Bird brain: Insult or praise?

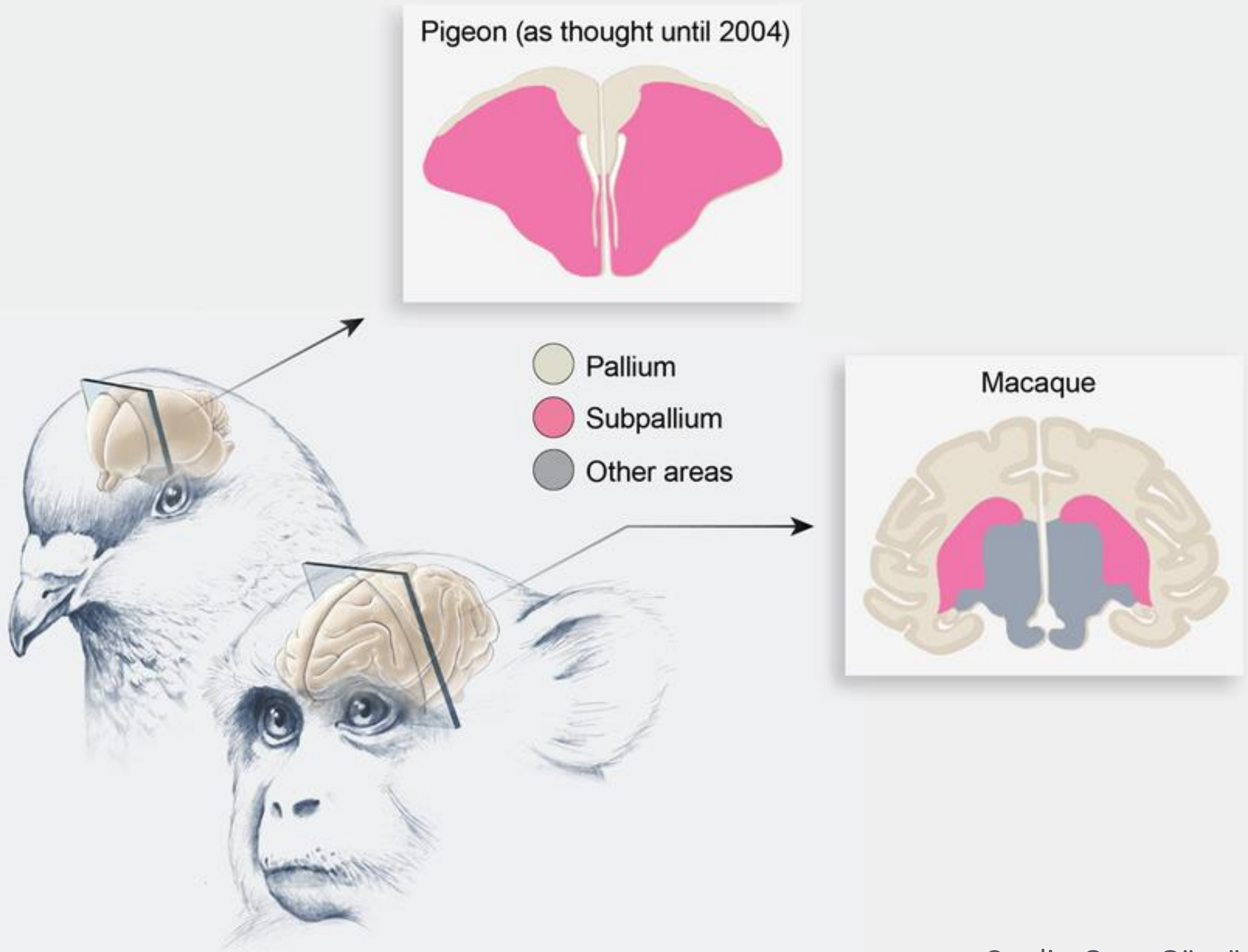
Carlos A. Botero Ph.D. Integrative Biology, The University of Texas at Austin

The Botero Lab @
The University of Texas at Austin
Department of Integrative Biology

“I think, therefore I am”

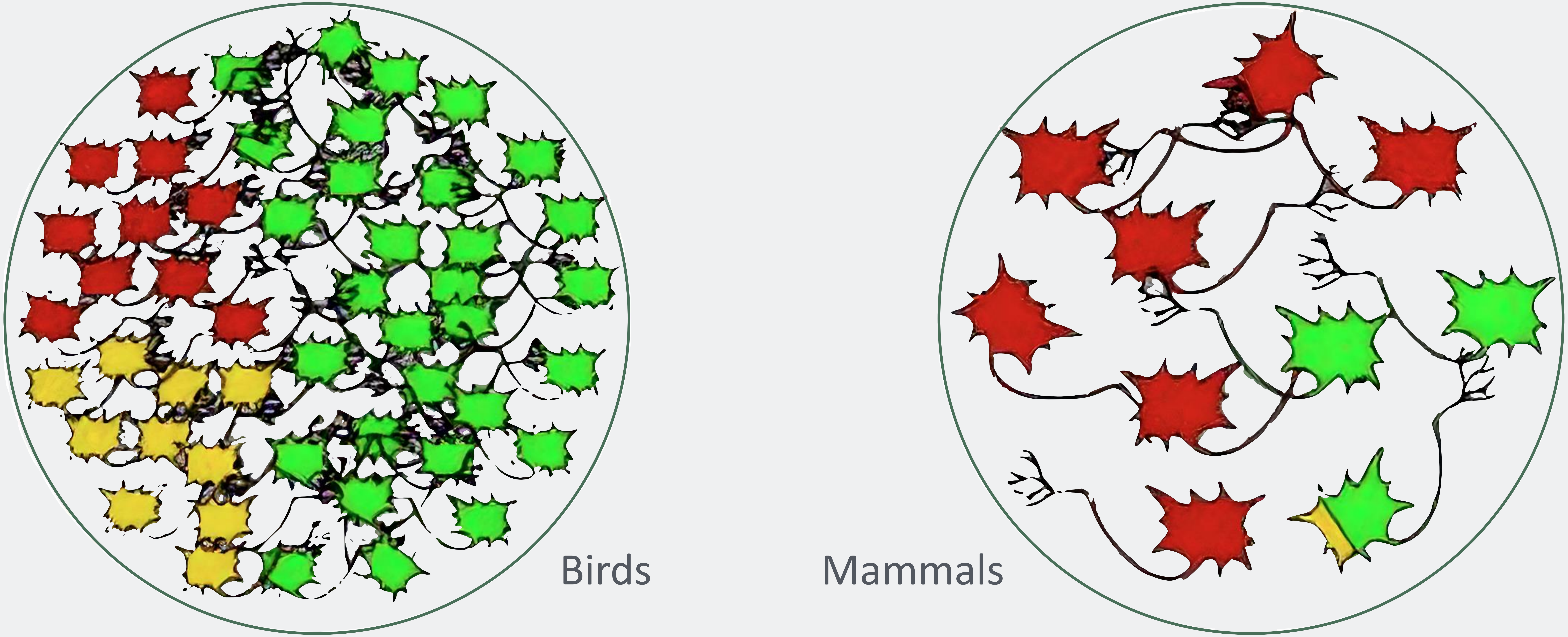
René Descartes

@medowbrookstables



Credit: Onur Güntürkün & Mesa Schumacher

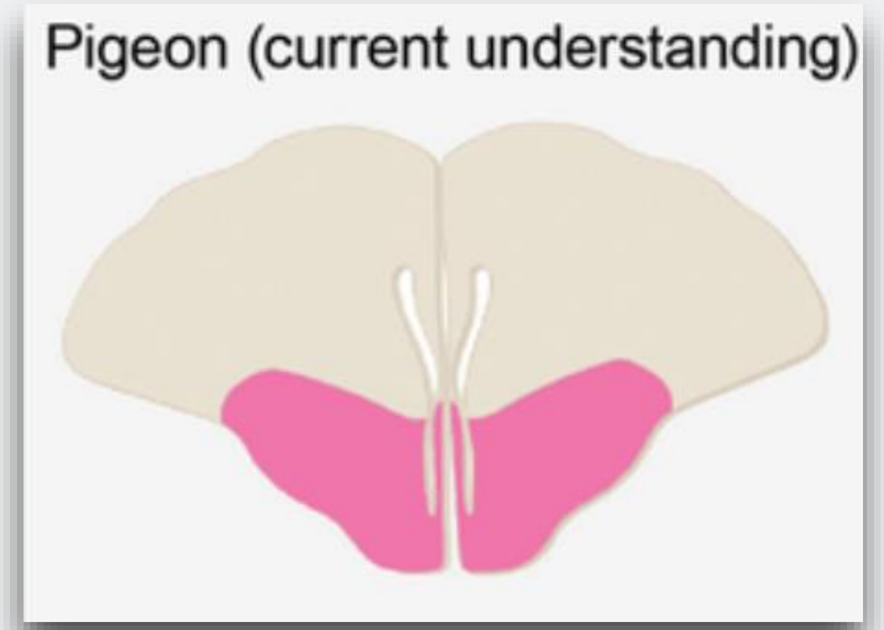
Credit: Tim Flach

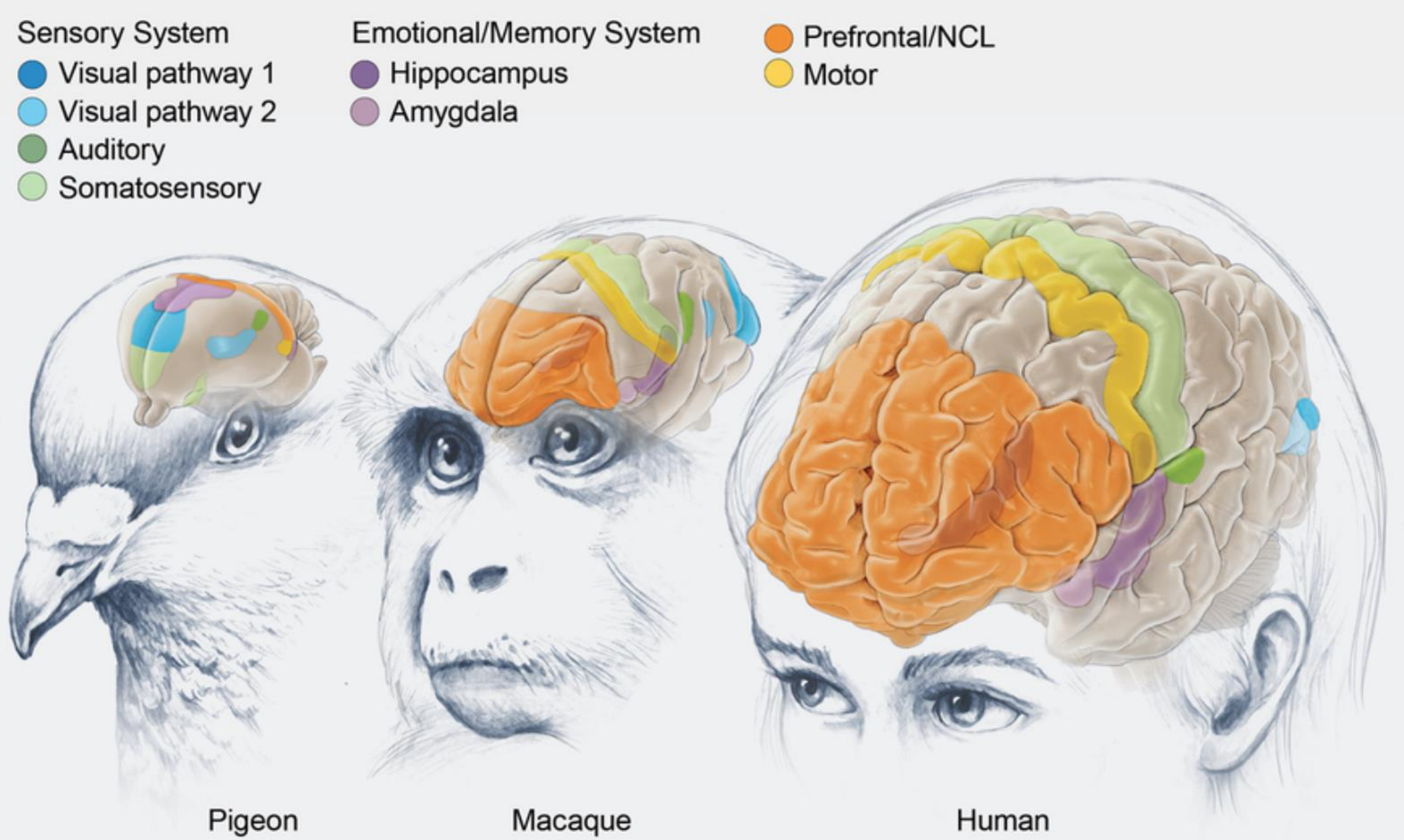


more neurons

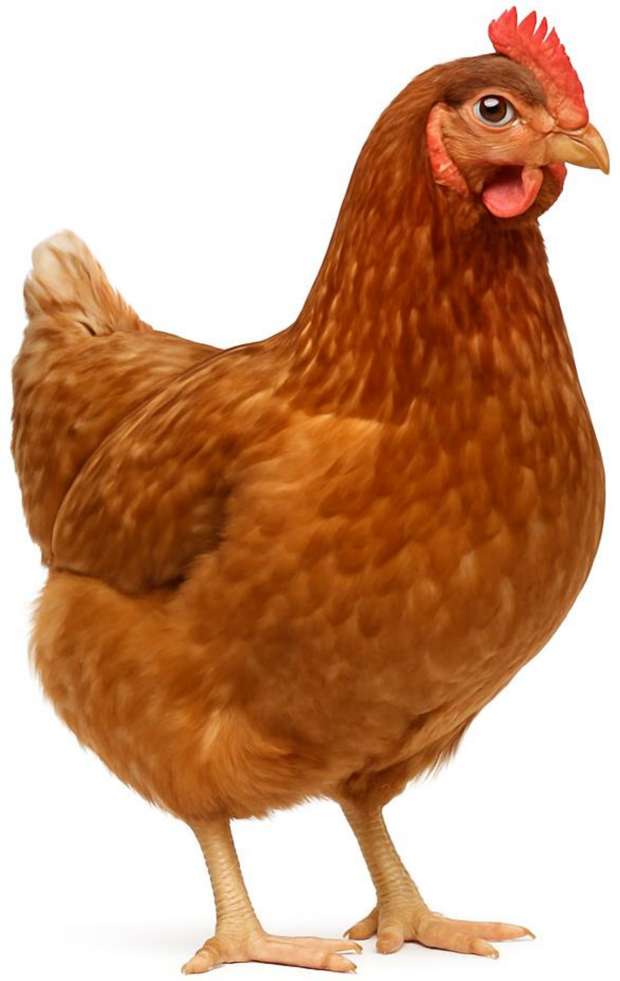
Olcowicz et al. (2016) *PNAS*

We had it all wrong!!!





Credit: Onur Güntürkün & Mesa Schumacher



Why are some species *smarter* than others?

Organisms tend to adapt to the conditions they experience…

“Natural selection”




… but intelligent “hacks” lower the costs of maladaptation

Cognitive buffer hypothesis (Allman 1993)

Bigger brains likely evolved in response to variable environments

Can INTER-specific differences in brain size tell us something about differential abilities to *adapt*, *learn* and *solve problems*?

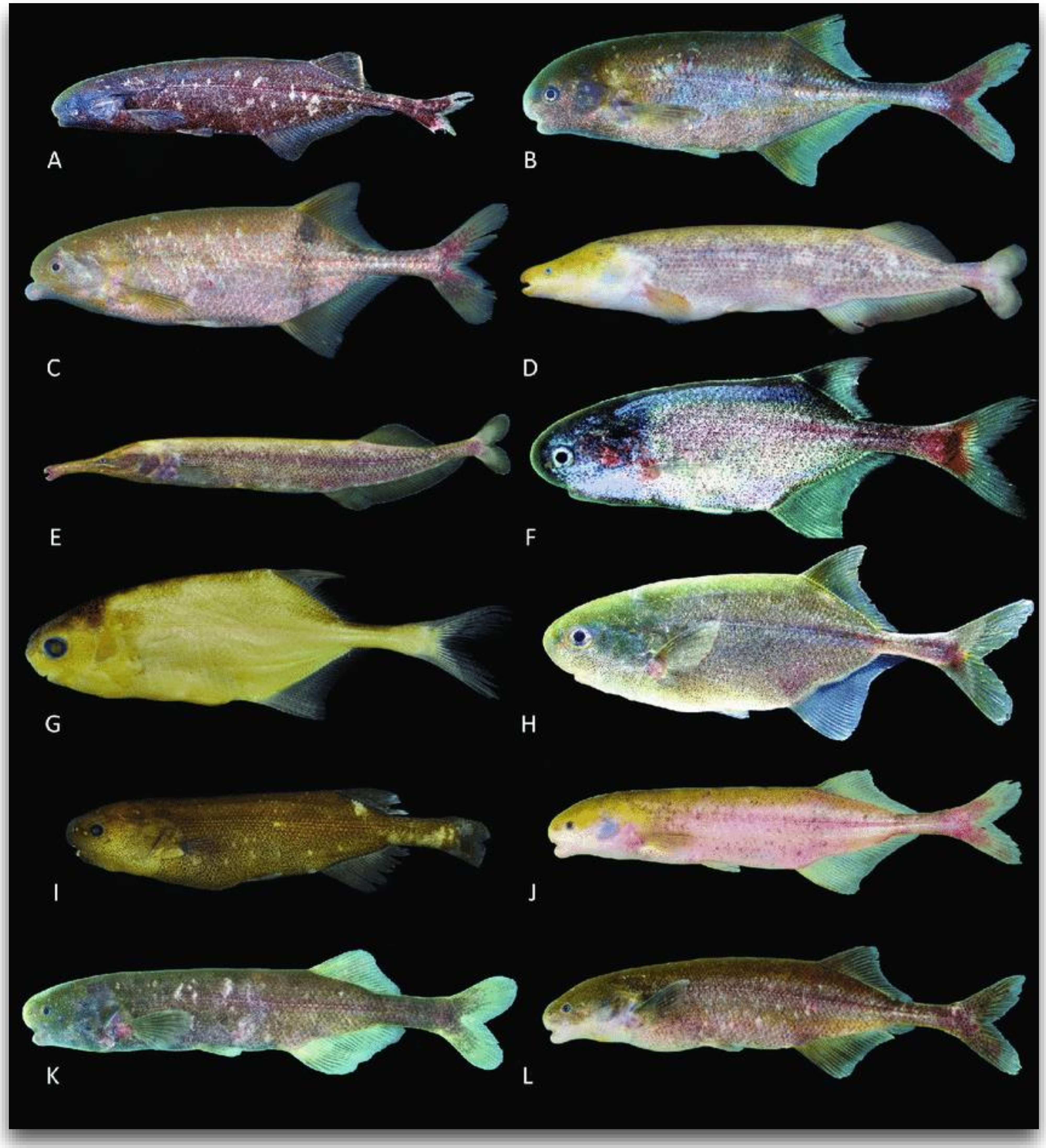
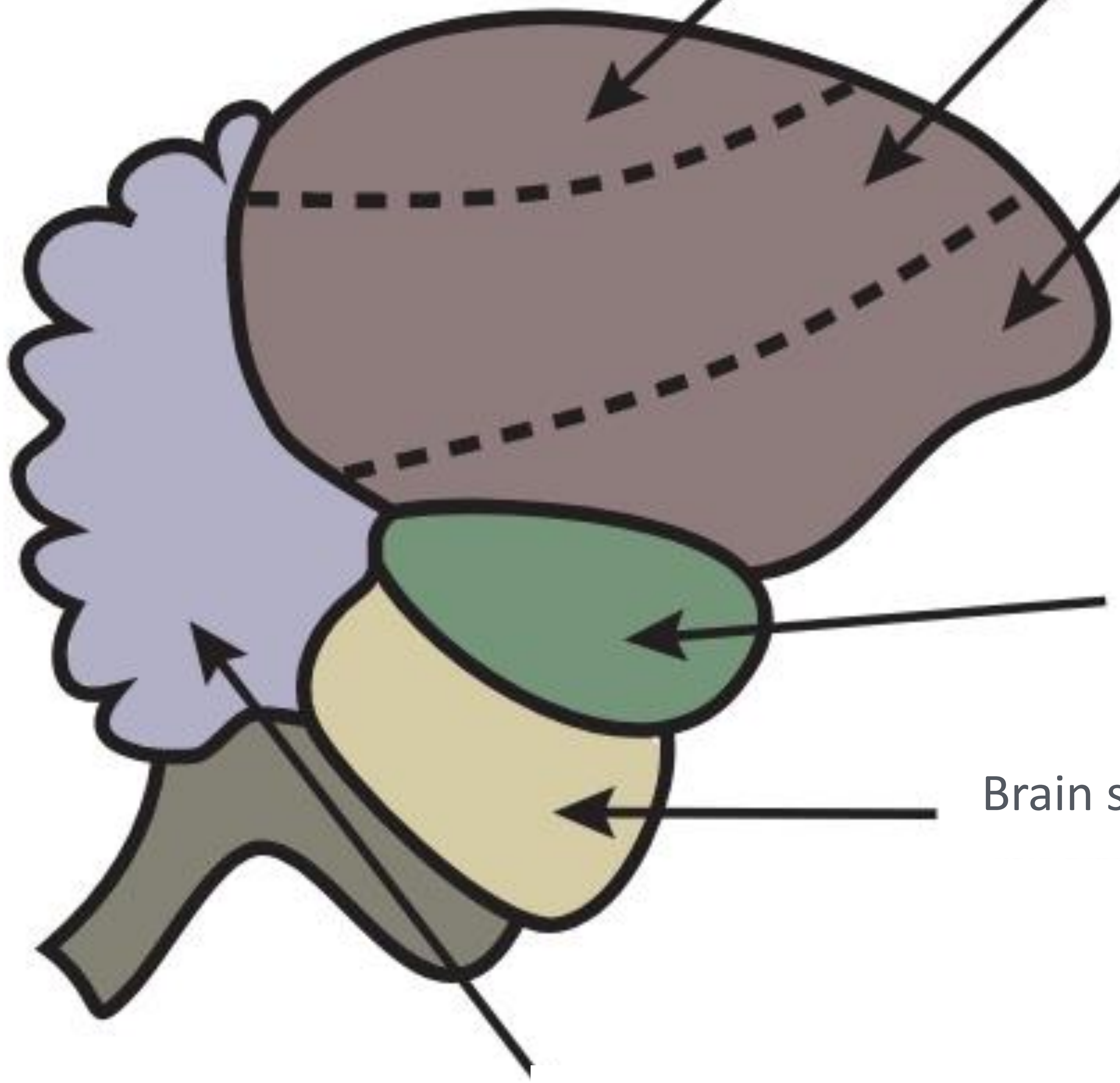


Image credit: John P. Sullivan

Not always!!

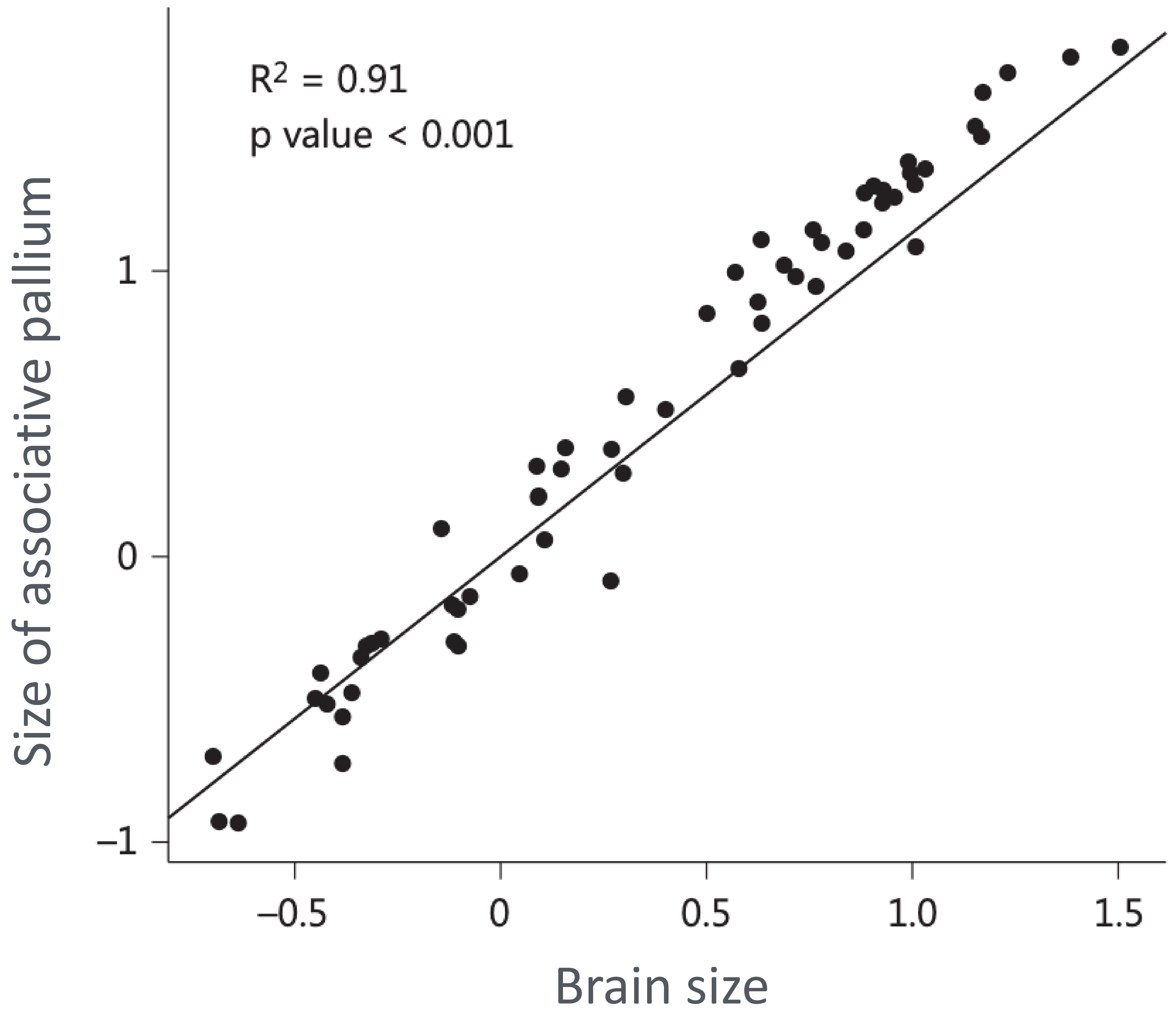
Birds are a lucky exception…

Different bits evolved at a similar rate…

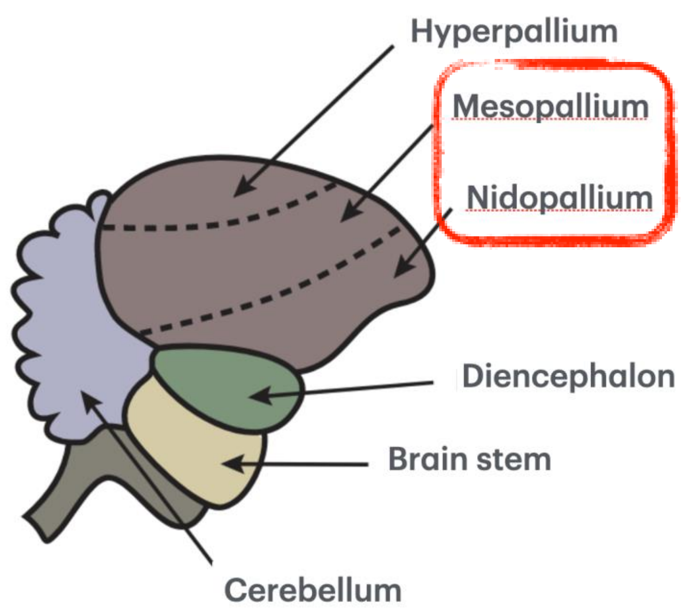


Modified from: Sayol et al. (2016) *Brain Behav Evol*

Birds are a lucky exception…



Brain size is indicative of the size of areas that control what we think of as "intelligence"



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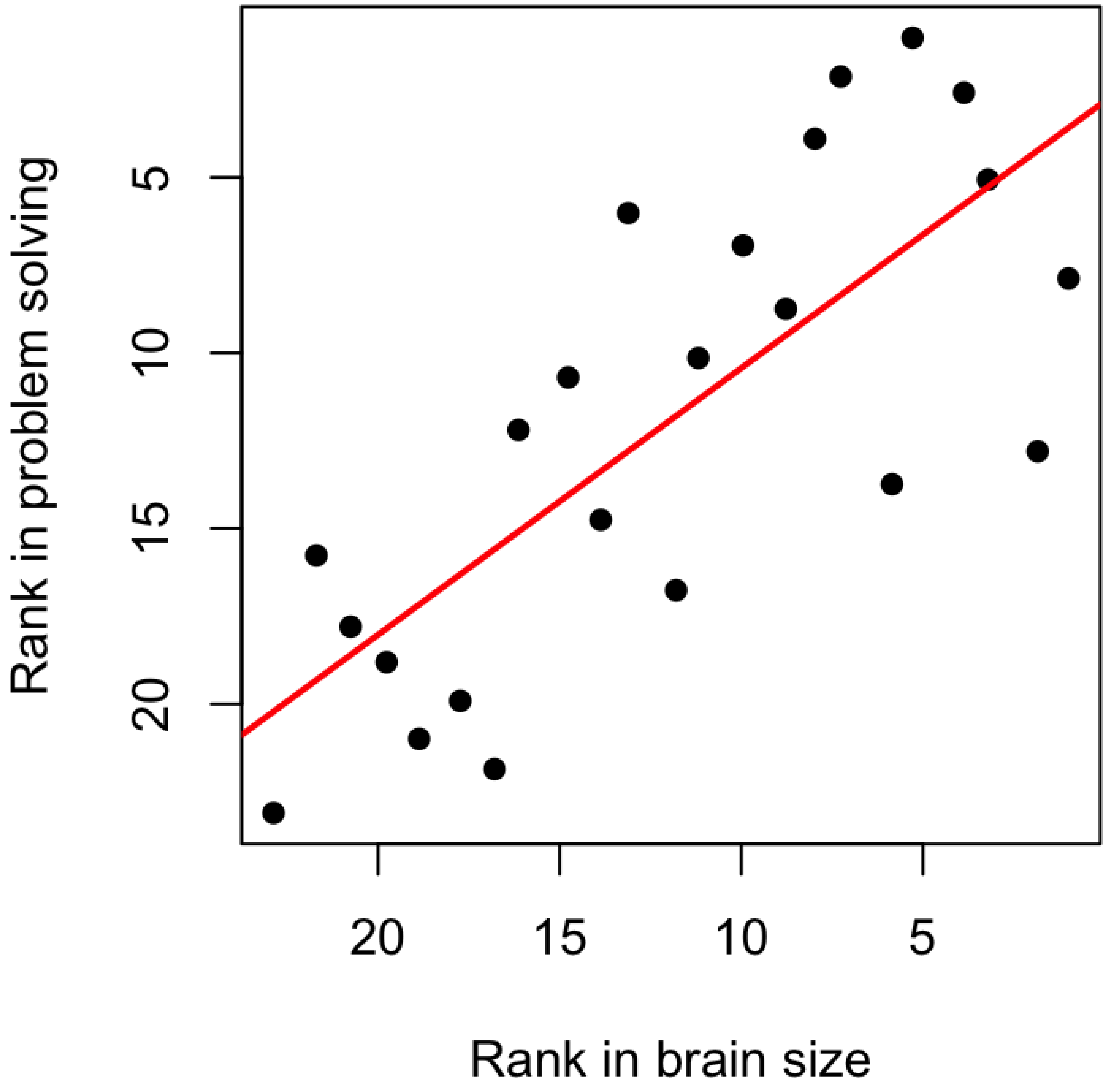
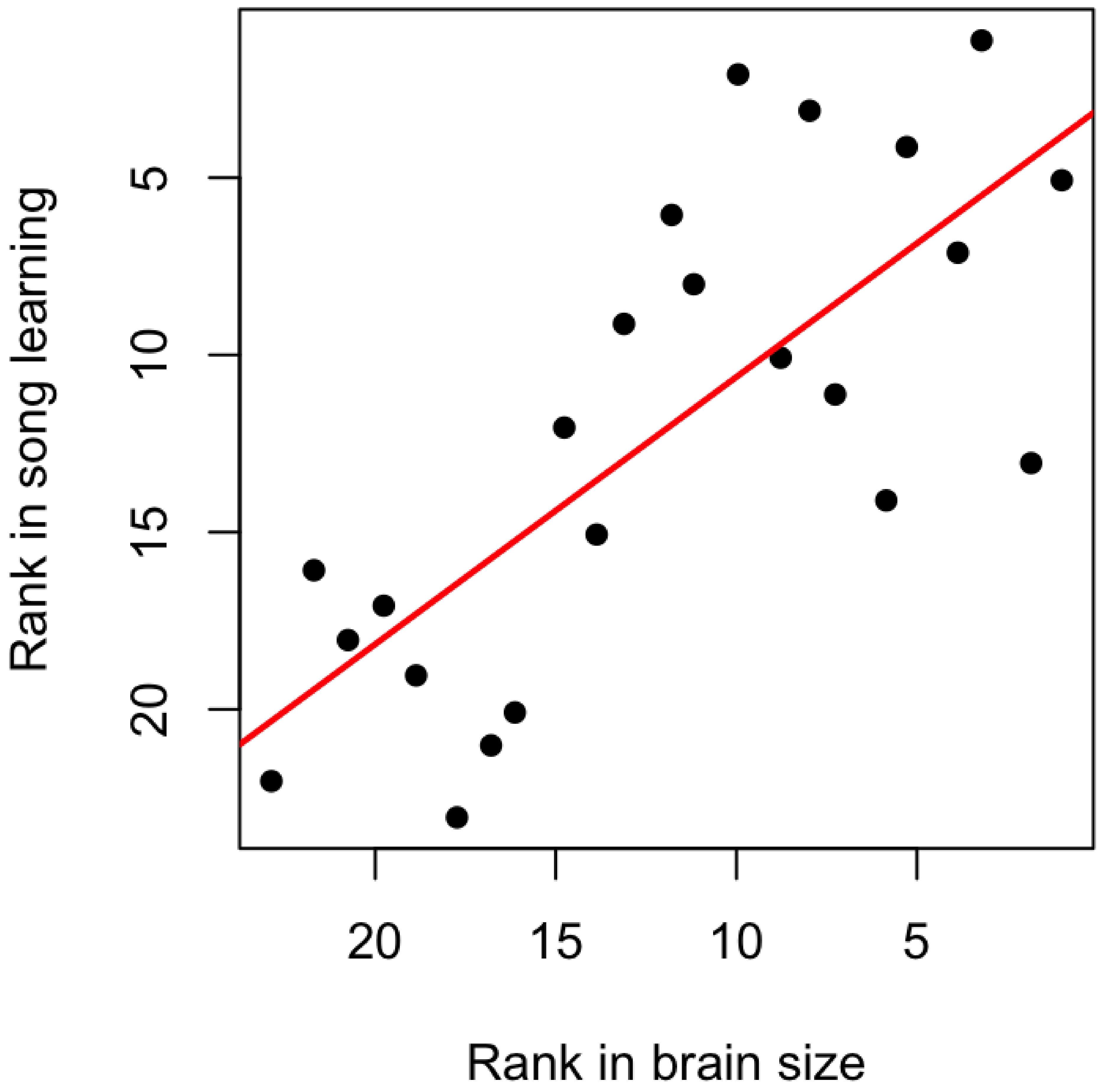
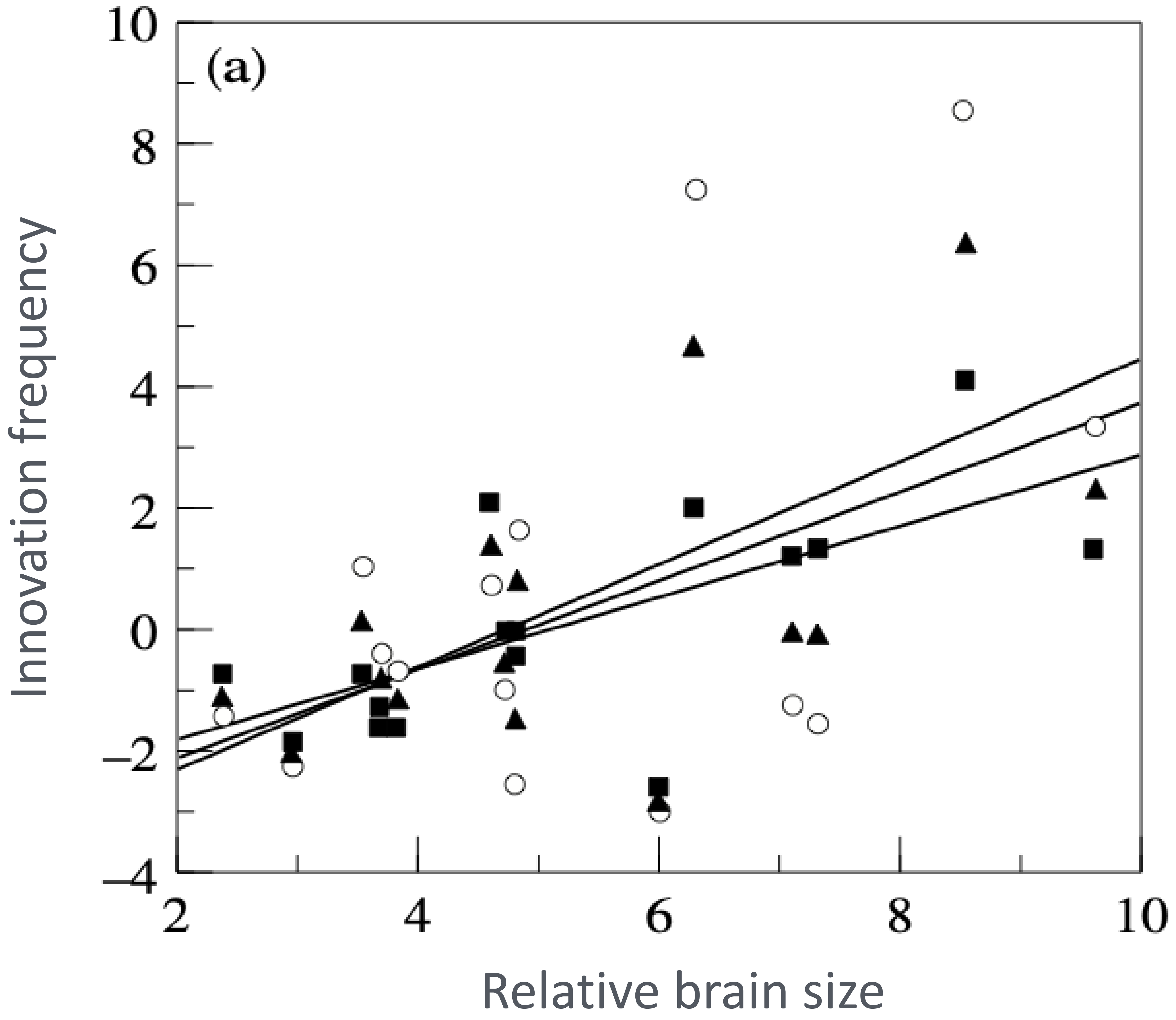




Modified from: Audet et al (2023) *Science*

Birds are a lucky exception…

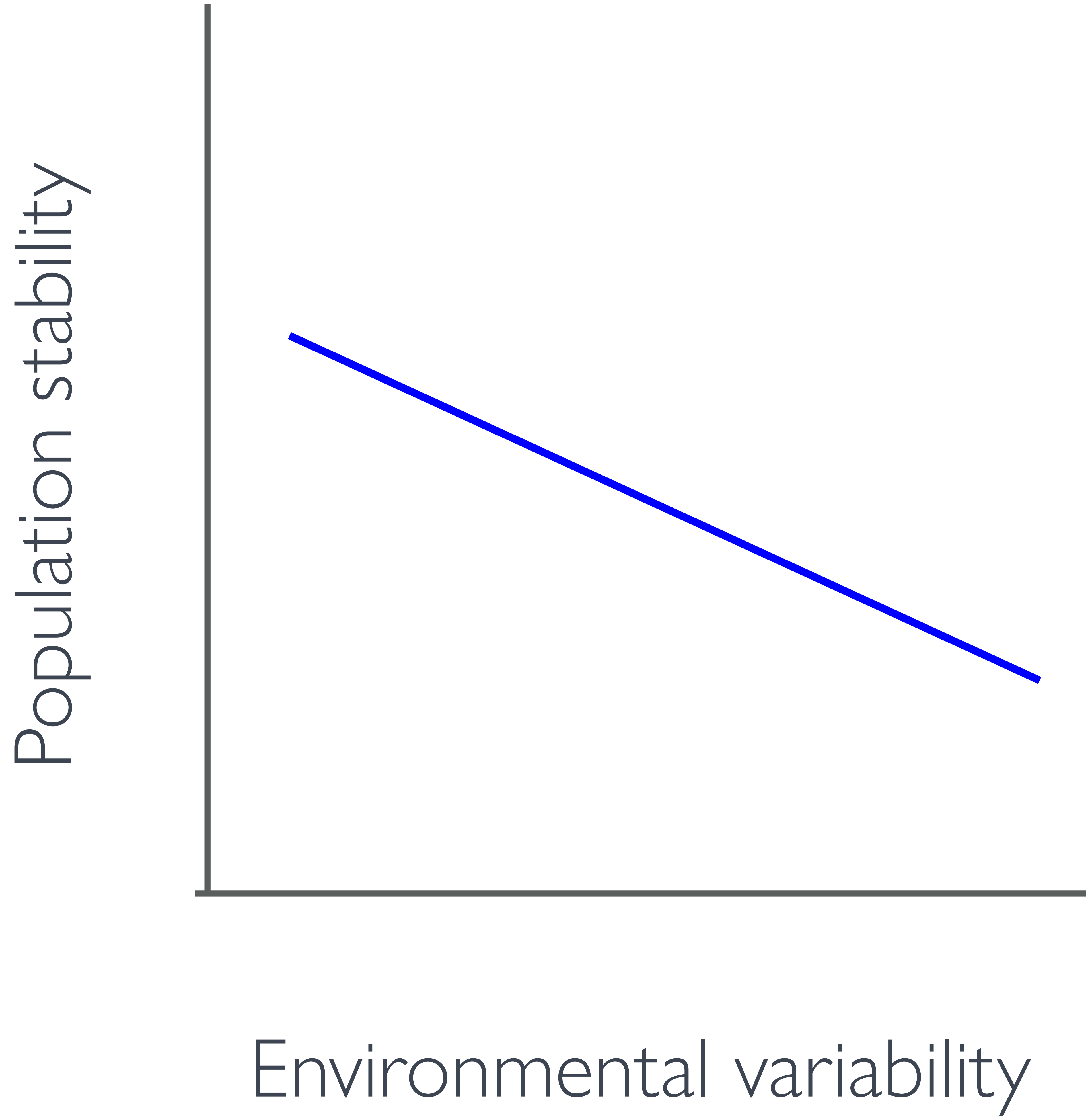
… and is a good predictor of behavioral flexibility



Modified from: Lefebvre et al. (1997) *Anim.Behav.*

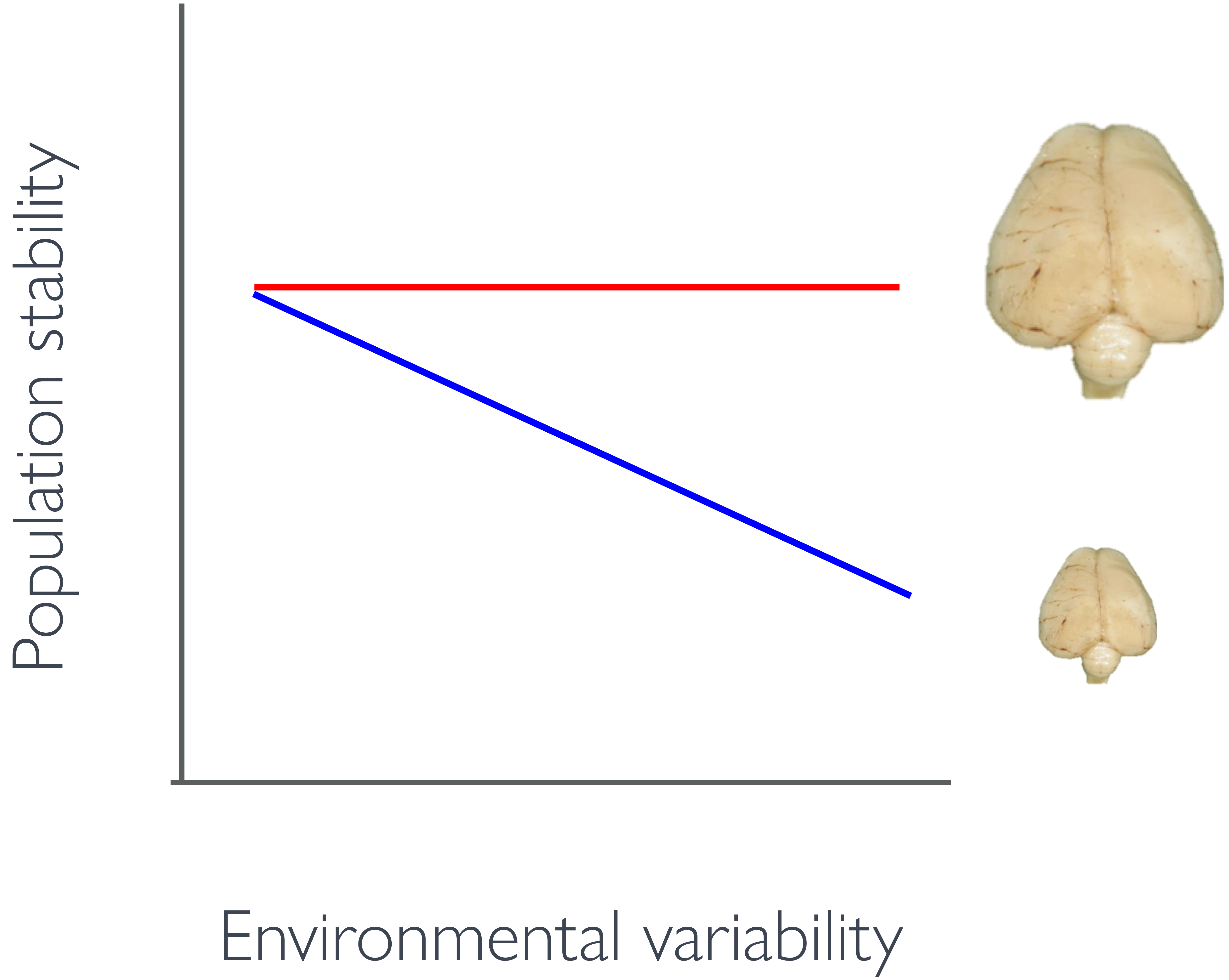
Do birds with bigger brains live in variable environments?

A better test of the cognitive buffer hypothesis



Trevor Fristoe, Ph. D.

A better test of the cognitive buffer hypothesis

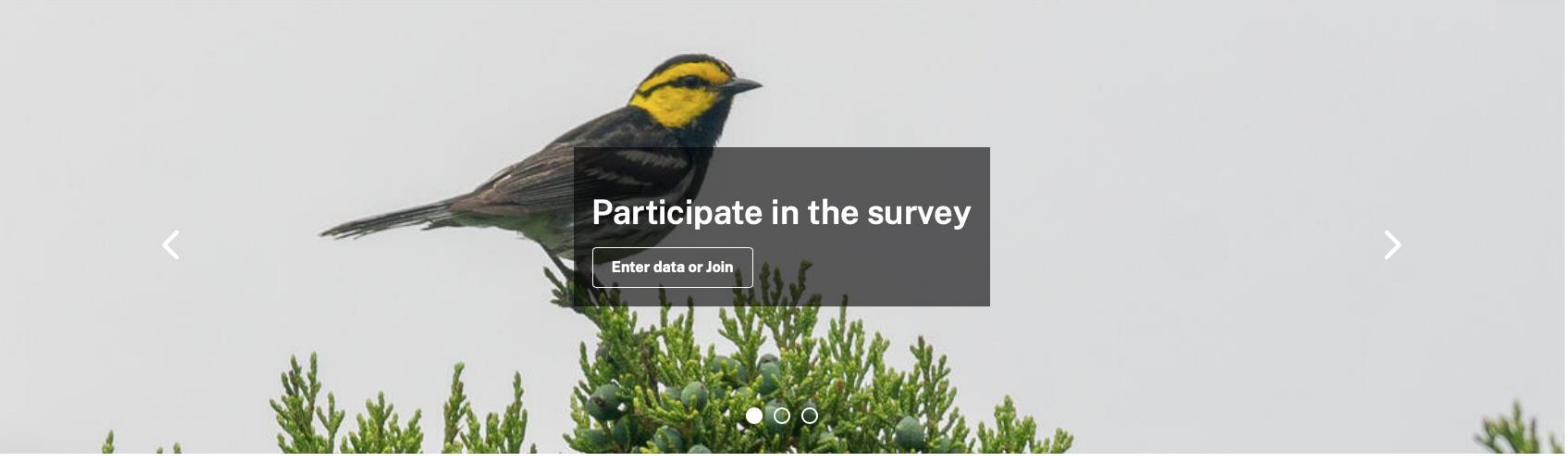


Trevor Fristoe, Ph. D.

North American Breeding Bird Survey

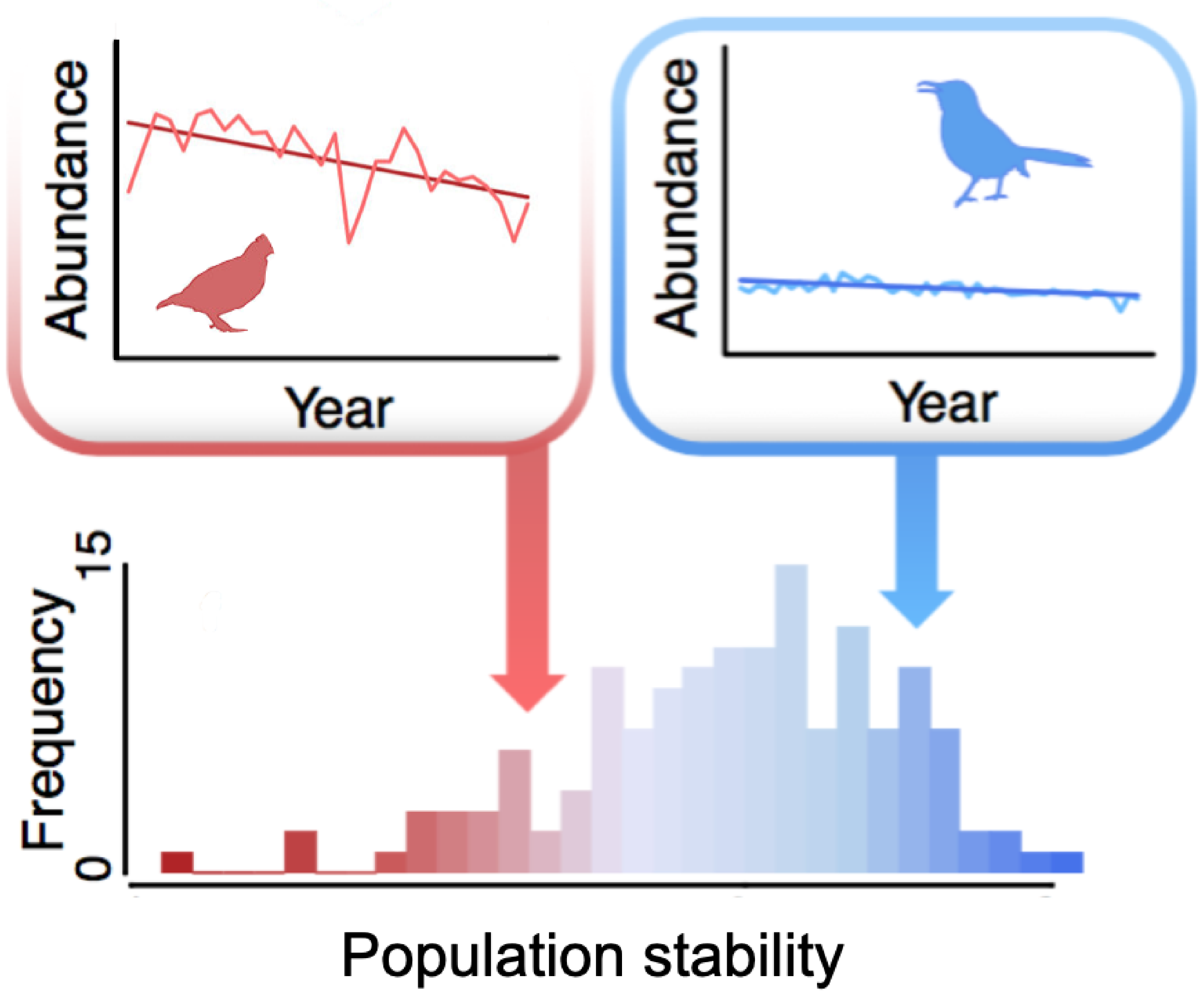
ACTIVE

By Eastern Ecological Science Center February 11, 2025



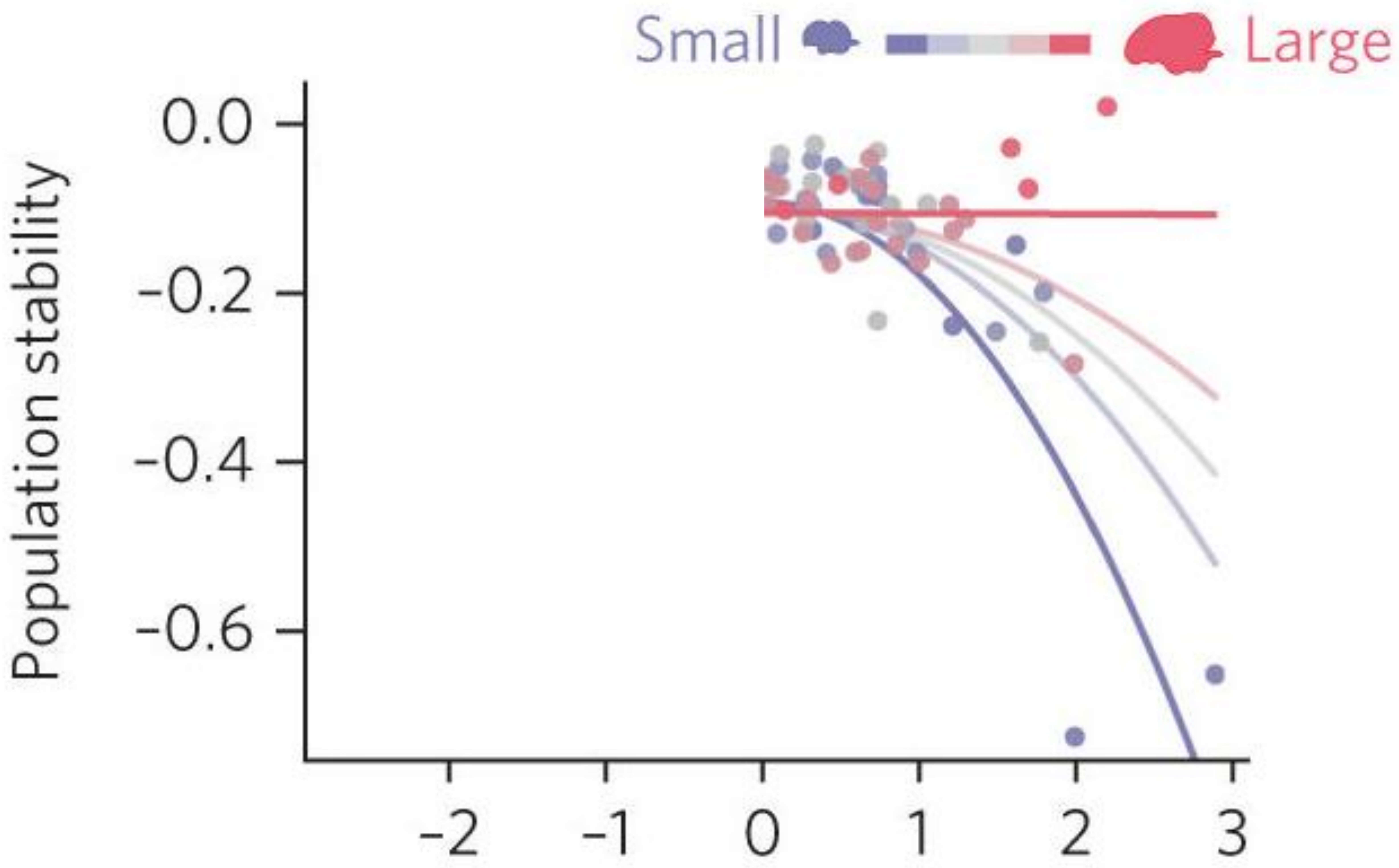
The North American Breeding Bird Survey (BBS) is the primary source for critical quantitative data to evaluate the status of continental bird species, keeping common birds common and helping fuel a $75 billion wildlife watching industry. Each year thousands of citizen scientists skilled in avian identification collect data on BBS routes throughout North America allowing us to better understand bird population changes and manage them. The USGS Eastern Ecological Science Center, Environment and Climate Change Canada, and the Mexican National Commission for the Knowledge and Use of

Breeding Bird Survey



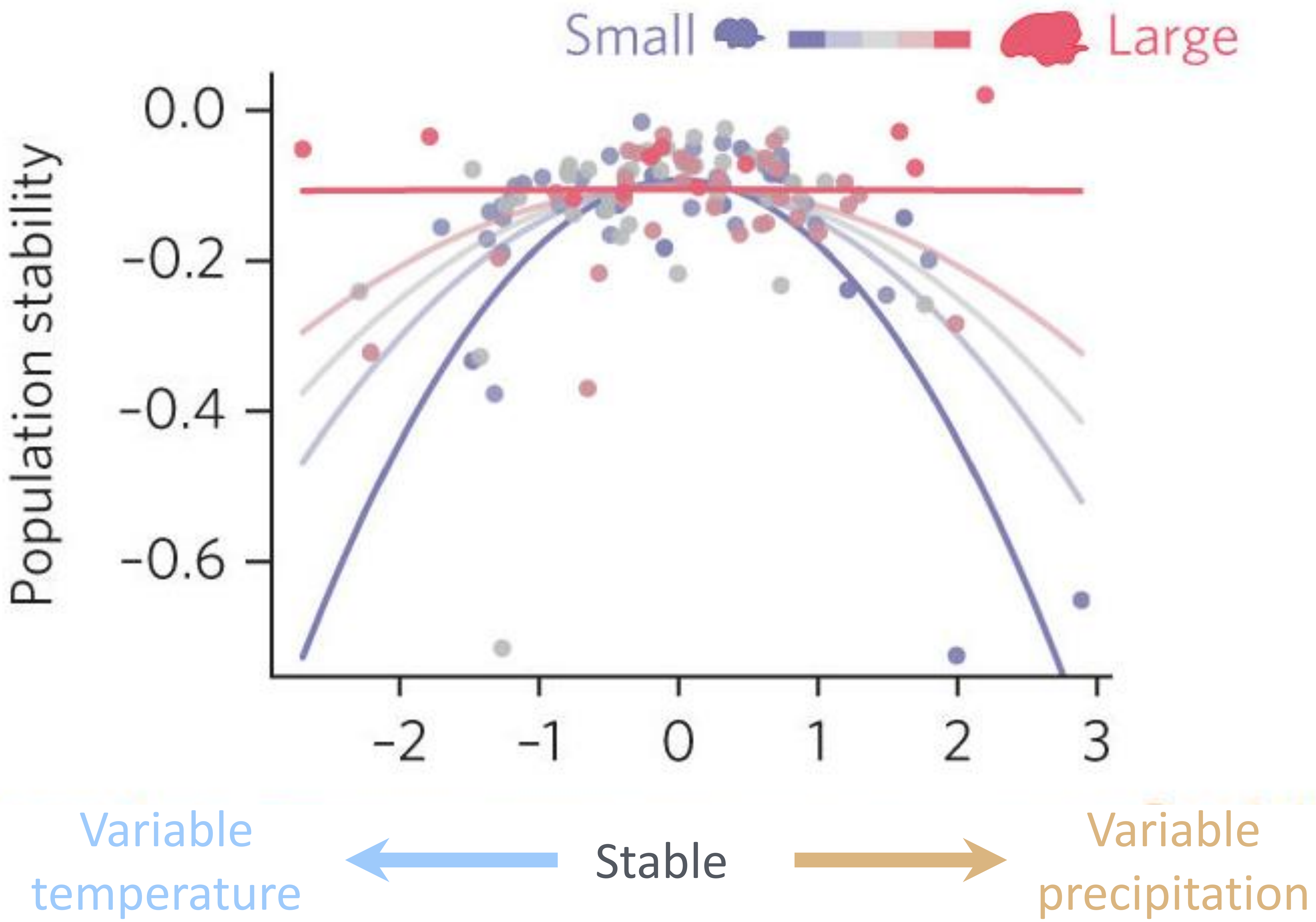
Remote sensing data

Fristoe, Iwaniuk & Botero (2017) ***Nature Ecol. & Evol.***



Stable → Variable precipitation

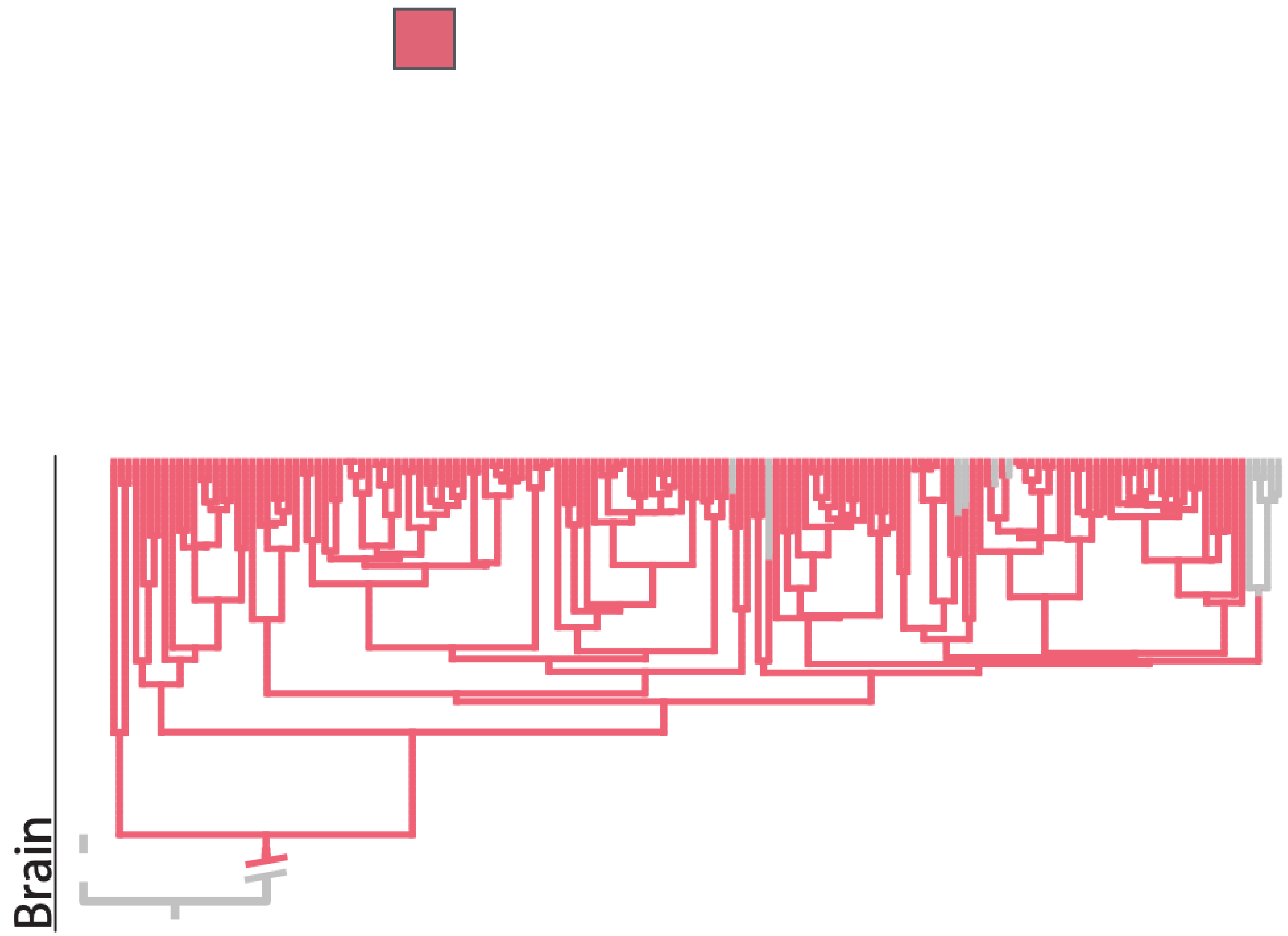
Fristoe, Iwaniuk & Botero (2017) ***Nature Ecol. & Evol.***

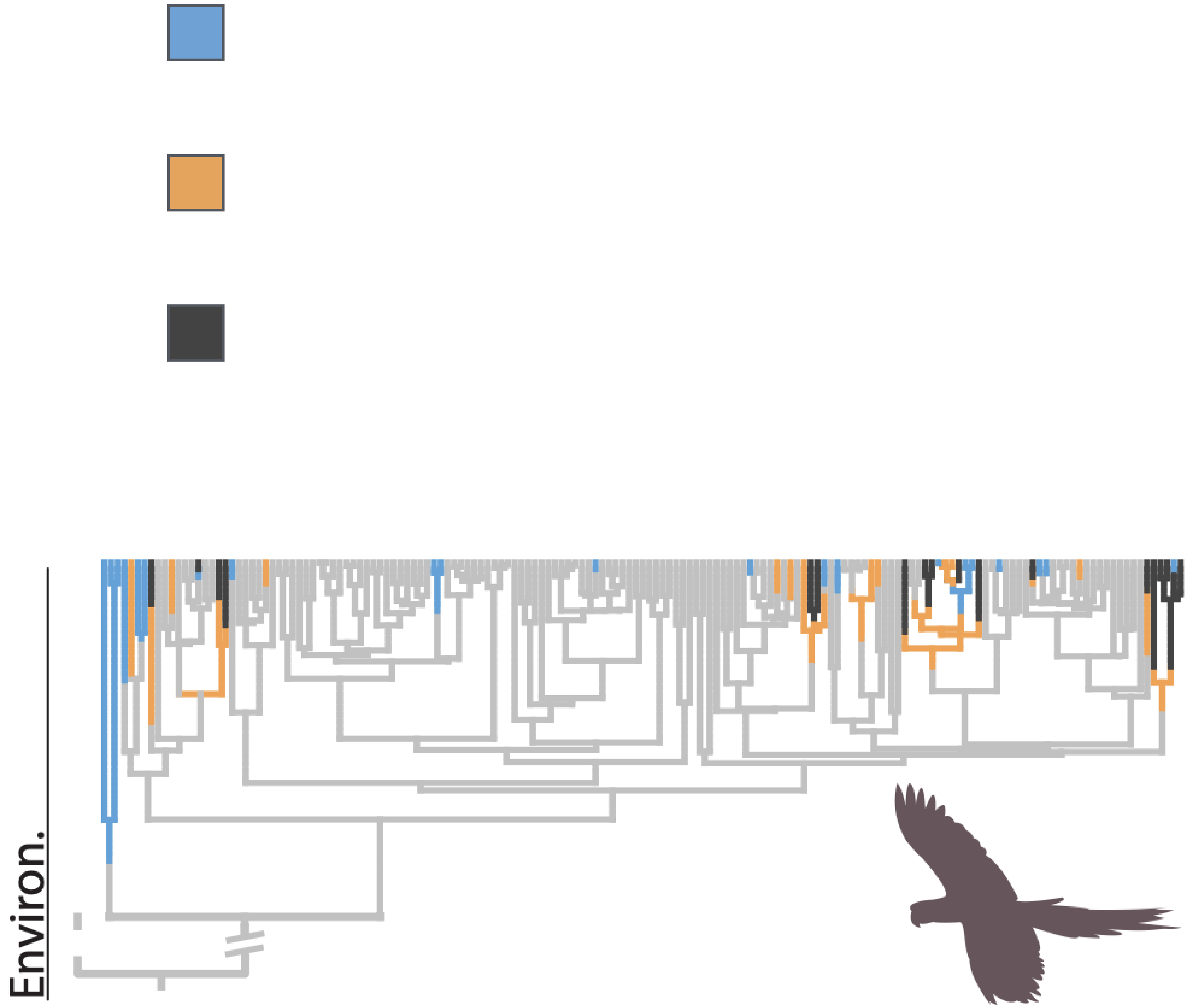


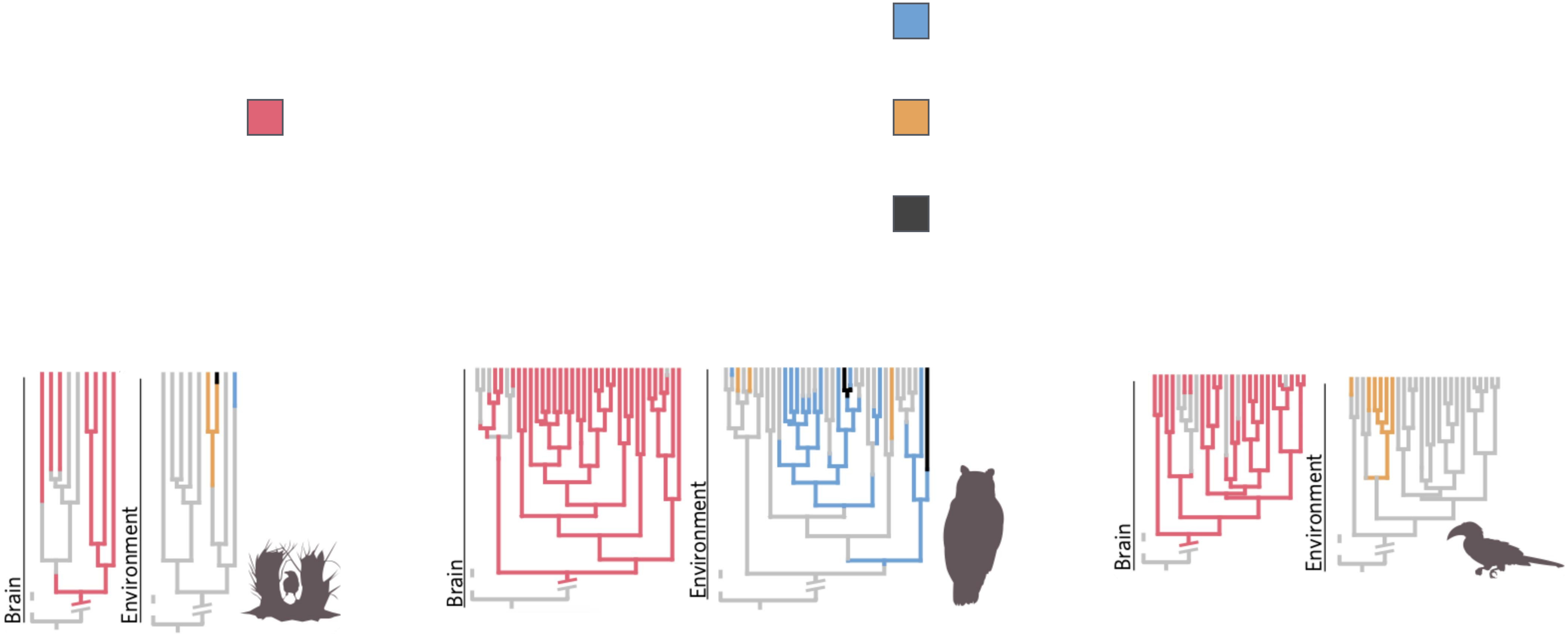
Fristoe, Iwaniuk & Botero (2017) ***Nature Ecol. & Evol.***

Variable environments

Big brains


Brain


Environ.


Brain
Environment
Brain
Environment
Brain
Environment

(1) Big brains help deal with environmental variability

(2) BUT environmental variability was not the main reason why big brains evolved in birds…

Are big brains required to deal with variability?

Do they lead to wider ecological niches?

Do they facilitate taking over the world?

Are big brains required to deal with variability?

Trevor Fristoe, Ph. D.

nature COMMUNICATIONS

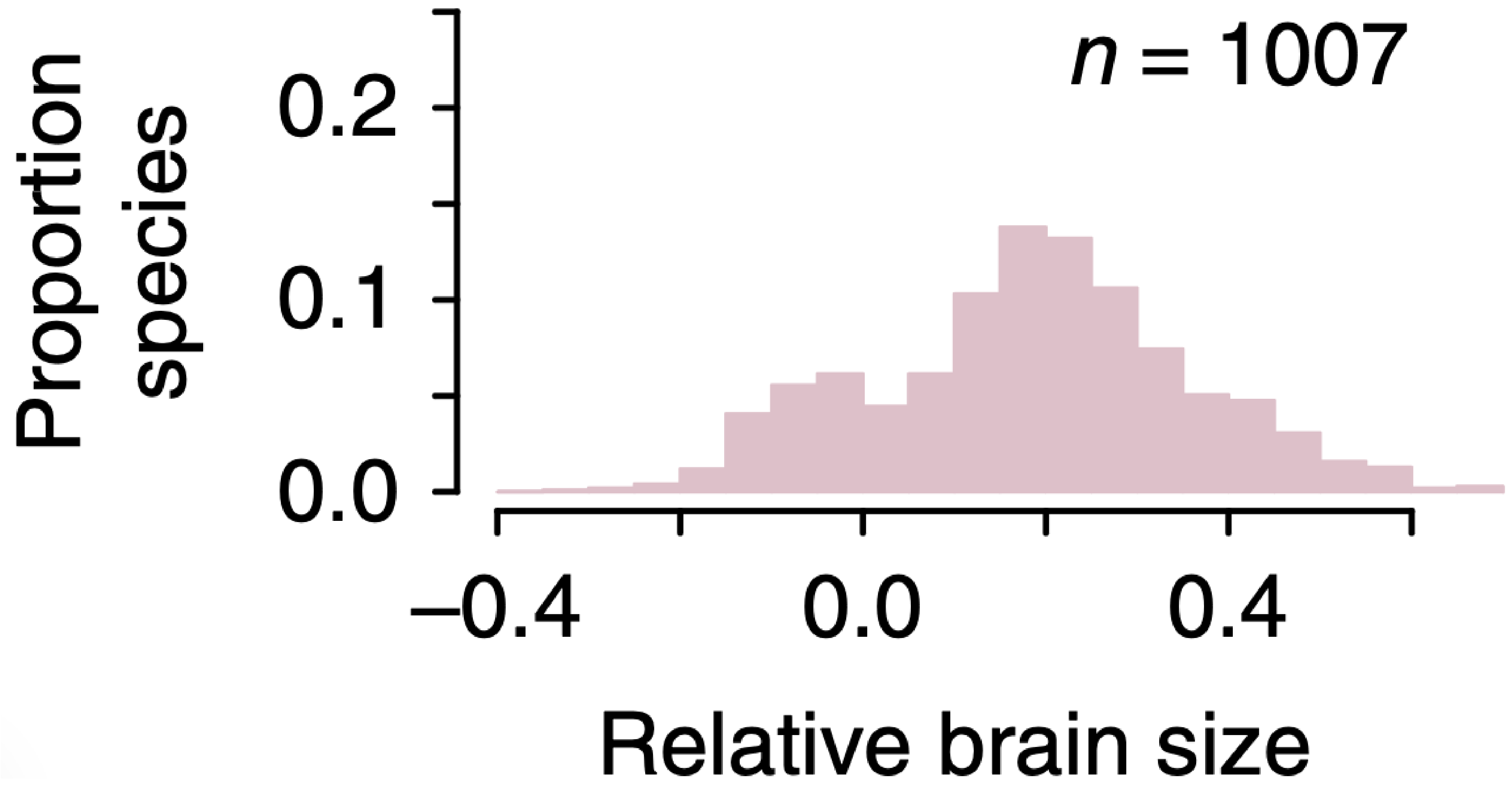
ARTICLE

https://doi.org/10.1038/s41467-019-11757-x OPEN

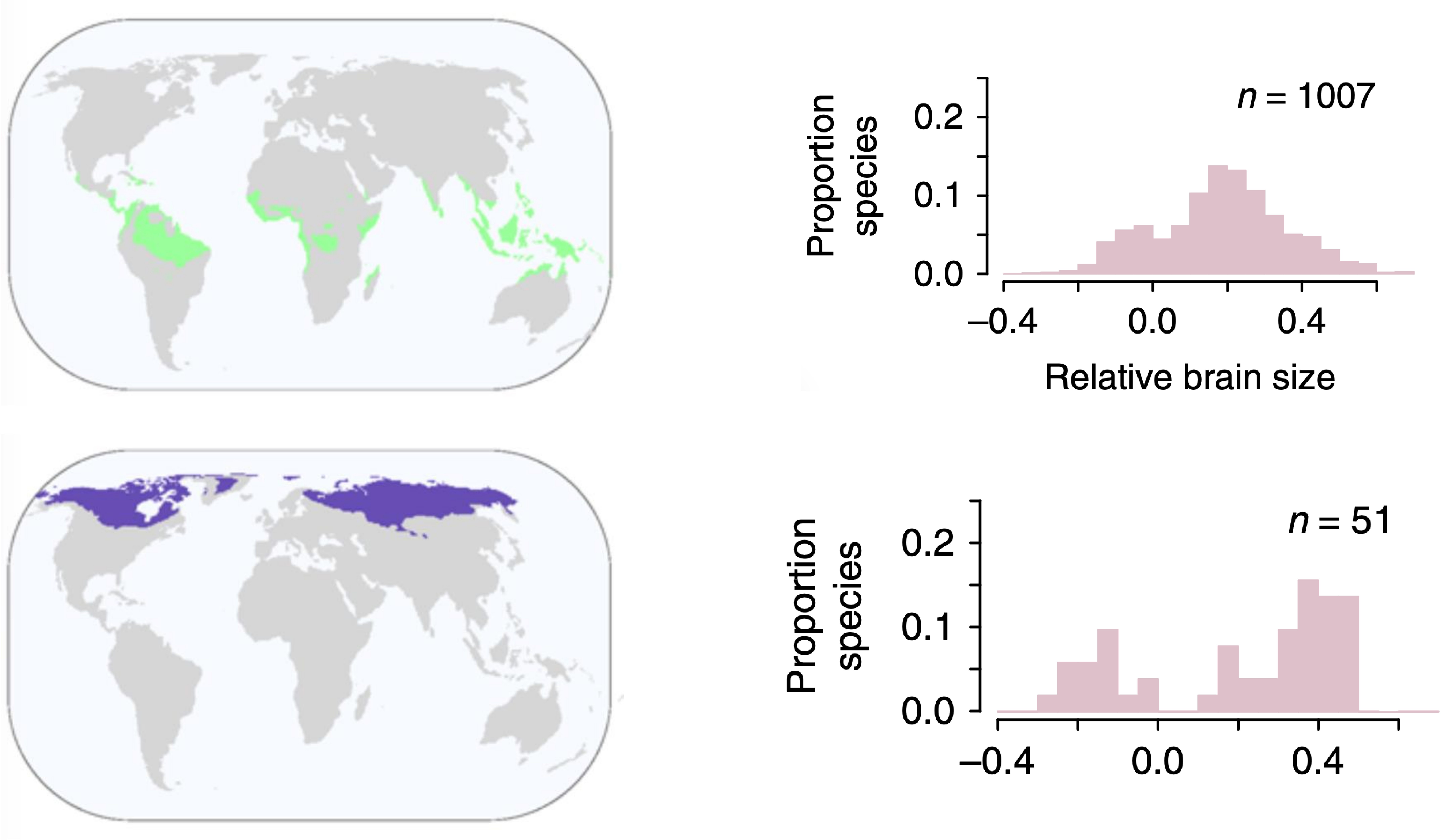
Alternative ecological strategies lead to avian brain size bimodality in variable habitats

Trevor S. Fristoe [1,2] & Carlos A. Botero [2]

The ecological contexts that promote larger brains have received considerable attention, but those that result in smaller-than-expected brains have been largely overlooked. Here, we use a global sample of 2062 species to provide evidence that metabolic and life history tradeoffs govern the evolution of brain size in birds and play an important role in defining the ecological strategies capable of persisting in Earth's most thermally variable and unpredictable habitats. While some birds cope with extreme winter conditions by investing in large brains (e.g., greater capacity for planning, innovation, and behavioral flexibility), others have small brains and invest instead in traits that allow them to withstand or recover from potentially deadly events. Specifically, these species are restricted to large body sizes, diets consisting of difficult-to-digest but readily available foods, and high reproductive output. Overall, our findings highlight the importance of considering strategic tradeoffs when investigating potential drivers of brain size evolution.

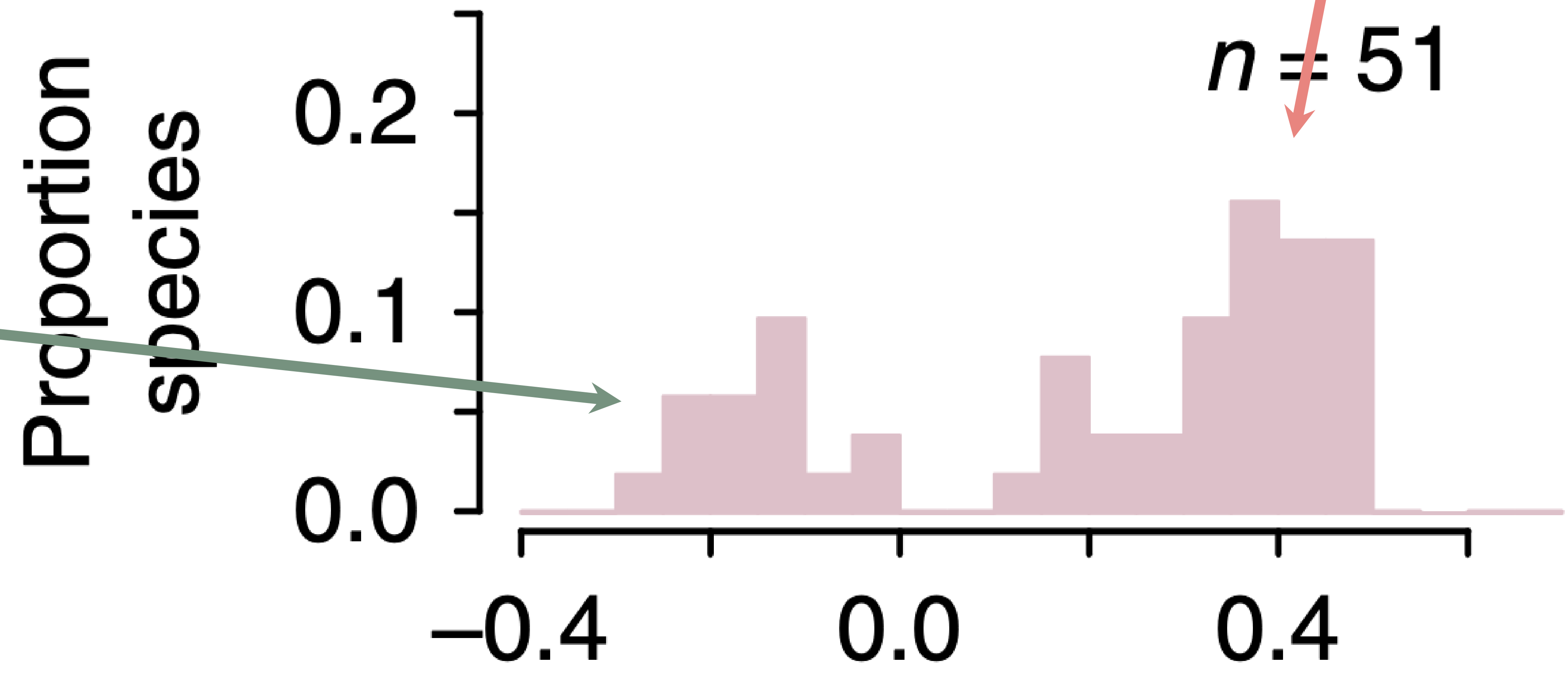


n = 1007
Proportion species
0.2
0.1
0.0
–0.4
0.0
0.4
Relative brain size


n = 1007
Proportion species
0.2
0.1
0.0
–0.4
0.0
0.4
Relative brain size
n = 51
Proportion species
0.2
0.1
0.0
–0.4
0.0
0.4

- Big bodies
- Lots of babies
- Plant diets

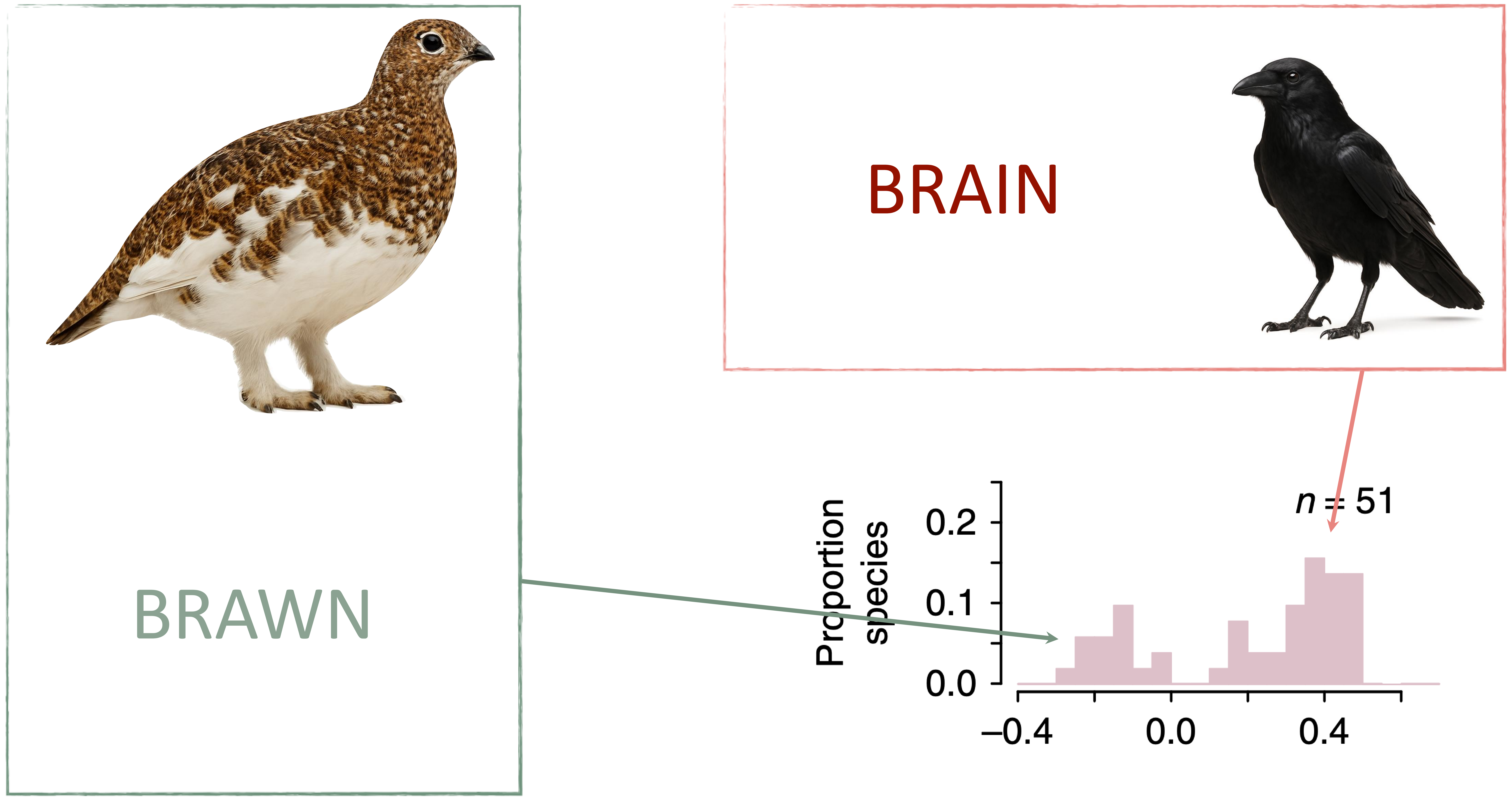
- Flexible behavior
- Advance planning
- Social structures



BIG brains are expensive!!

2% body weight

20% Energy budget


BRAIN
BRAWN
n = 51
Proportion species
0.2
0.1
0.0
−0.4
0.0
0.4

No

Are big brains required to deal with variability?

Do they lead to wider ecological niches?

Do they facilitate taking over the world?

Do bigger brains lead to wider climate niches?

nature communications

Article

https://doi.org/10.1038/s41467-025-58815-1

The global determinants of climate niche breadth in birds

Received: 11 June 2024

Accepted: 2 April 2025

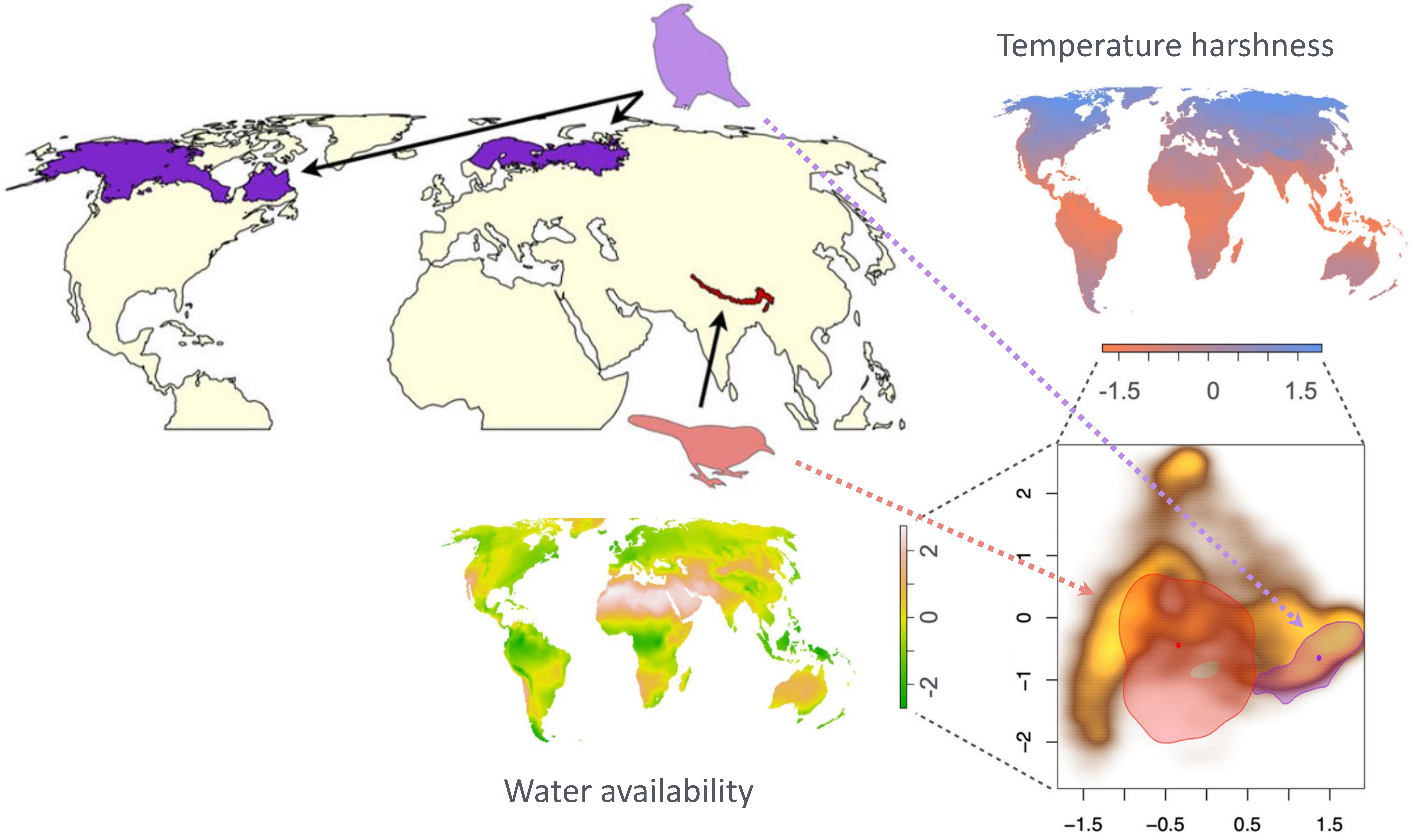
Published online: 17 April 2025

Check for updates

João Fabrício Mota Rodrigues & Carlos A. Botero

Understanding why certain species occupy wider climate niches than others is a fundamental pursuit in ecology with important implications for conservation and management. However, existing synthesis on this topic has focused on the consequences rather than the causes of climate niche expansion, leading to significant gaps in our understanding of the possible evolutionary drivers of this important ecological property. Here we leverage species distribution models powered by millions of citizen science sightings of birds to determine how a comprehensive suite of parameters influences the breadth of climate niches. Our analyses show that migration and more central locations in climate space are directly associated with wider climate niches. Additionally, they indicate that larger brains, smaller bodies, and broader dietary requirements are indirectly associated with narrower niches, presumably because they enable the occupancy of geographically widespread habitats that occupy narrow areas in climate niche space. Through follow-up analyses we further clarify how the different factors considered in this study help shape niche breadth by affecting the colonization of more versus less frequently used habitats. Overall, our findings shed light on critical, yet highly under-appreciated properties of climate niches, underscoring the complexity and interconnectivity of the factors that shaped their evolution among birds.

Fabricio Rodrigues , Ph.D.

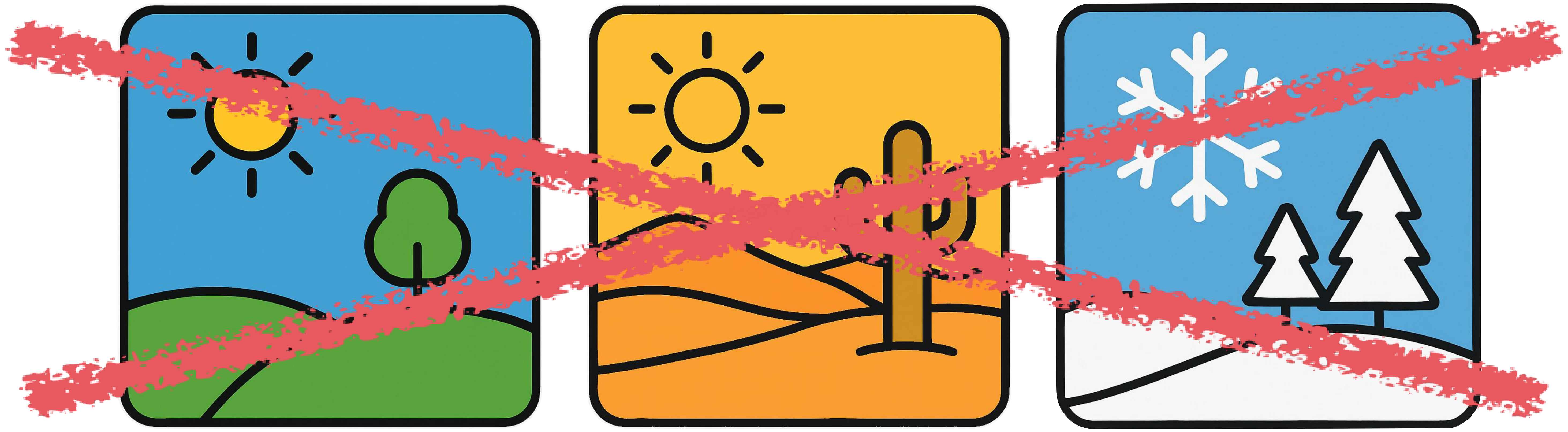


Temperature harshness
-1.5
0
1.5
2
1
0
−1
−2
2
0
-2
−1.5
−0.5
0.5
1.5
Water availability

Do bigger brains lead to wider climate niches?

Temporally variable habitats

Different habitats



No

Are big brains required to deal with variability?

Do they lead to wider ecological niches?

Not necessarily

Do they facilitate taking over the world?

Do bigger brains facilitate taking over the world?

Joan Garcia-Porta, Ph.D.

nature COMMUNICATIONS

ARTICLE

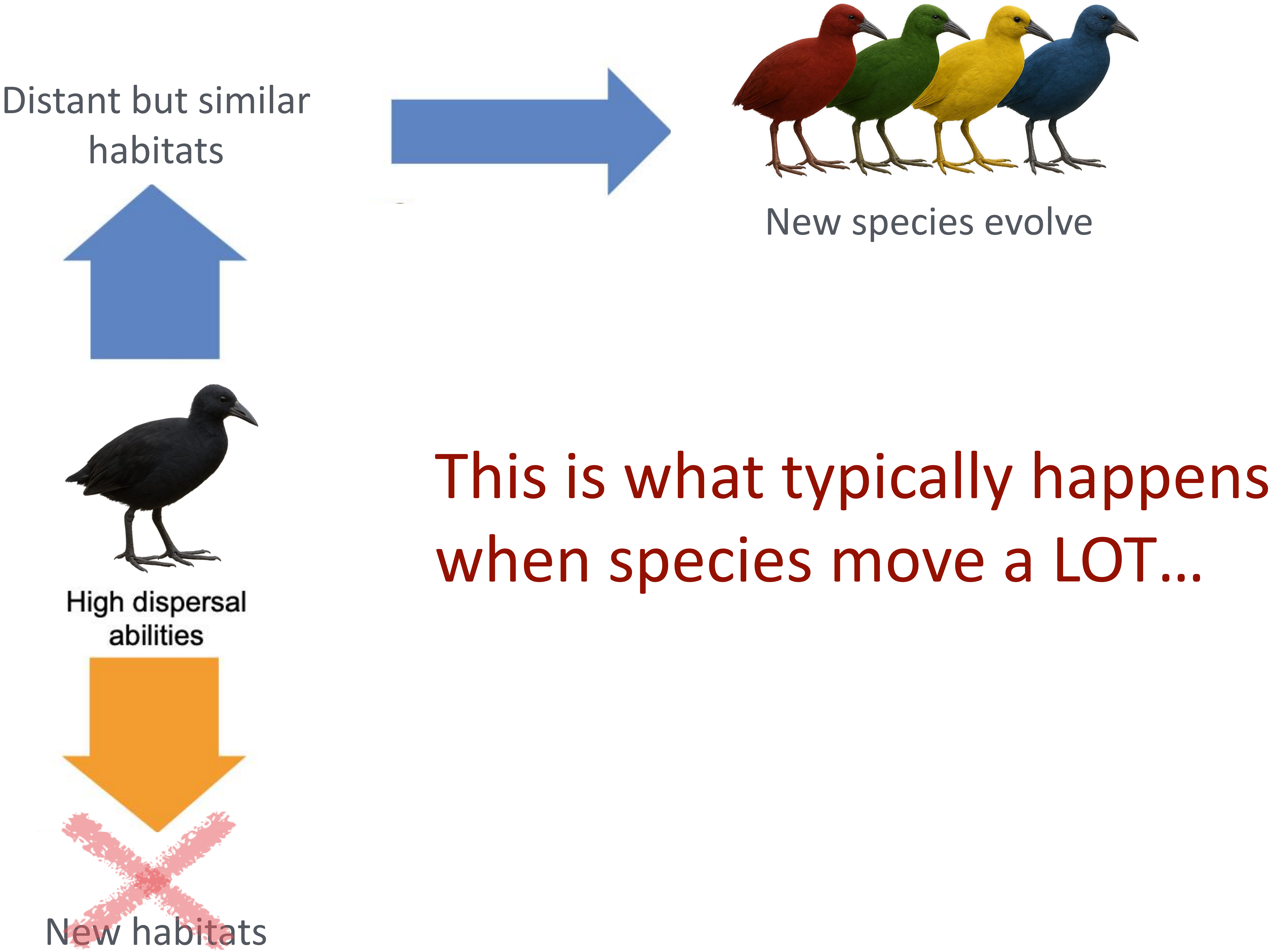
https://doi.org/10.1038/s41467-022-29707-5 OPEN

Check for updates

Niche expansion and adaptive divergence in the global radiation of crows and ravens

Joan Garcia-Porta[1,2]✉, Daniel Sol[2,3], Matt Pennell[4], Ferran Sayol[5], Antigoni Kaliontzopoulou[6] & Carlos A. Botero[1]

The processes that allow some lineages to diversify rapidly at a global scale remain poorly understood. Although earlier studies emphasized the importance of dispersal, global expansions expose populations to novel environments and may also require adaptation and diversification across new niches. In this study, we investigated the contributions of these processes to the global radiation of crows and ravens (genus *Corvus*). Combining a new phylogeny with comprehensive phenotypic and climatic data, we show that *Corvus* experienced a massive expansion of the climatic niche that was coupled with a substantial increase in the rates of species and phenotypic diversification. The initiation of these processes

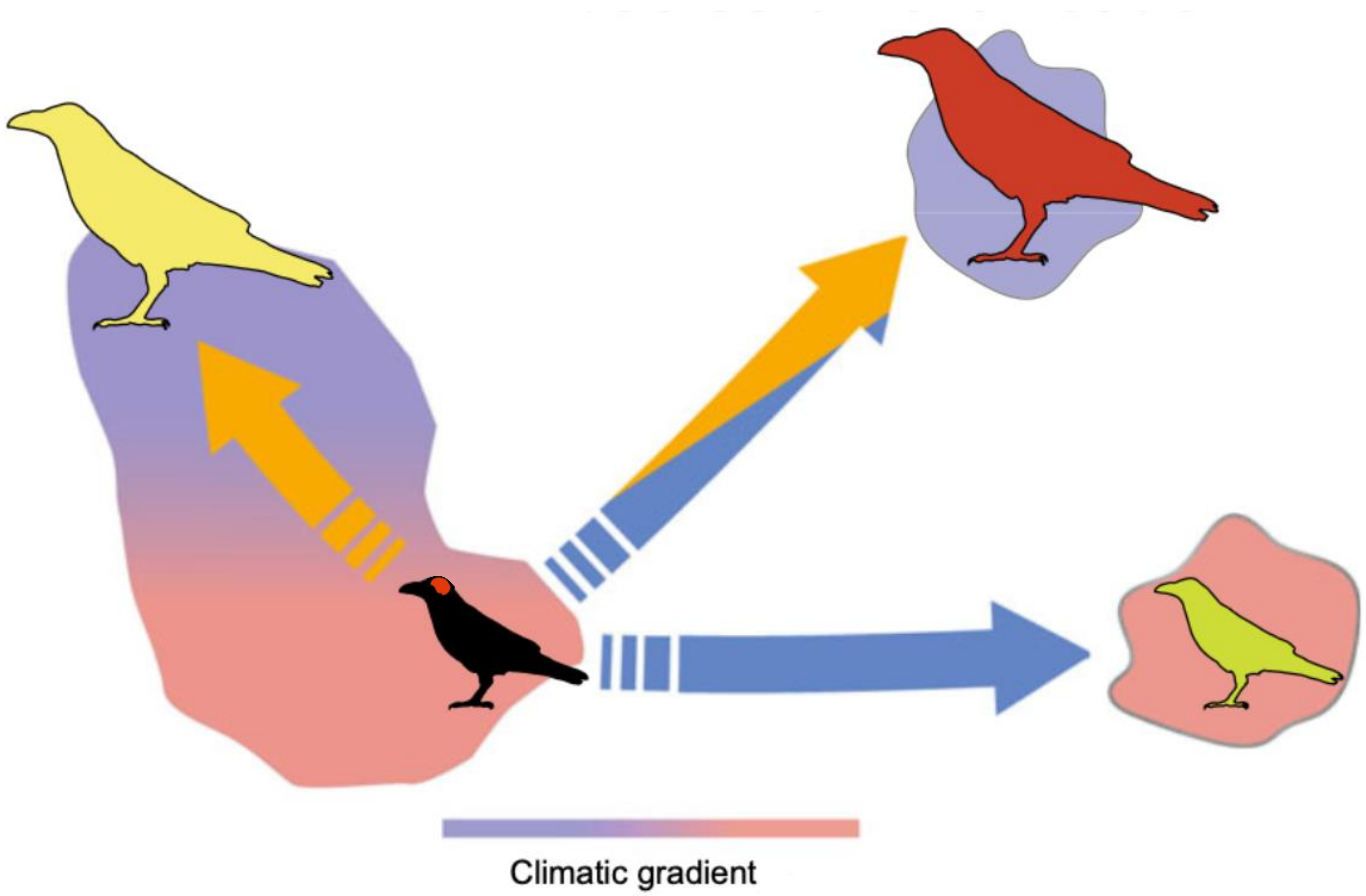

Distant but similar habitats
New species evolve
High dispersal abilities
New habitats
This is what typically happens when species move a LOT…

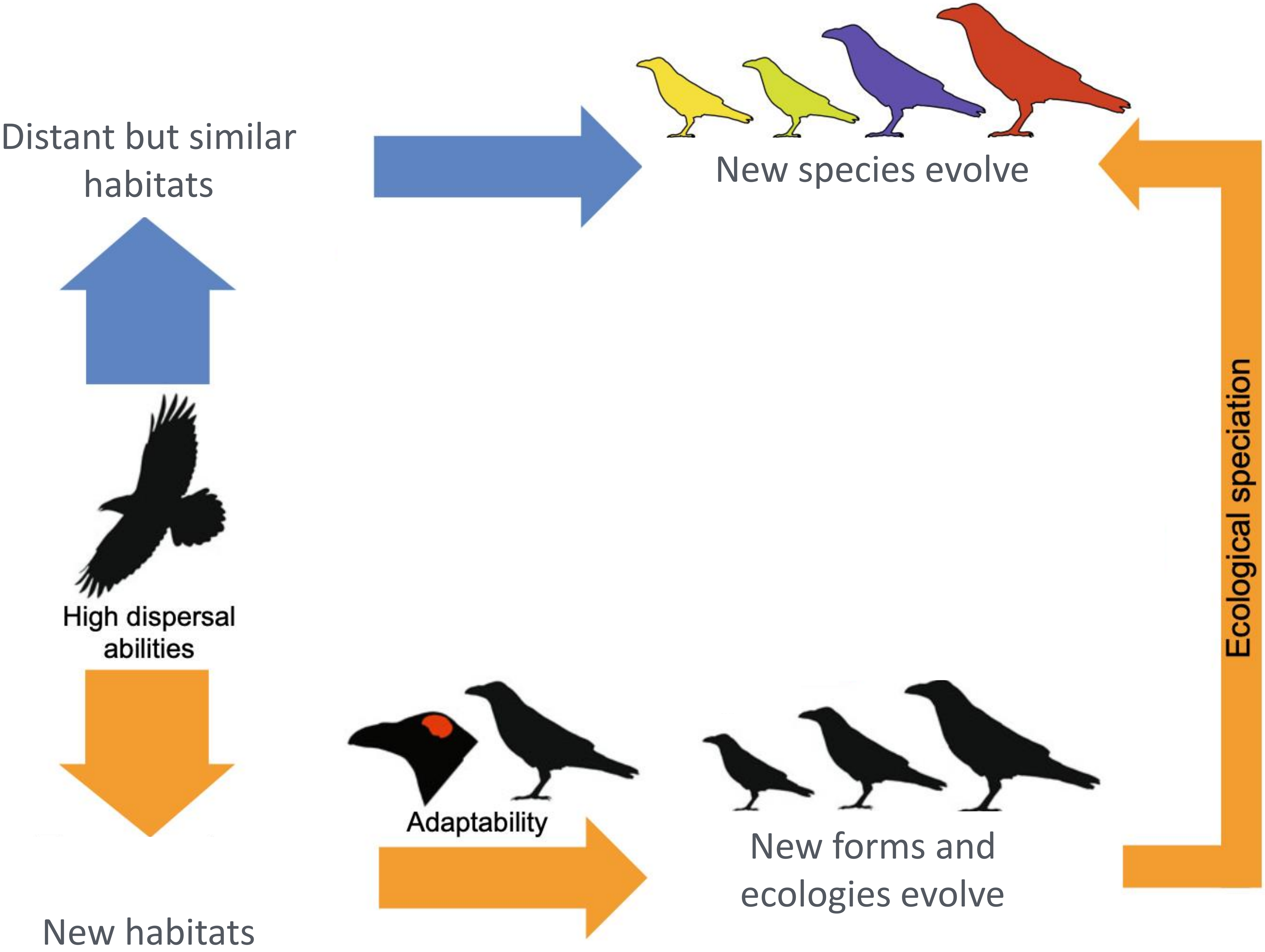
… but ancestral crows were not typical!

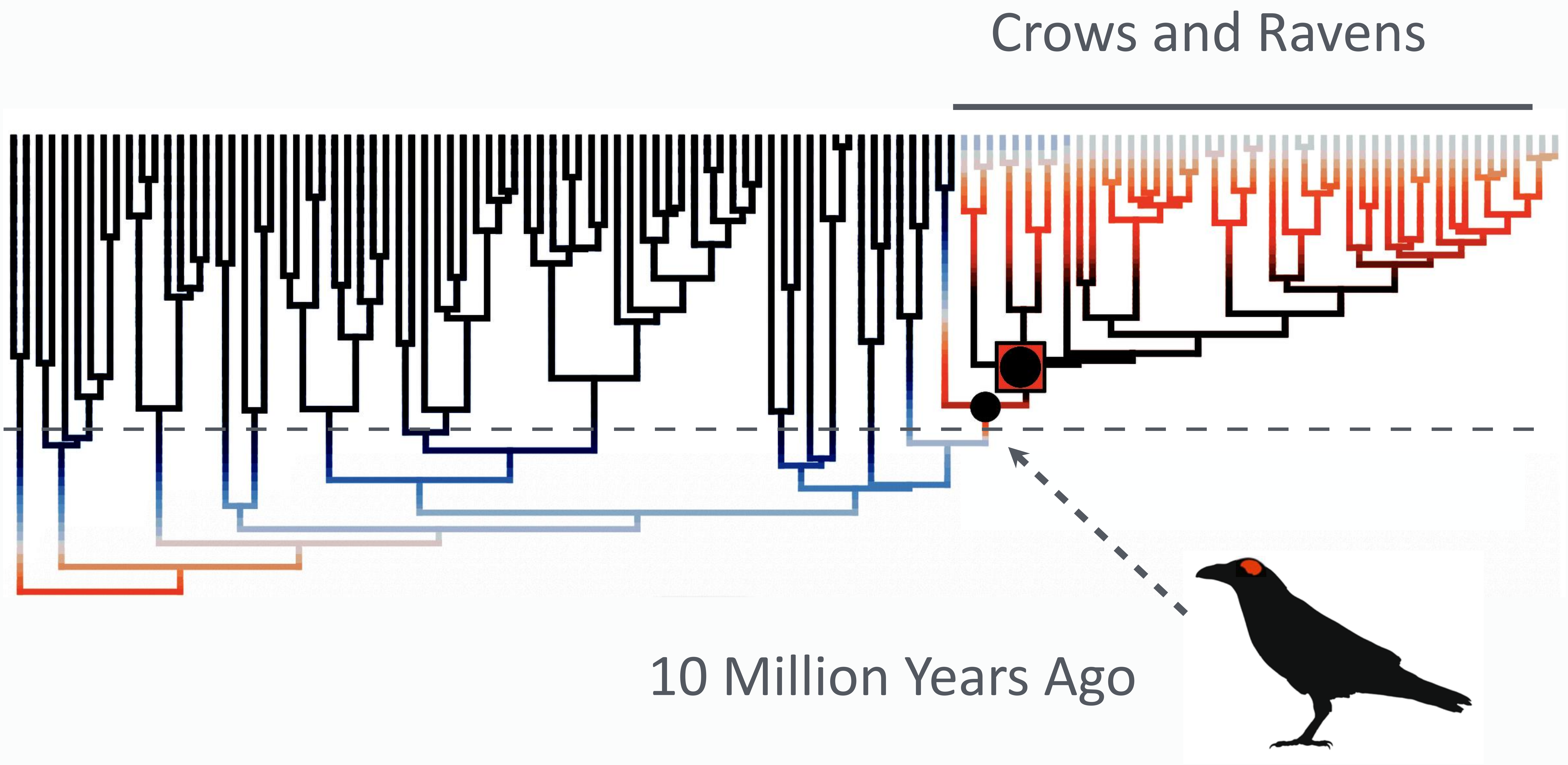
- BIG
- Long wings
- Huge brains

Ancestral crow

… but ancestral crows were not typical!




Distant but similar habitats
New species evolve
High dispersal abilities
Ecological speciation
Adaptability
New forms and ecologies evolve
New habitats


Crows and Ravens
10 Million Years Ago

No

Are big brains required to deal with variability?

Do they lead to wider ecological niches?

Not necessarily

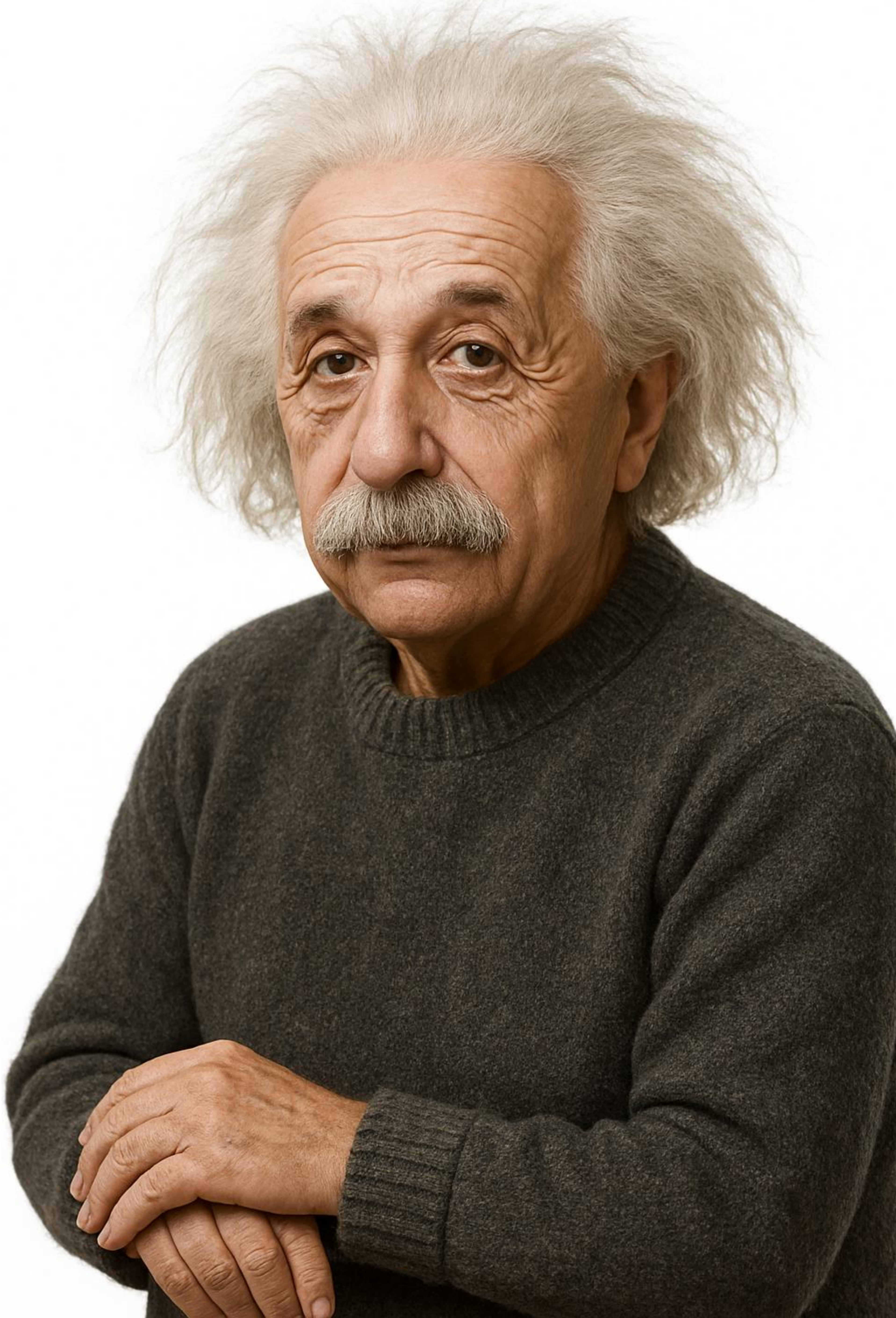
Kind of…

Do they facilitate taking over the world?

Take home messages

- “Intelligence” has profound implications on the ecology and evolution of organisms.

- Intelligence is costly so more is not always better!



The Botero Lab

https://boterolab.weebly.com

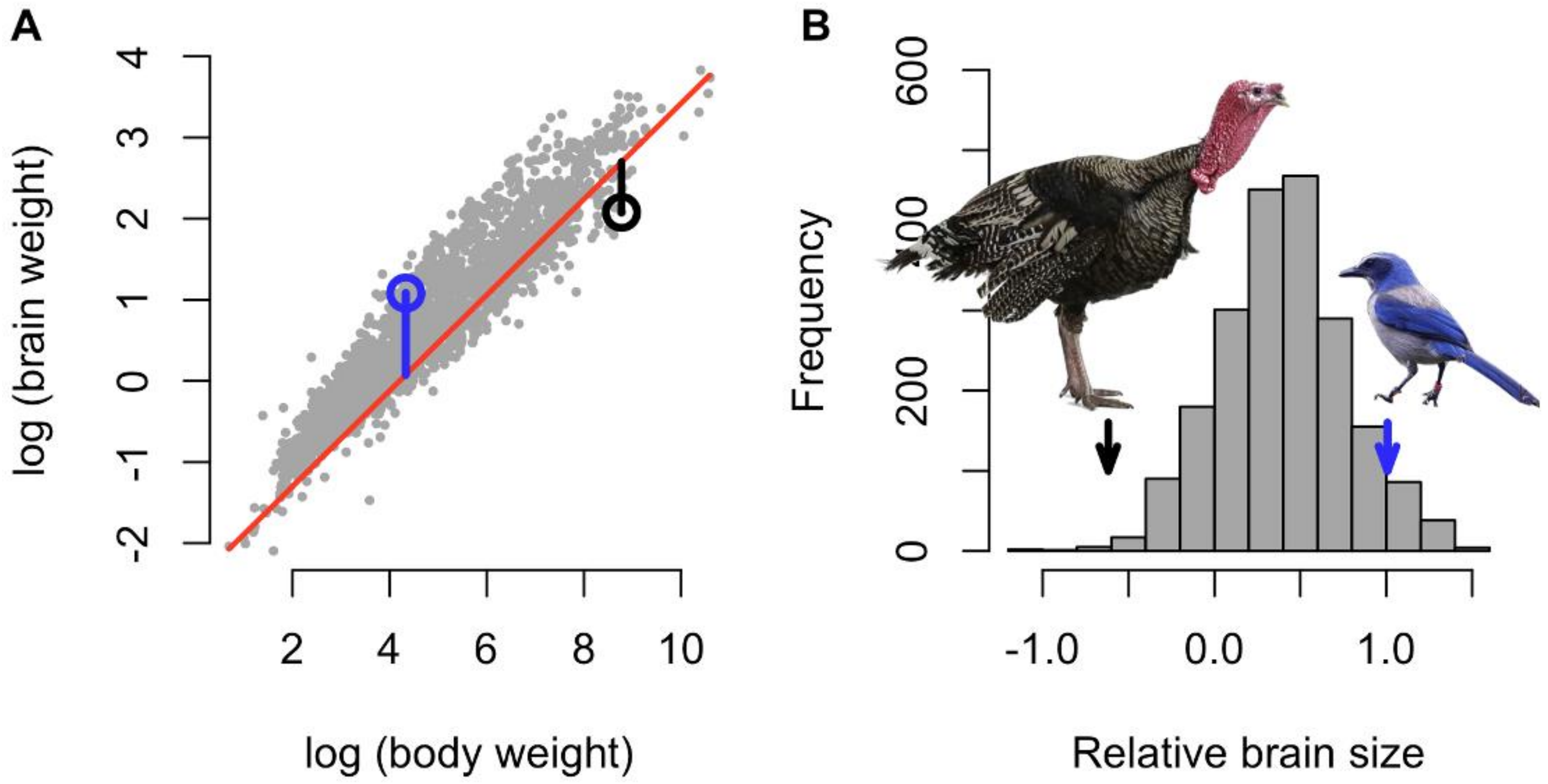
Collaborators
- Joseph Culver
- Onur Güntürkün
- Young-Gyu Yoon
- Jason Trobaugh
- Mehdi Behroozi

Postdocs
- Fabricio Rodrigues
- Kathryn Chenard
- Joan Garcia-Porta
- Trevor Fristoe

Graduate students
- Justin Baldwin
- Alvin Agato
- Annie Bice
- Seanna Gaines

The University of Texas at Austin
Washington University in St. Louis
Ruhr Universität Bochum RUB
KAIST 1971
HFSP International Human Frontier Science Program Organization
NSF

Absolute v. relative brain size



More volume
than surface

More surface
than volume

ECOLOGY LETTERS

Ecology Letters, (2020) 23: 316–325 doi: 10.1111/ele.13434

LETTER

Shared morphological consequences of global warming in North American migratory birds

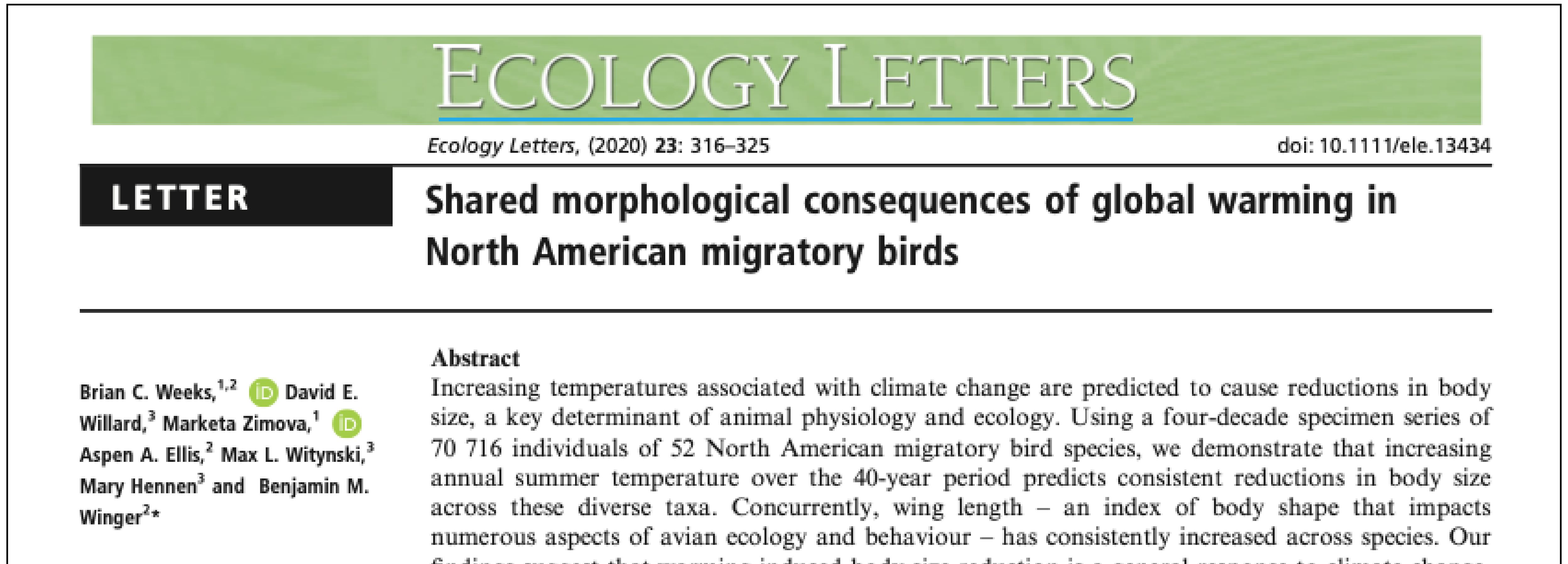
Brian C. Weeks,[1,2] David E. Willard,[3] Marketa Zimova,[1] Aspen A. Ellis,[2] Max L. Witynski,[3] Mary Hennen[3] and Benjamin M. Winger[2]*

Abstract

Increasing temperatures associated with climate change are predicted to cause reductions in body size, a key determinant of animal physiology and ecology. Using a four-decade specimen series of 70 716 individuals of 52 North American migratory bird species, we demonstrate that increasing annual summer temperature over the 40-year period predicts consistent reductions in body size across these diverse taxa. Concurrently, wing length – an index of body shape that impacts numerous aspects of avian ecology and behaviour – has consistently increased across species. Our

More volume
than surface

More surface
than volume


ECOLOGY LETTERS

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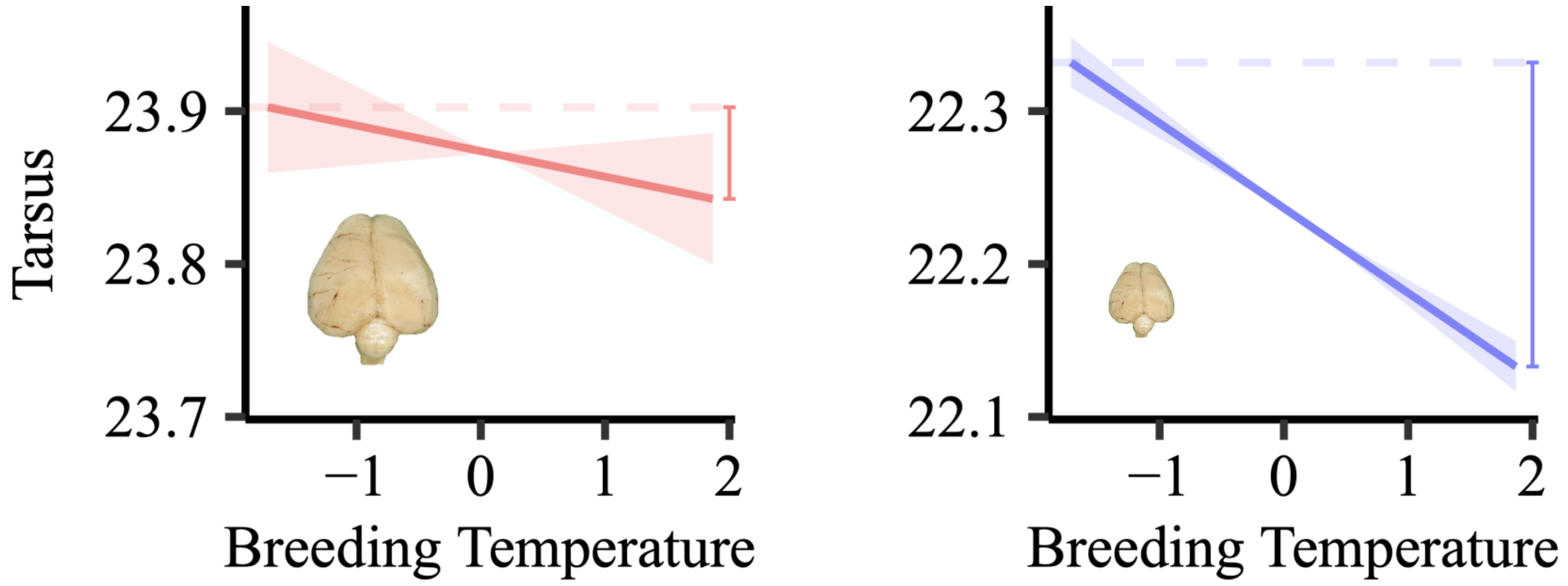
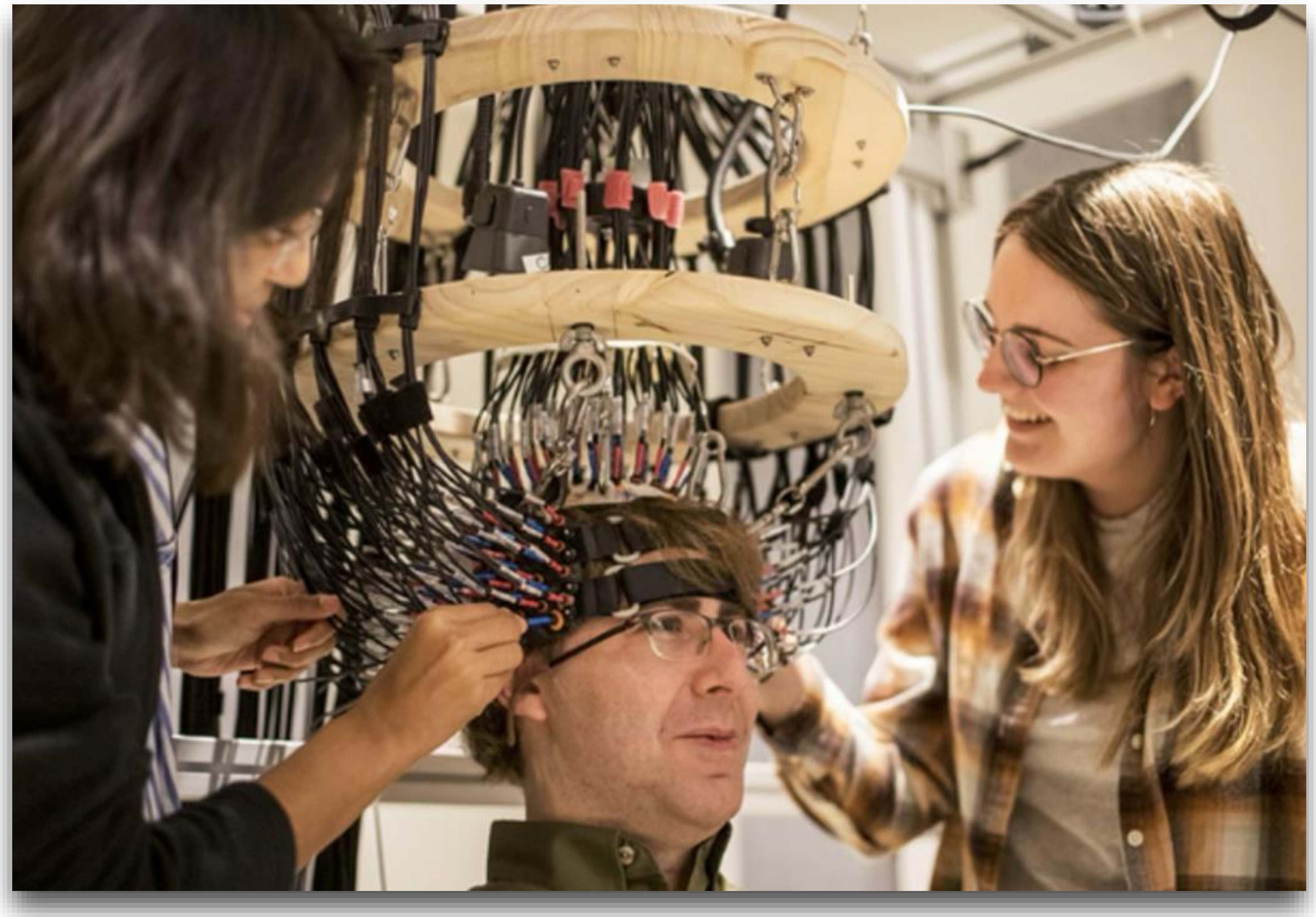
Justin Baldwin, Ph.D.



Baldwin, Garcia & Botero (2022) *Ecology Letters*

Diffuse Optical Tomography (DOT)



Joseph Culver

Washington University in St.Louis

Onur Güntürkün

RUHR UNIVERSITÄT BOCHUM

RUB

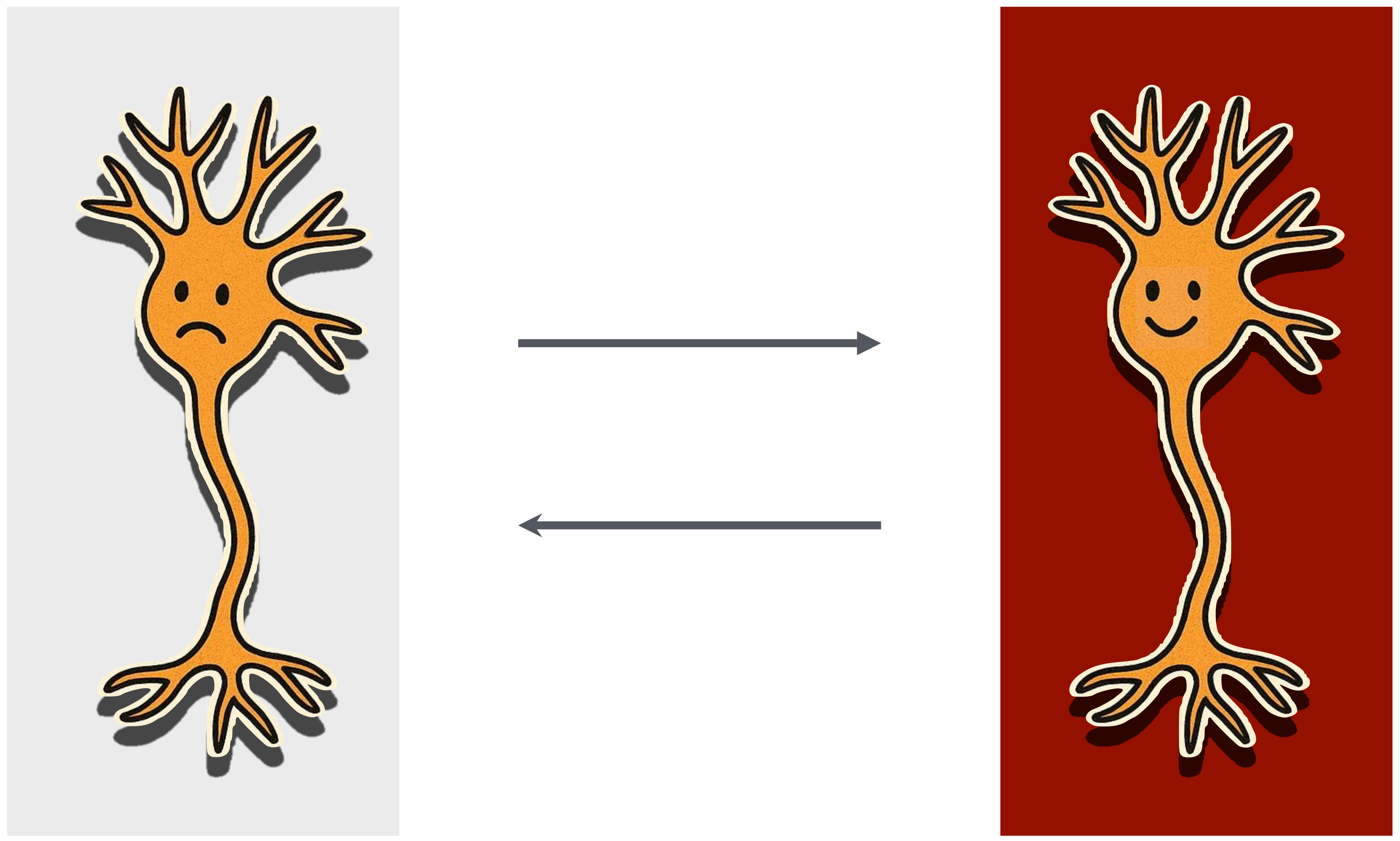
Young-Gyu Yoon

KAIST

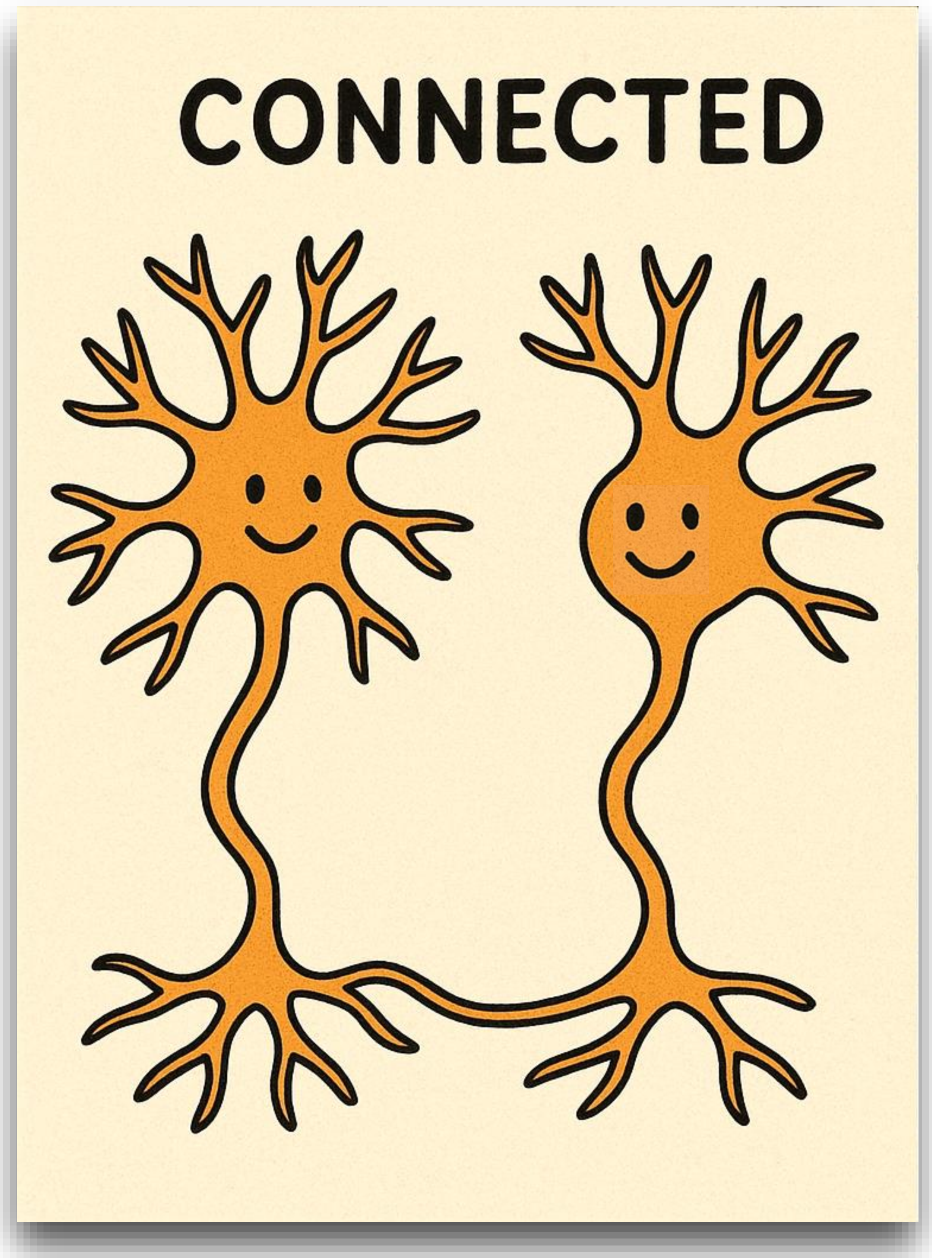
1971

KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY

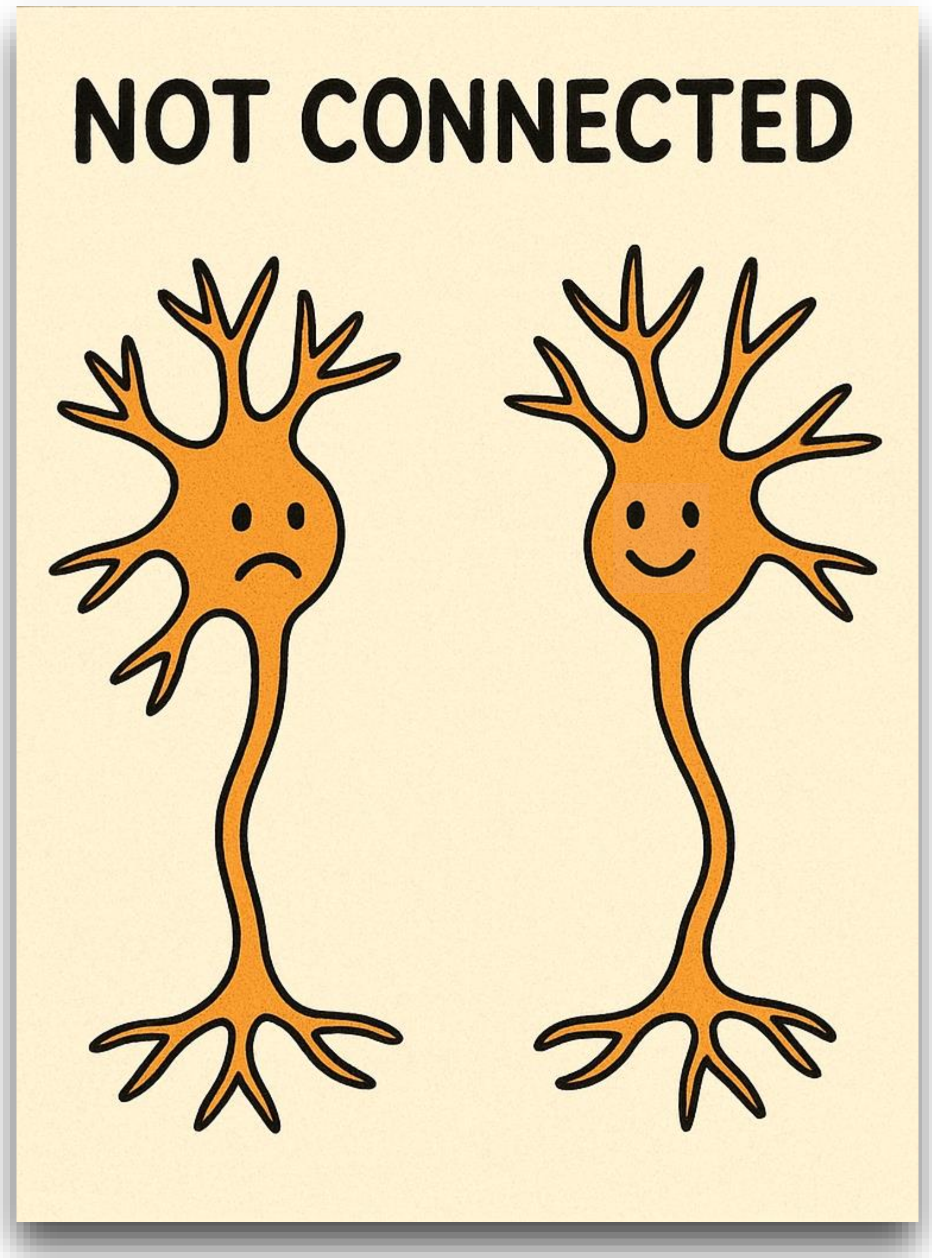
한국과학기술원



Neural activity is coupled with increased blood flow

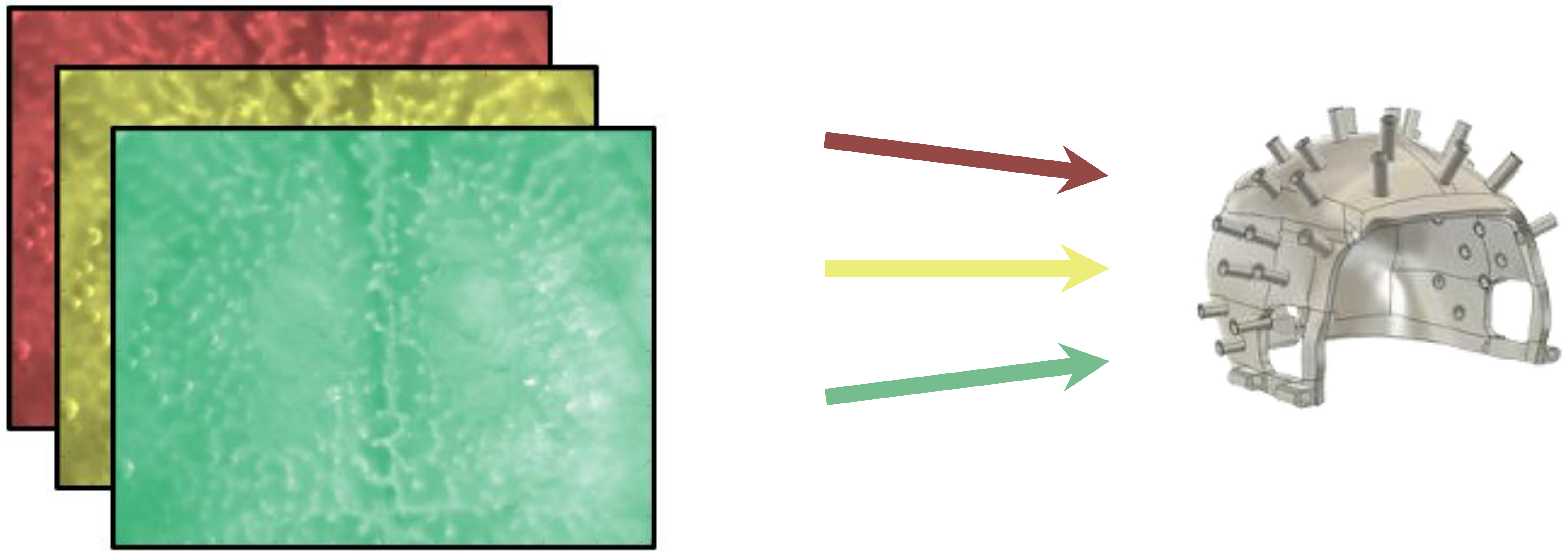


Similar activity patterns

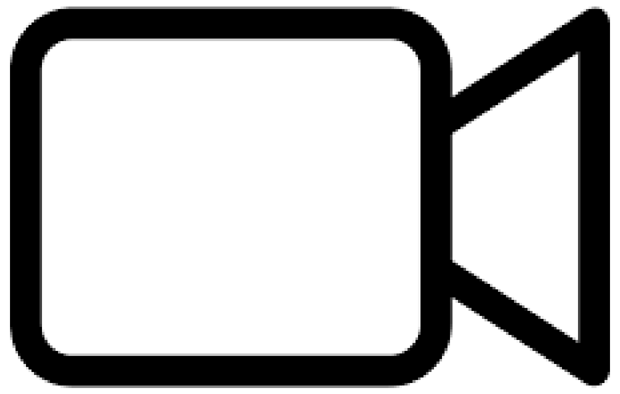


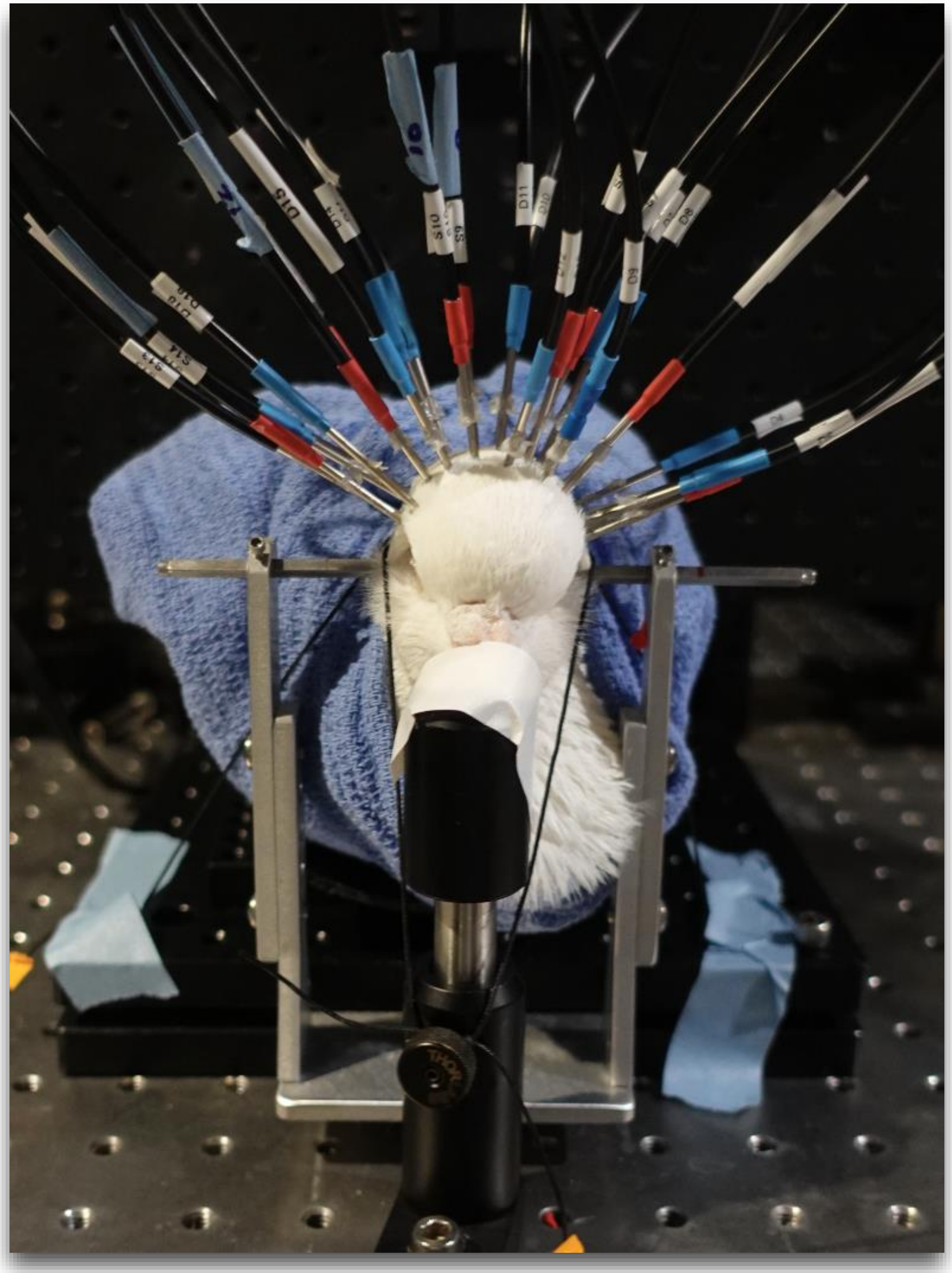
Independent activity patterns

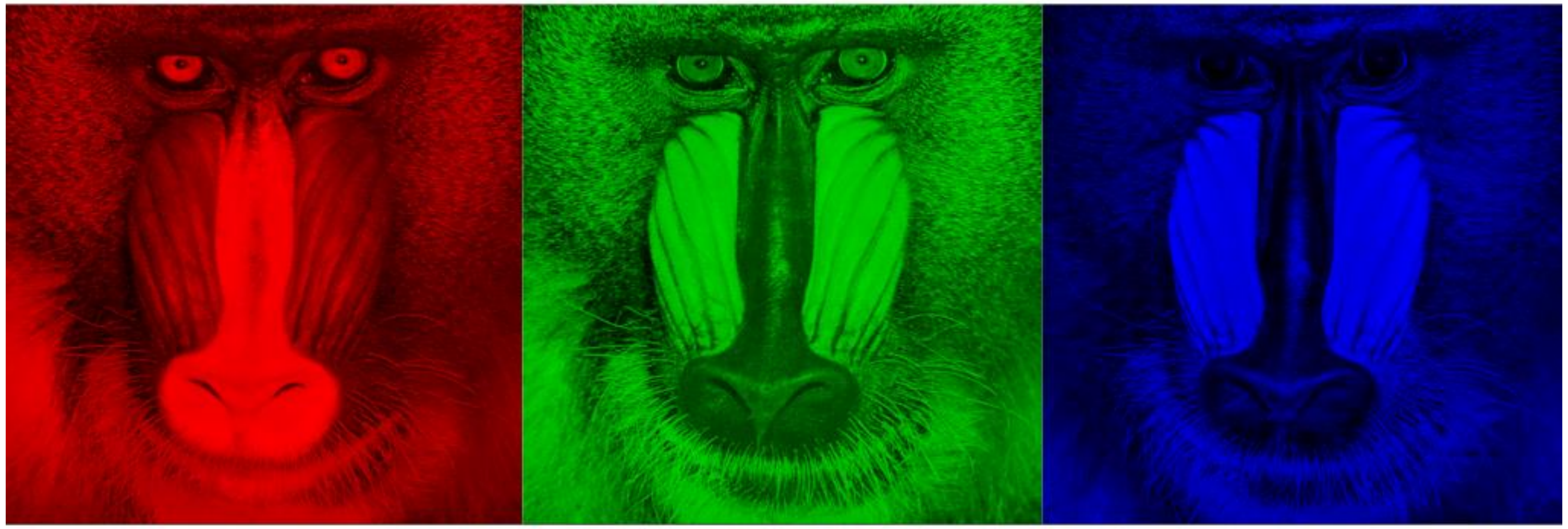
Light sources in red



Light sensors in blue







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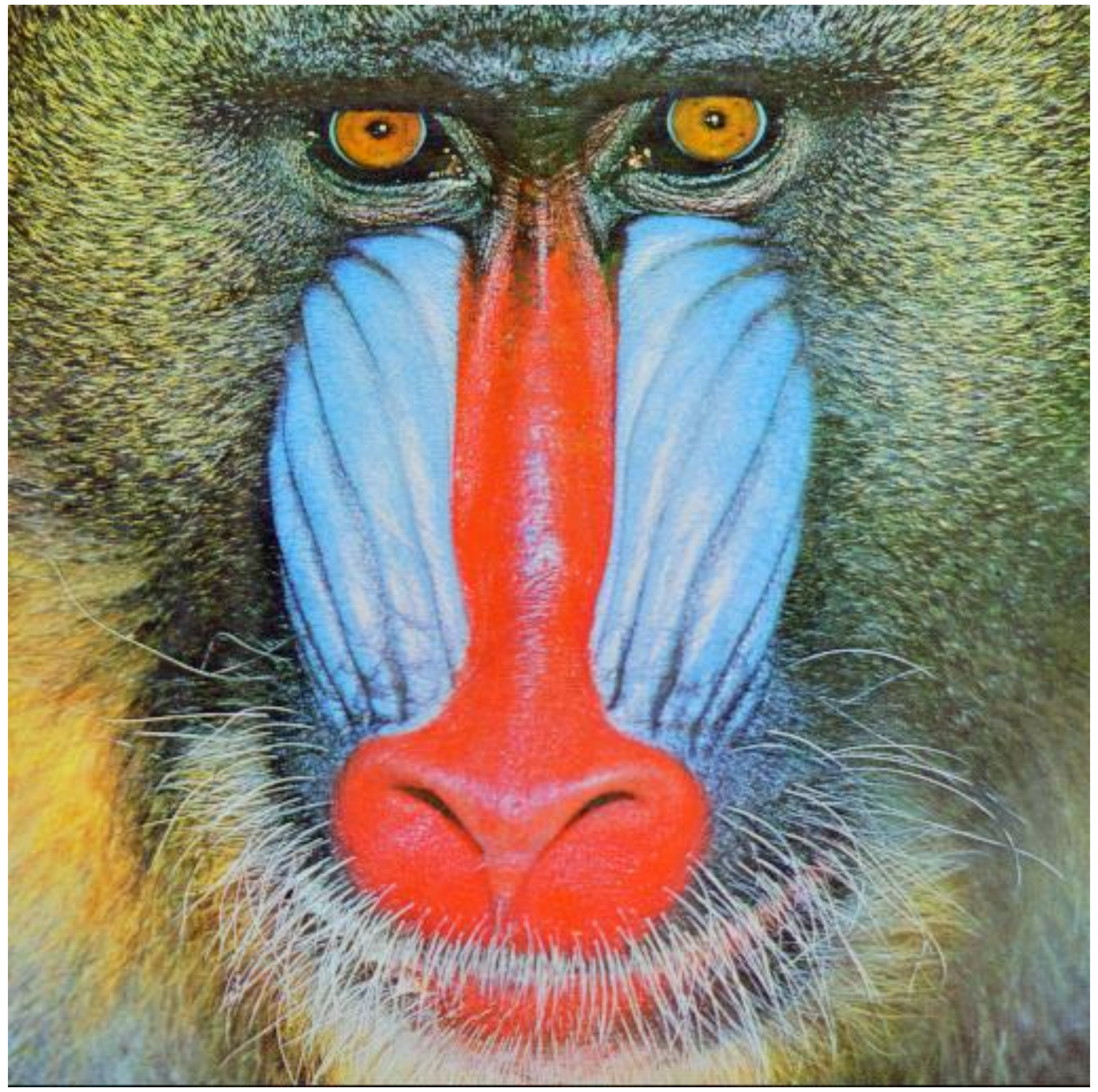
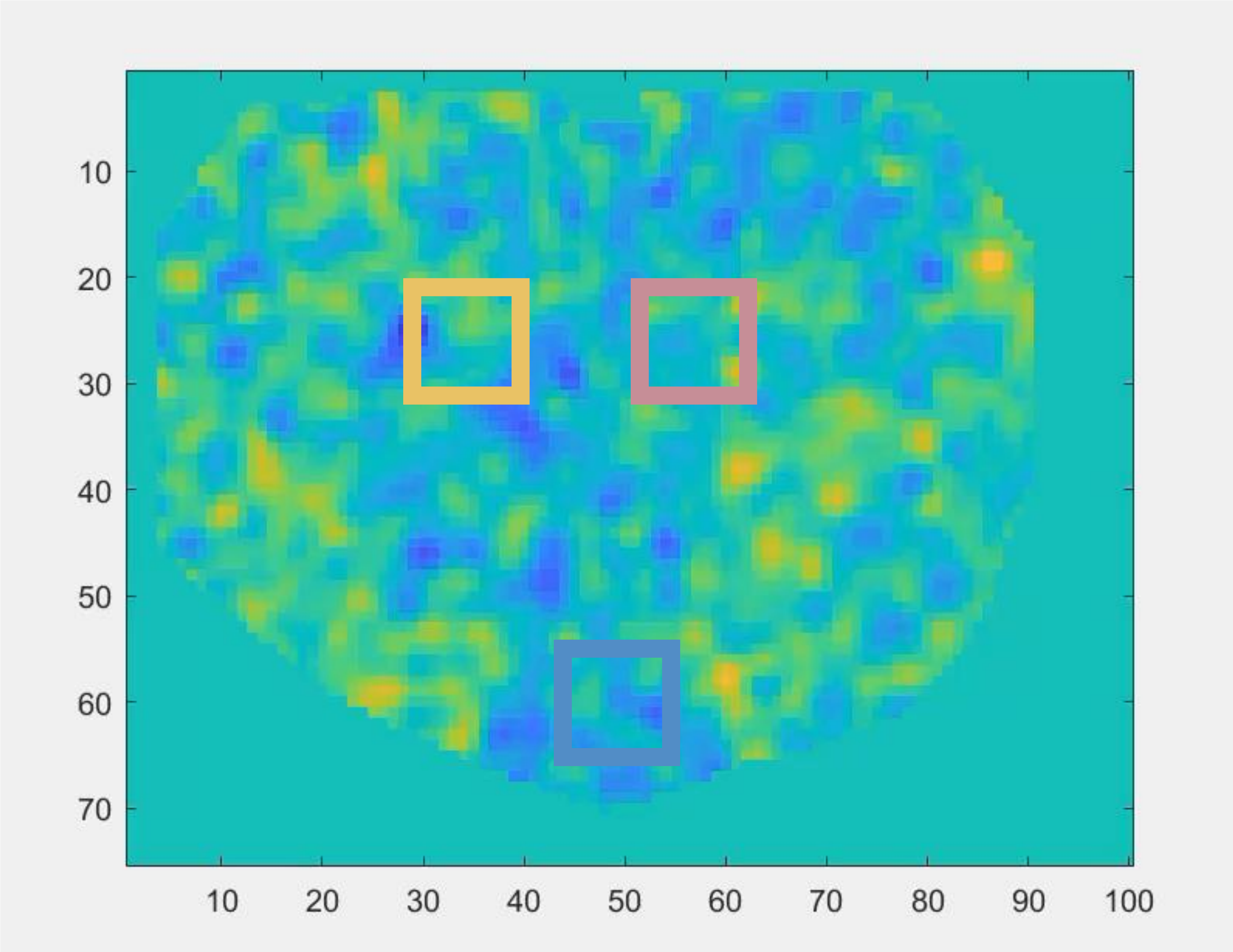
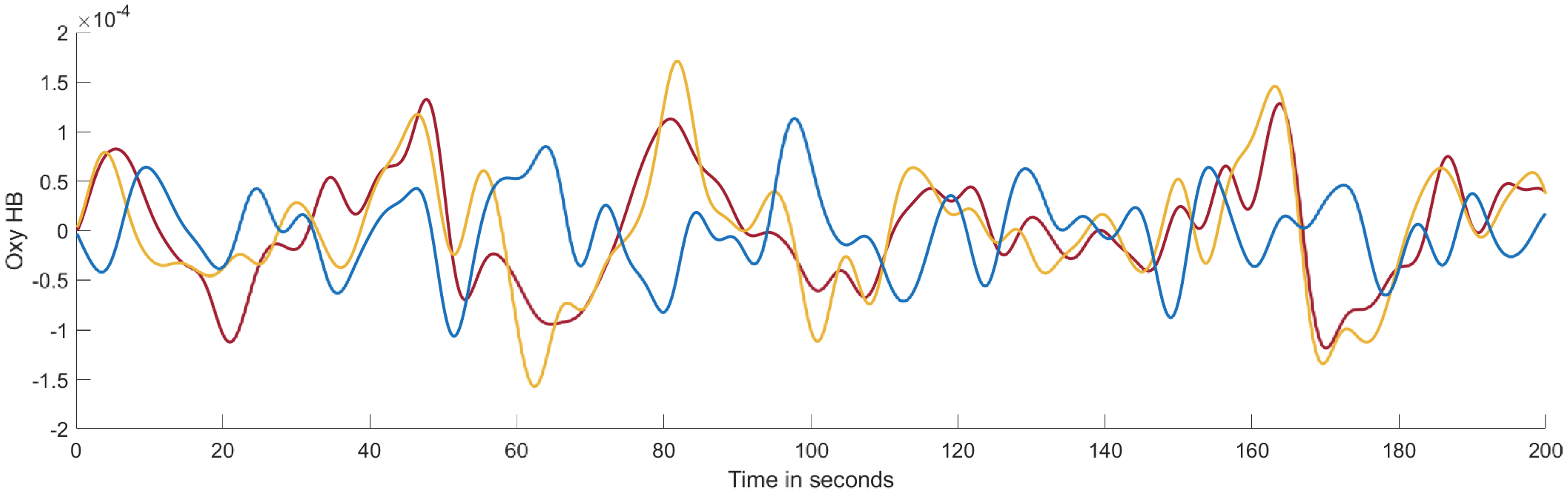
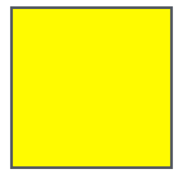


Source: Ryan Walker (R bloggers)

Where is *oxygenated blood* being used in the brain?

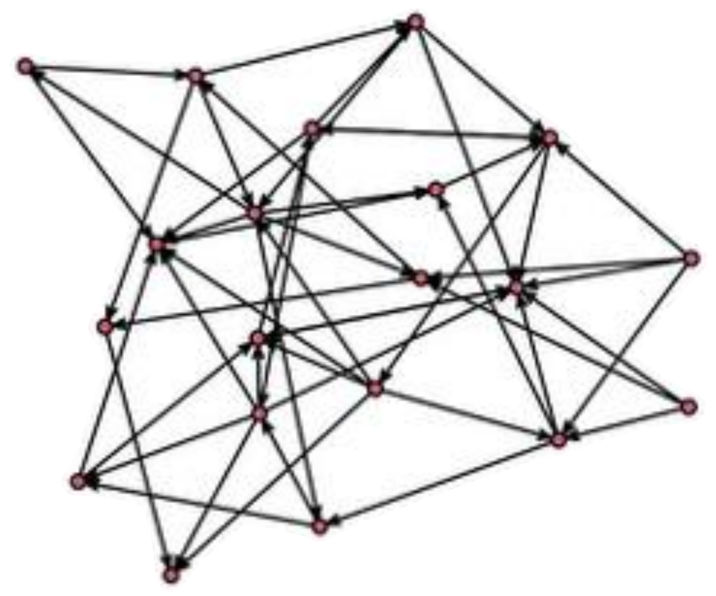




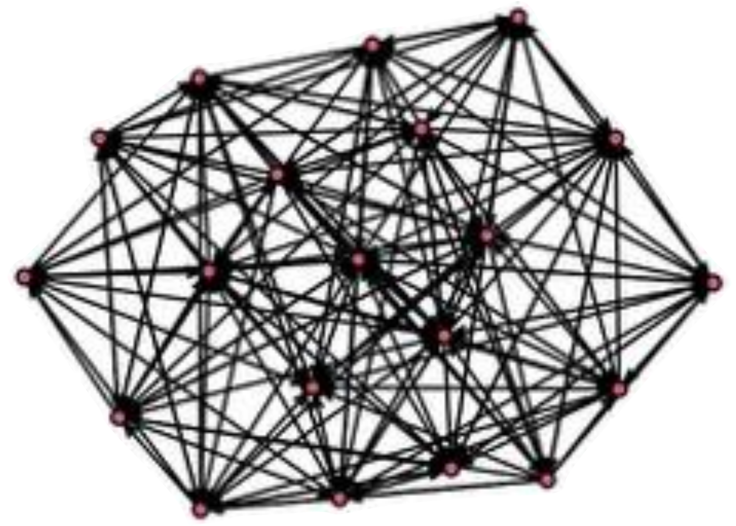


= Oxygenated blood

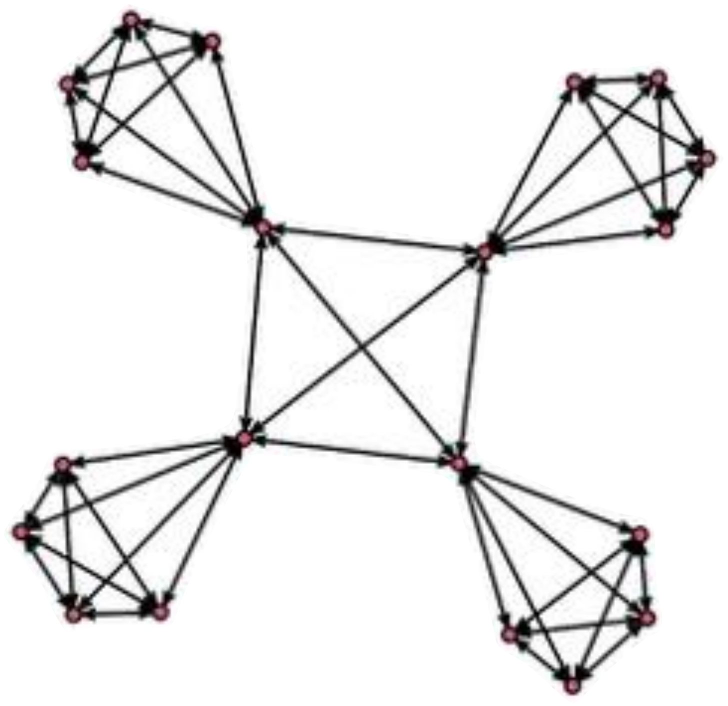
Indiscriminate connections Low redundancy



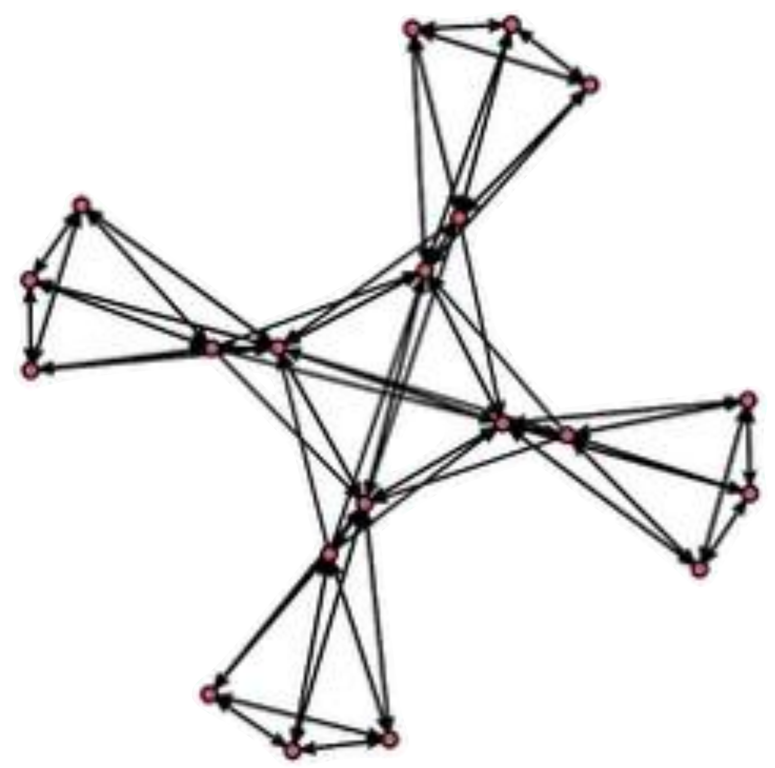
Indiscriminate connections High redundancy



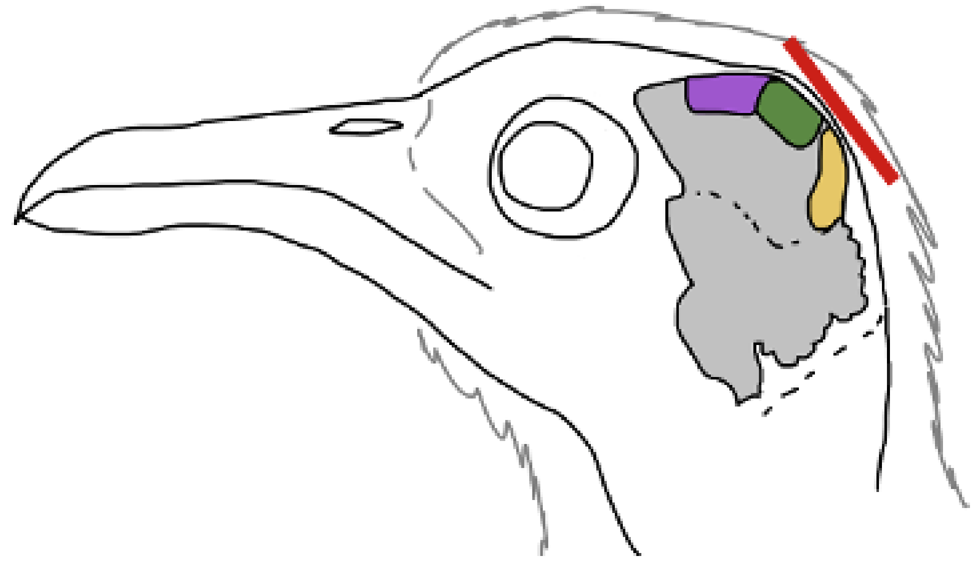
Optimized connectivity Low redundancy



Optimized connectivity High redundancy

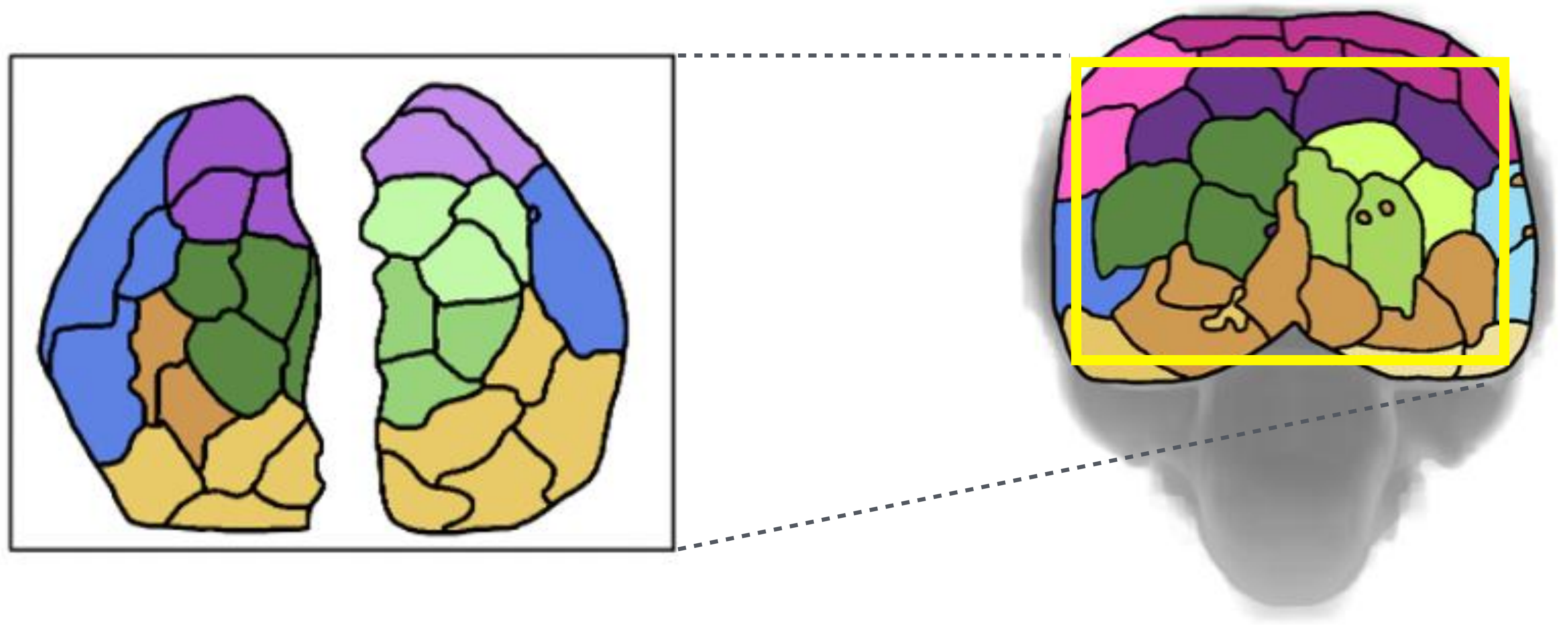


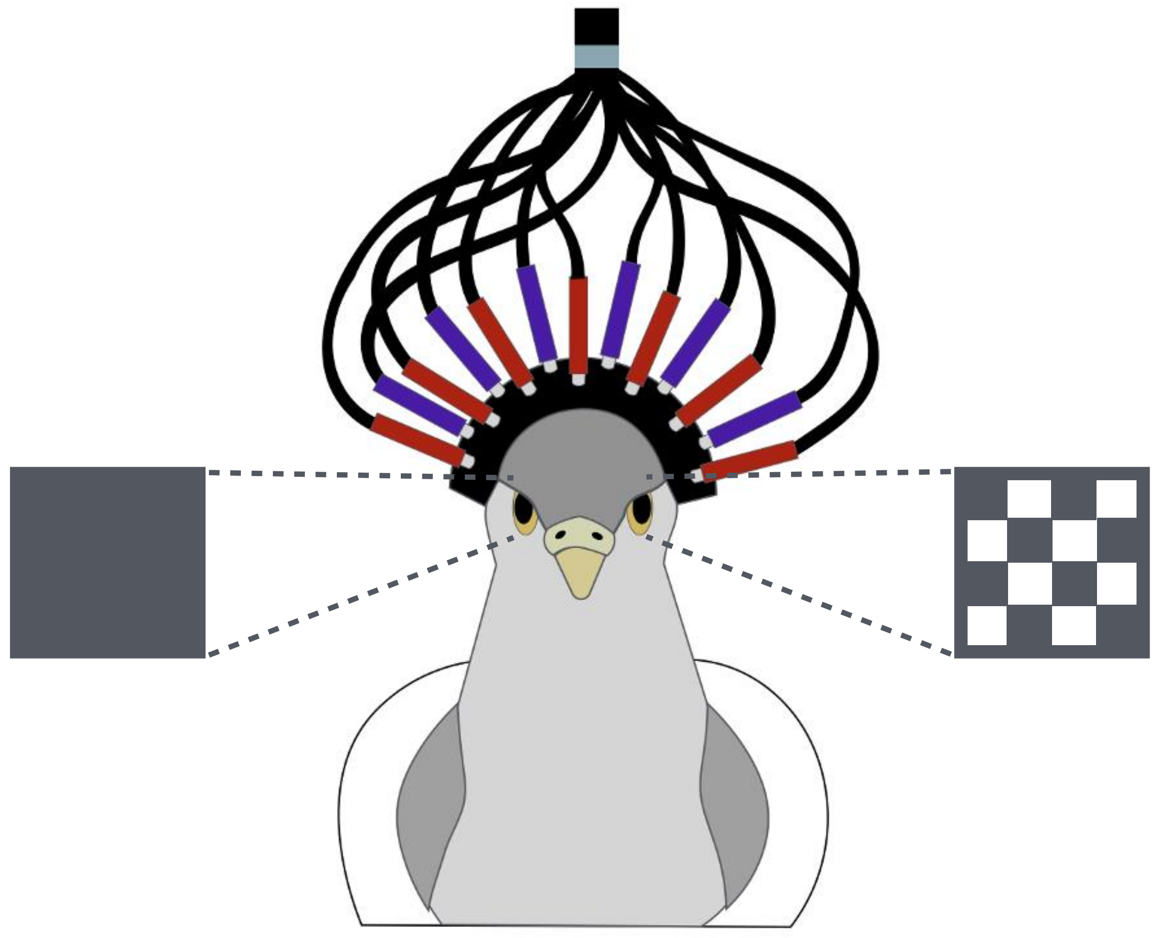
View

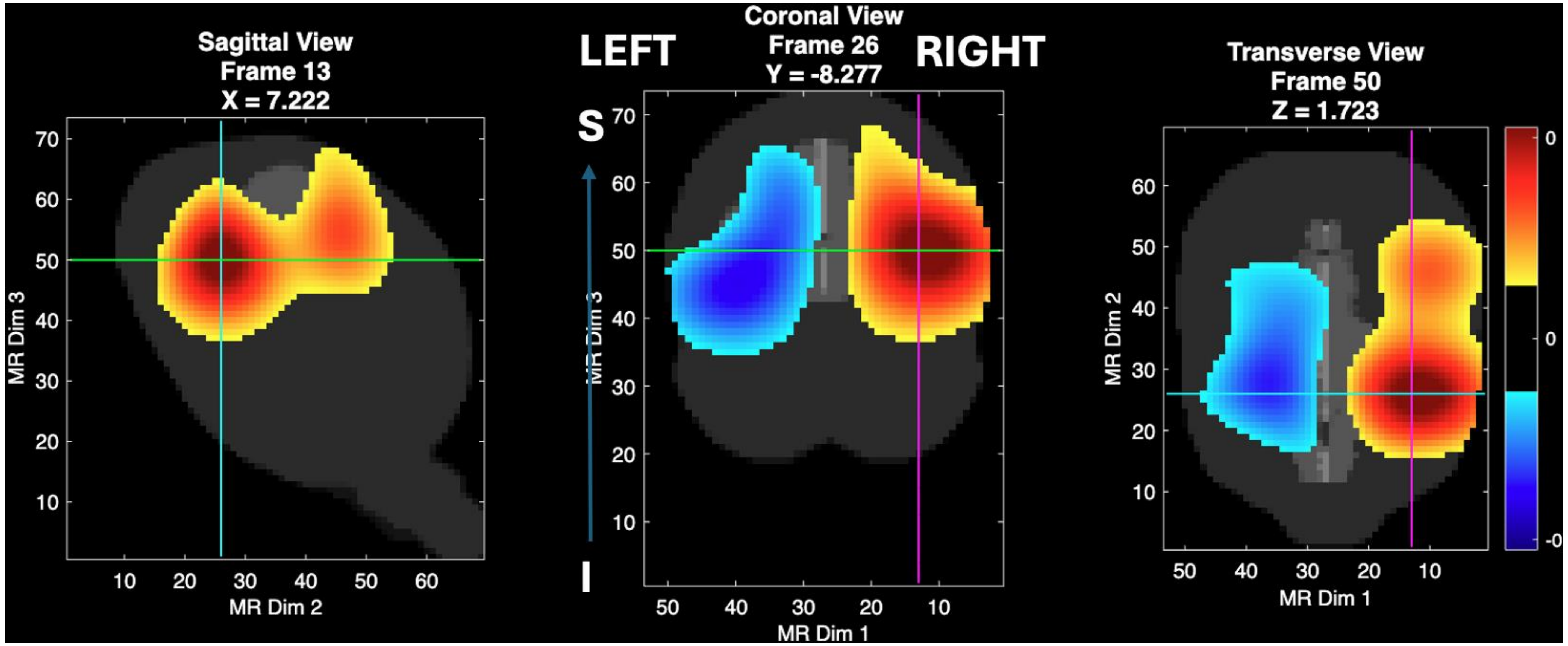


Optical

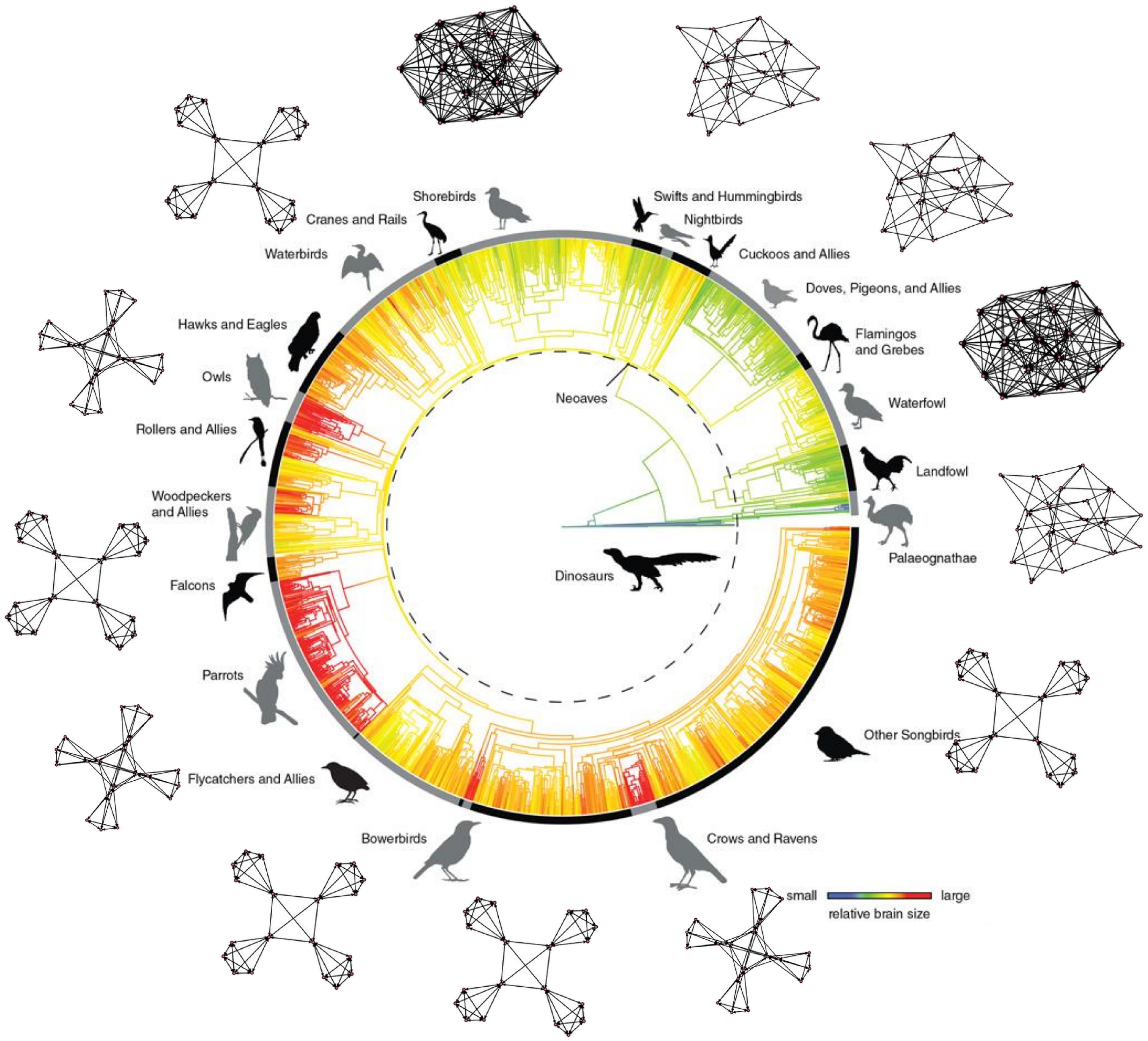
fMRI







The ecology and evolution of brain connectivity



Coming soon!

"I think, therefore I am"

... better?