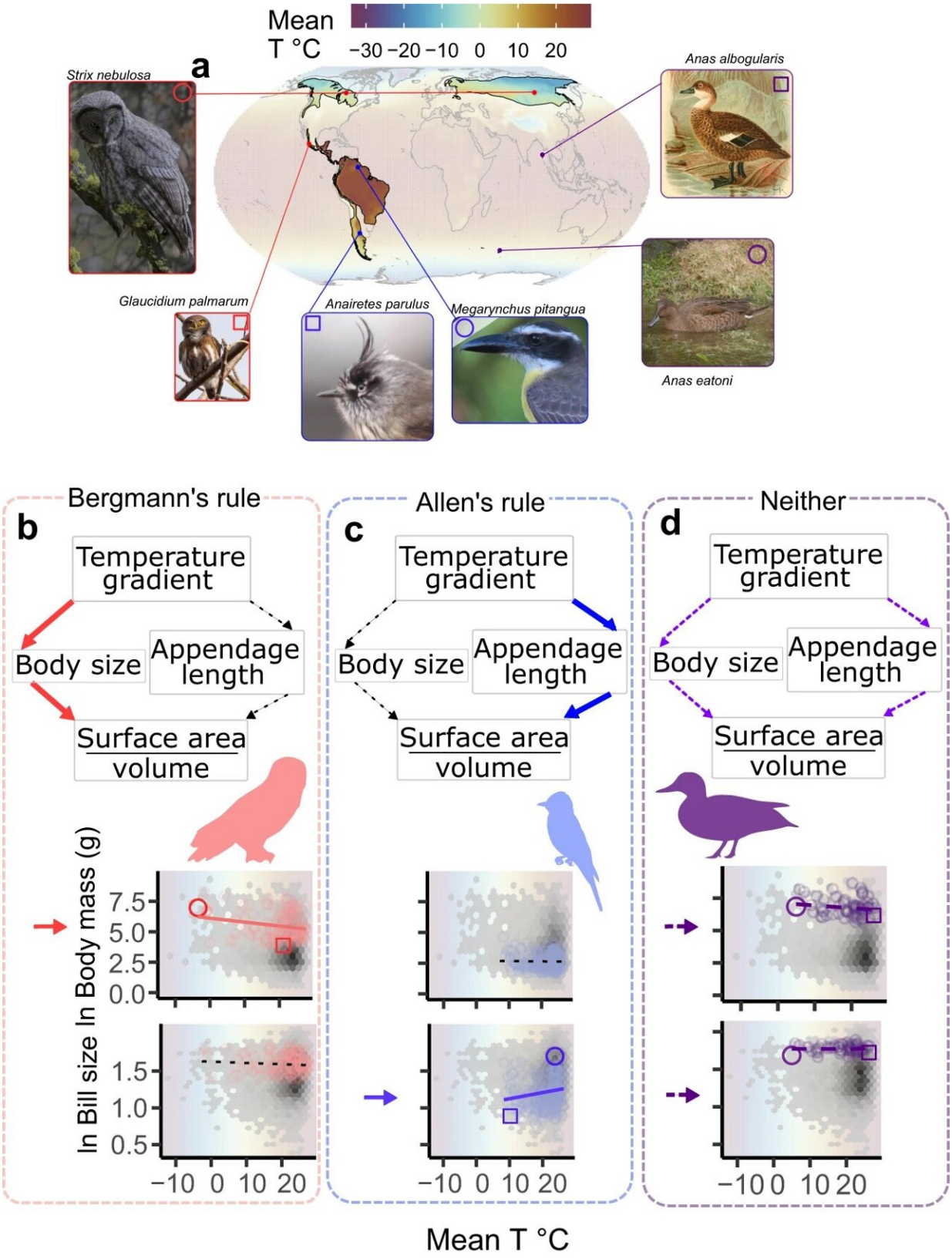
Mean
T °C
−30 −20 −10 0 10 20
a
Strix nebulosa
Anas albogularis
Glaucidium palmarum
Anairetes parulus
Megarynchus pitangua
Anas eatoni
Bergmann's rule
Allen's rule
Neither
b
c
d
Temperature gradient
Body size
Appendage length
Surface area volume
ln Bill size ln Body mass (g)
7.5
5.0
2.5
0.0
1.5
1.0
0.5
−10 0 10 20
Mean T °C

Complementarity between Bergmann's and Allen's rules. While some bird families conform to either Bergmann's rule or Allen's rule, most families conform to neither. For example, while owls exhibit significant changes in body but not bill size (red in **a** and **b**) and flycatchers exhibit significant changes in bill but not body size (blue in **a** and **c**), ducks exhibit instead complementary changes in both body and bill size that are subtle and difficult to detect statistically even though they exhibit the same trends that were predicted by Bergmann and Allen (purple in **a** and **d**). Symbols in scatterplots depict the species highlighted in **a**. Regression lines highlight conformance to rules (solid red/blue—significant conformance; loosely dashed black– non-significant change in one of bill or body size; densely dashed purple—non-significant trend in both bill and body sizes). We thank Gregory "Slobirdr" Smith, Ayna Cumplido, Félix Uribe, N. Hanuise, Ron Knight, John G. Keulemans, xgirouxb, and Andy Wilson for making their artwork and photos available on Wikimedia Commons and Phylopic under Creative Commons license CC-BY-SA (see Supplemental Information[52]; https://creativecommons.org/licenses/by-sa/4.0/). Credit: *Nature Communications* (2023). DOI: 10.1038/s41467-023-39954-9

New clues about the subtle but previously poorly understood evolutionary dance happening between temperatures and changes in the size of animal body parts have been revealed in a study led by researchers at The University of Texas at Austin. The new research offers important insights about how animals, particularly birds, may adapt to the rapid rise in temperatures driven by global climate change.

The study, published in *Nature Communications*, looked at nearly 7,000 species of terrestrial nonmigratory birds—which is nearly two-thirds of all bird species—and focused on how bird morphology has evolved along gradients in ambient temperature and other agents of selection.

Two widely accepted "rules" in biology indicate that as local temperatures change, animals are likely to adjust their heat transfer capabilities by changing the size of their bodies and extremities.

Bergmann's rule states that colder climates spawn bigger bodies because they help retain heat while smaller bodies help shed it. As a result, a polar bear is more than 2½ times as tall at the shoulder as a sun bear from equatorial regions.

Allen's rule deals with extremities, such as limbs, ears and beaks, stating that animals in colder climates tend to have smaller extremities because extremities tend to have more surface than volume and are uniquely suited to shed heat. For example, arctic hares have evolved short legs and ears, whereas desert jackrabbits have evolved very long legs and ears.

"The problem is that everything we know about ecology tells us that changing the size of bodies and extremities can be problematic," said Carlos Botero, an associate professor of integrative biology at UT Austin and the lead author on the paper.

For example, if body size decreases, birds may not be able to hunt the same food as their ancestors. Similarly, if the average size or shape of a bill changes, birds may become less efficient foragers or have trouble producing typical mating calls.

It is not surprising that many prior studies have failed to find evidence for these predictions and that these so-called biological rules are currently controversial. The new study could clarify that debate by showing that although the patterns that biologist Carl Bergmann and zoologist Joel Asaph Allen predicted occur in the wild, the two separate mechanisms complement each other within avian lineages.

The study's researchers also wanted to figure out why a small number of bird families still follow the rules that most others appear to circumvent. They found that in many of those cases, the species involved had bumped up against some kind of natural constraint.

For example, owls have responded to temperature gradients primarily through body size adjustments such that the arctic great gray owl has a body nearly 2 feet long, whereas its relative, the Central American pygmy owl, which lives in the tropics, is only about 5 inches long. These birds, however, have highly specialized beaks that are almost the same size.

"When your hunting tactics depend on the size and shape of your beak, that structure is the last thing you want to change," said Justin Baldwin, a graduate student of Botero's at Washington University in St. Louis and first author on the paper. "As a result, it is likely less problematic to only change body size instead."

Another example involves flycatchers. The tufted tit-tyrant flycatcher lives in the coldest parts of South America and has a tiny beak, which helps it retain heat. Its cousin, the boat-billed flycatcher, has a comparatively massive bill and lives in warmer areas of the tropics. Both have diminutive body sizes.

"When you're already really small and you need to shed heat, it may be hard to get any smaller, so the next best available option is to expand the bill," Baldwin said.

More information: Justin W. Baldwin et al, Complementarity in Allen's and Bergmann's rules among birds, *Nature Communications* (2023). DOI: 10.1038/s41467-023-39954-9

Provided by University of Texas at Austin

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