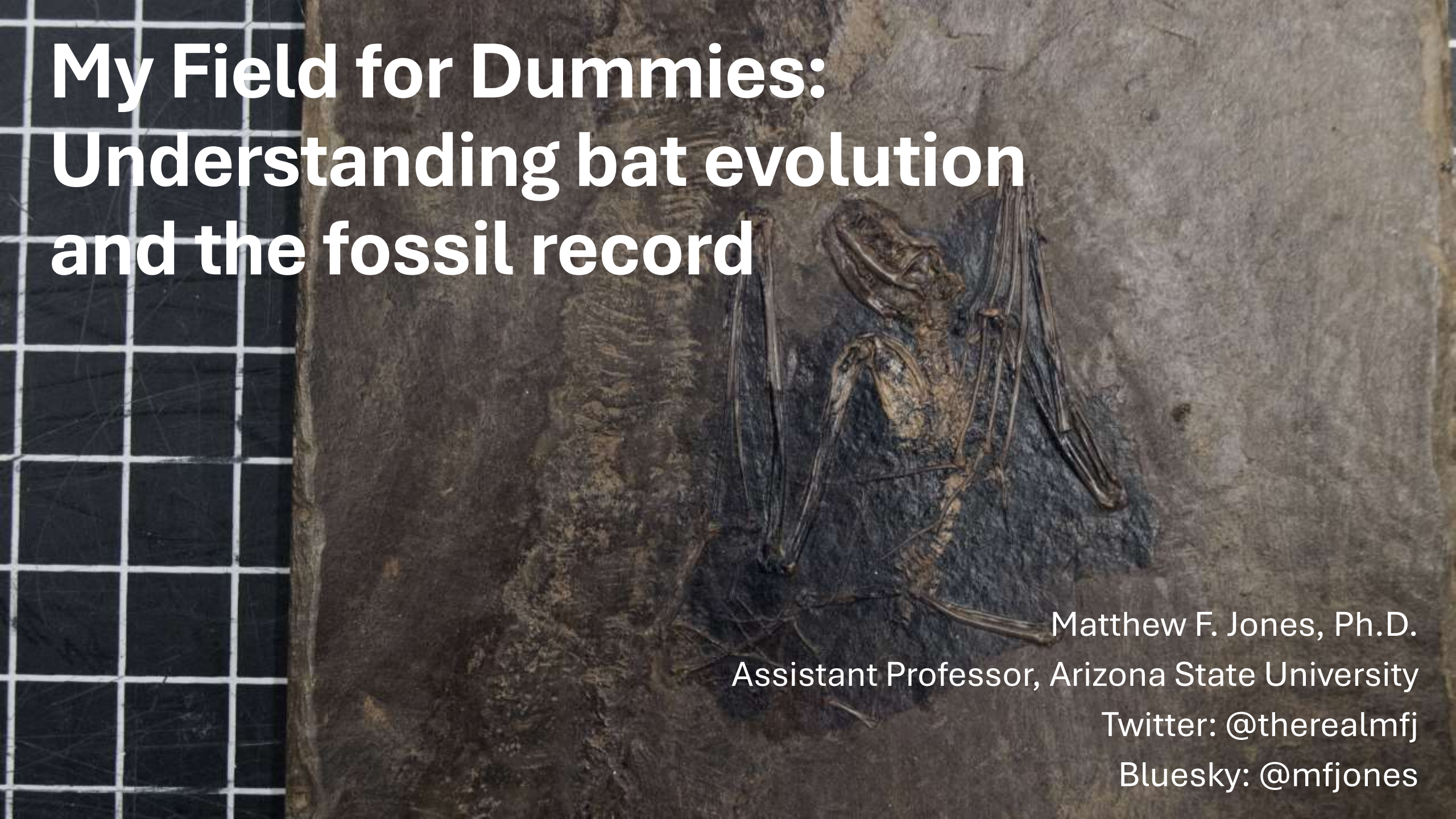
My Field for Dummies: Understanding bat evolution and the fossil record



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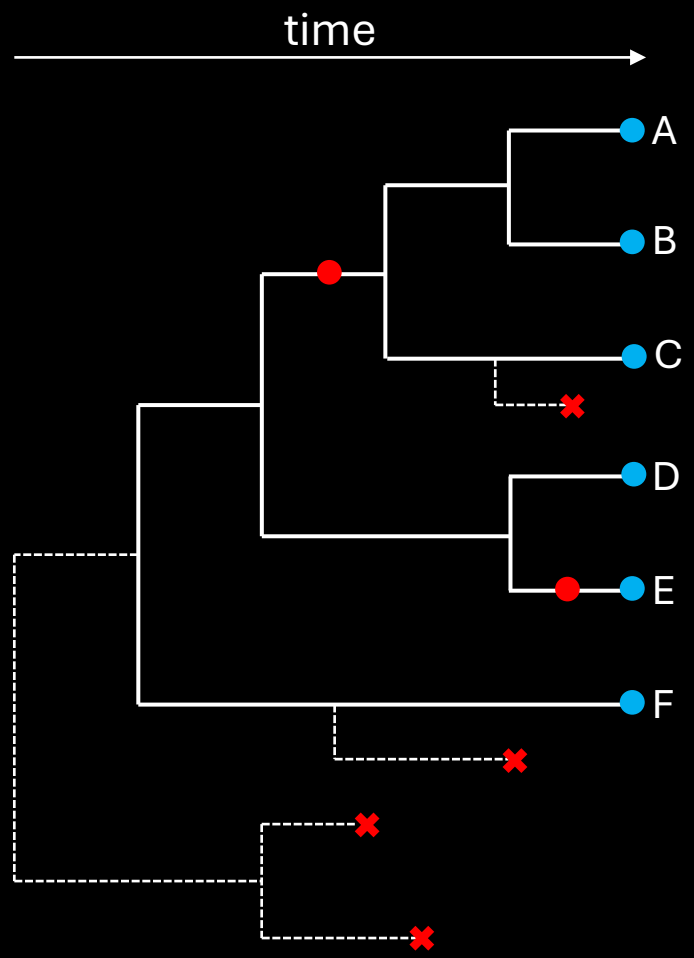
Bluesky: @mfjones

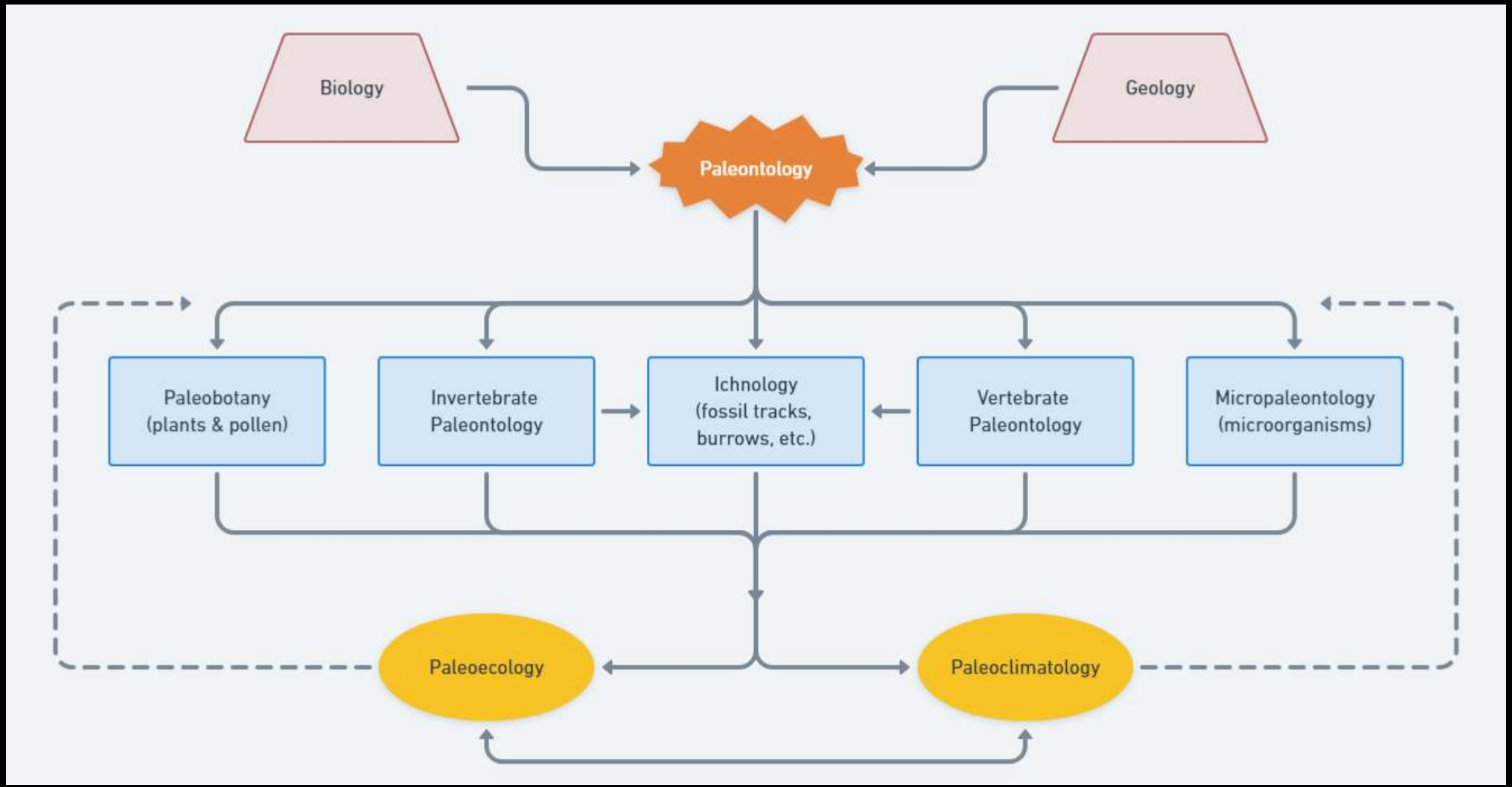
Outline

- Why study paleontology?
- The bat fossil record
- Early bat evolution
- Bat origins

Why study paleontology?

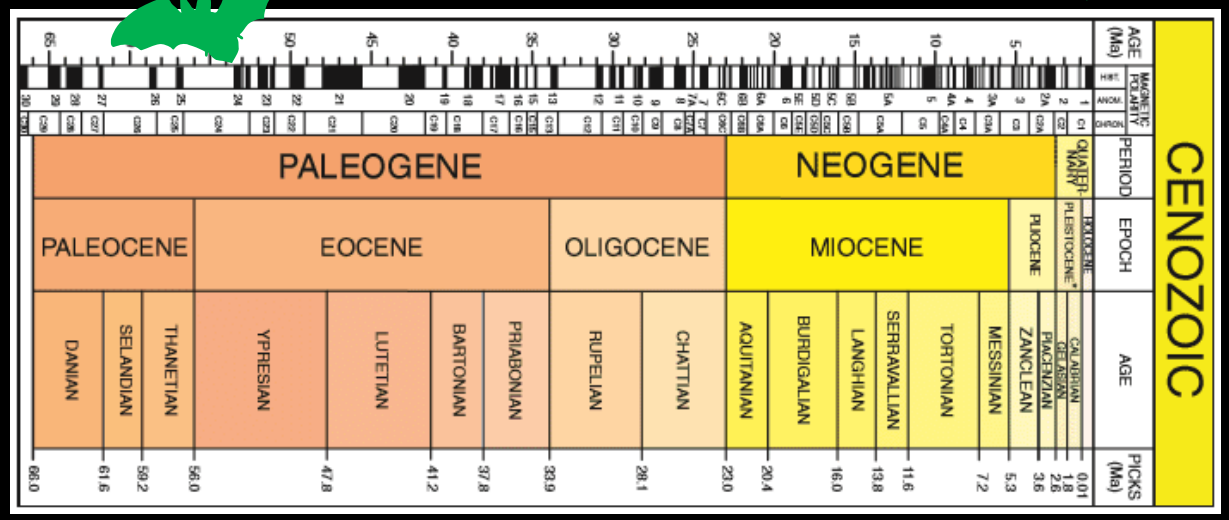


Why study paleontology?



Early Cenozoic Period

Paleocene and Eocene epochs chronicle the recovery post K–Pg mass extinction and the establishment of most modern orders of mammals



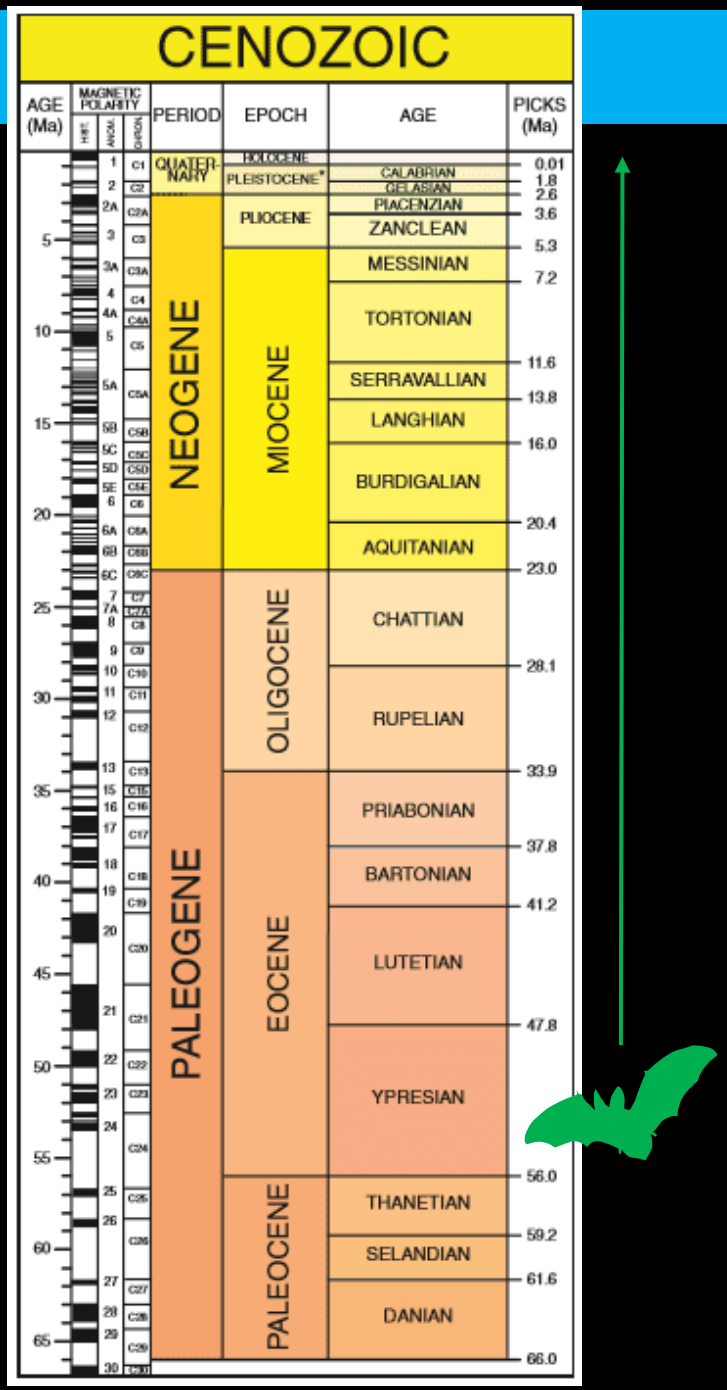


Figure credit: Geological Society of America

Paleontology field methods

Quarrying

- Useful for large fossils and/or locations where fossils are exceptionally abundant

Paleontology field methods

Surface prospecting

- Recovers small to large fossils exposed on surface
- Useful for identifying locations to quarry or screen-wash

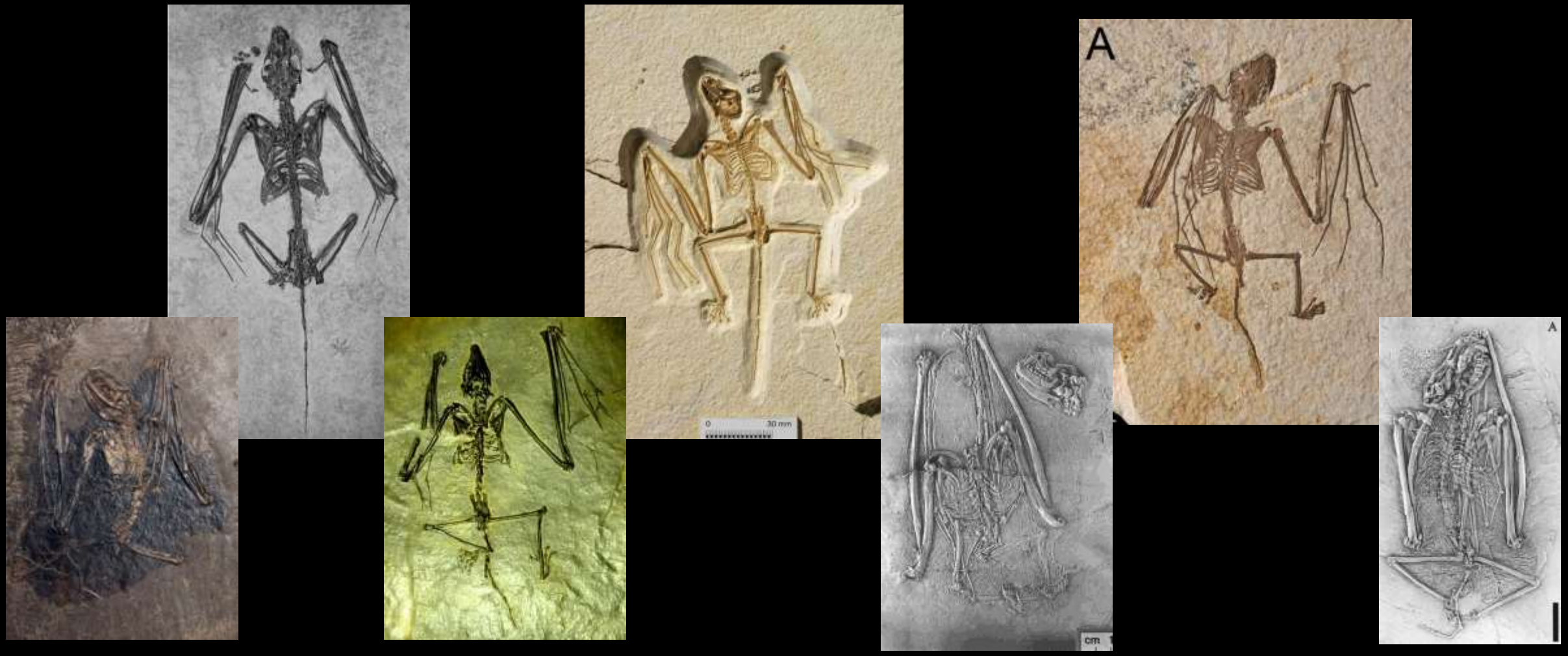
Paleontology field methods

Screen-washing

- Recovers small to tiny fossils
- Residue is sorted through under a microscope in the lab

The bat fossil record: what do we have?

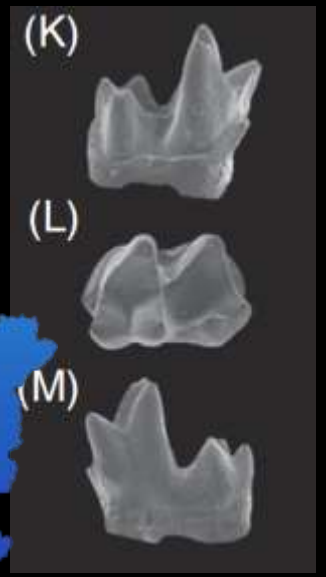
Green River Formation (52 mya) & Messel oil shale (48 mya)

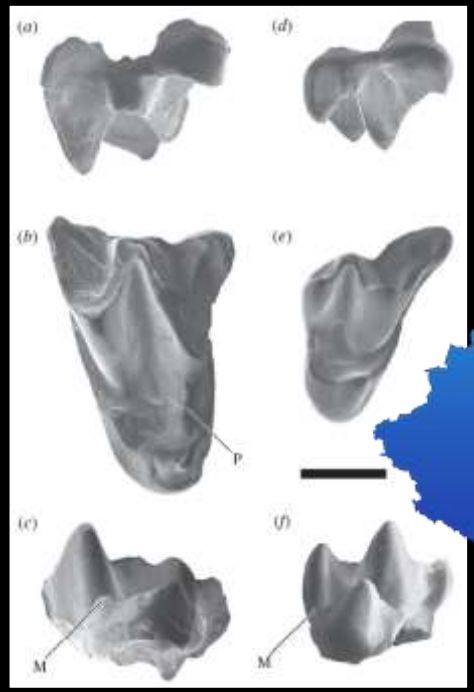


The bat fossil record: what do we have?

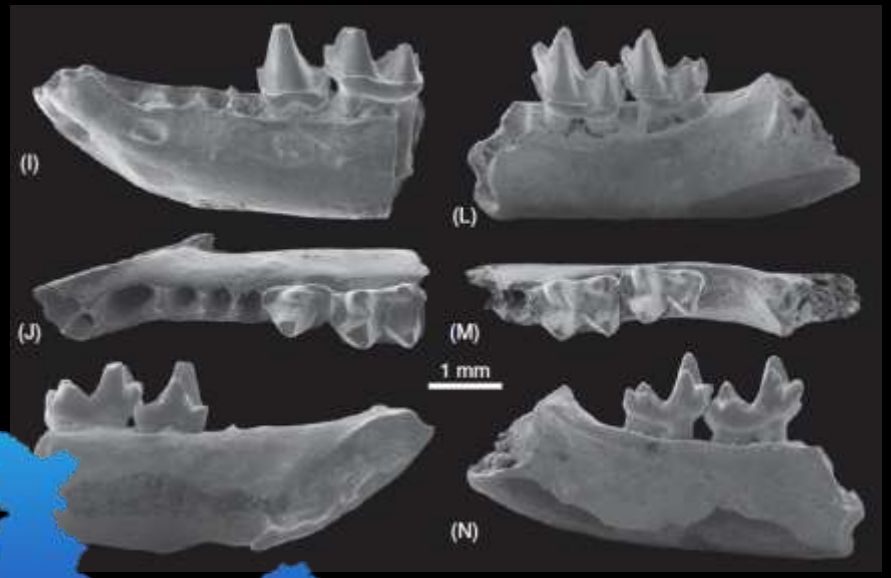
The oldest bats

Archaeonycteris praecursor
Portugal
56–55 mya

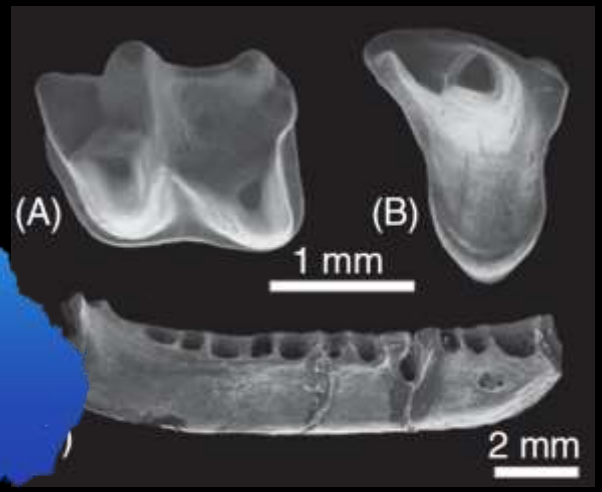




Altaynycteris aurora
China
56–55 mya



Jaegeria cambayensis
(& others)
India
54 mya



Australonycteris clarkae
Australia
54.5 mya

Figure credit: Smith et al. 2012; Jones et al. 2021

Mammal paleontology = mammal teeth

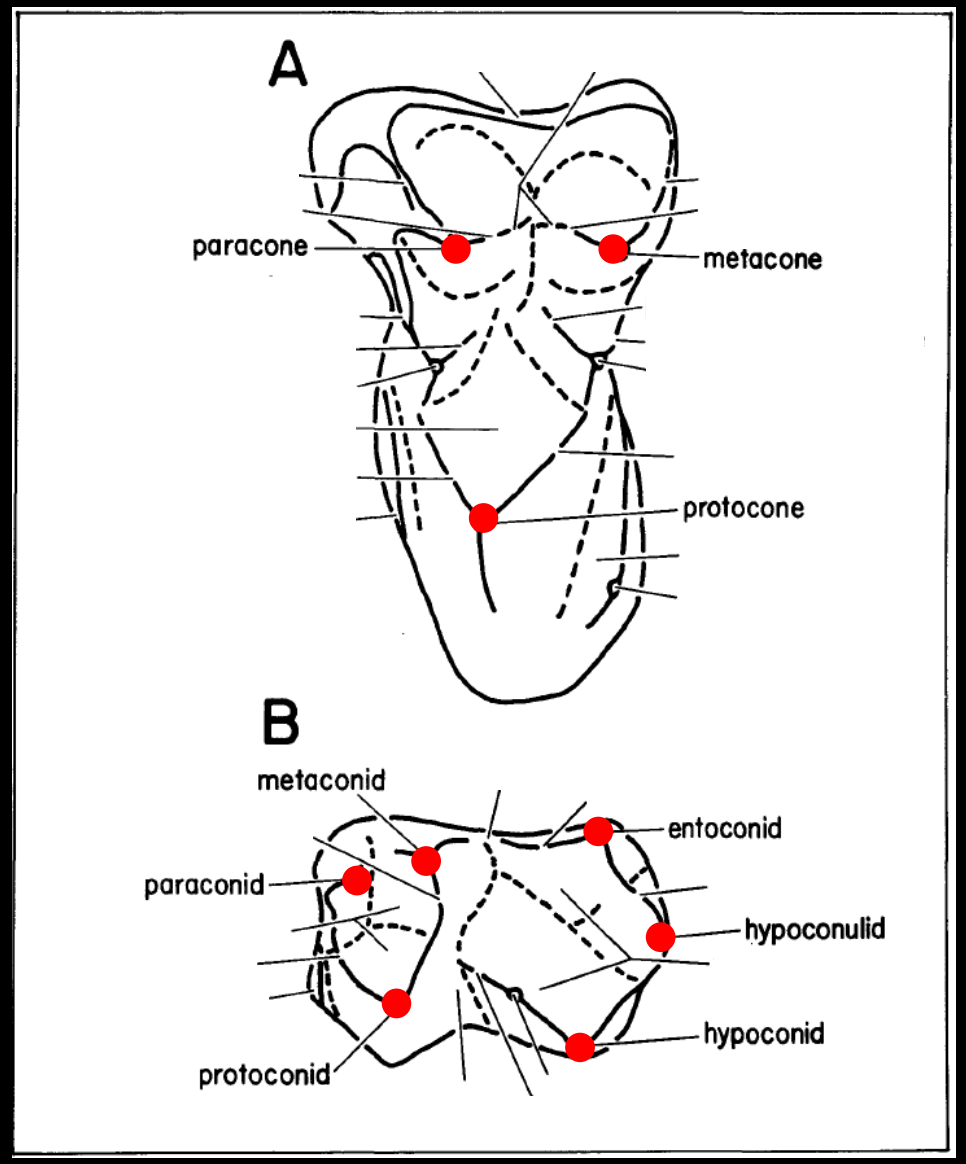
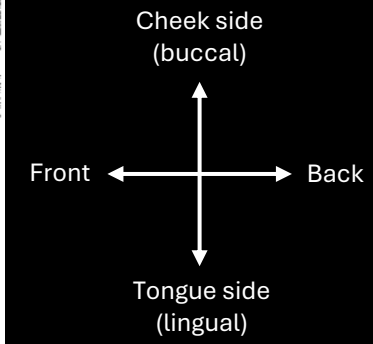
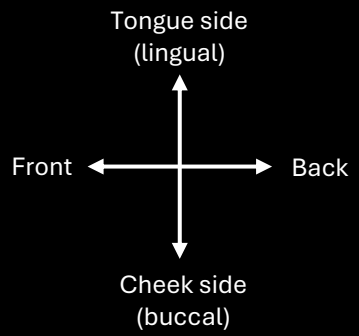


Figure credit: Bown and Kraus 1979

Upper Molar



Lower Molar



Placental mammals

- Tribosphenic molars
- Precise occlusion
- Covered in enamel

Mammal paleontology = mammal teeth

Generalized placental mammal molars

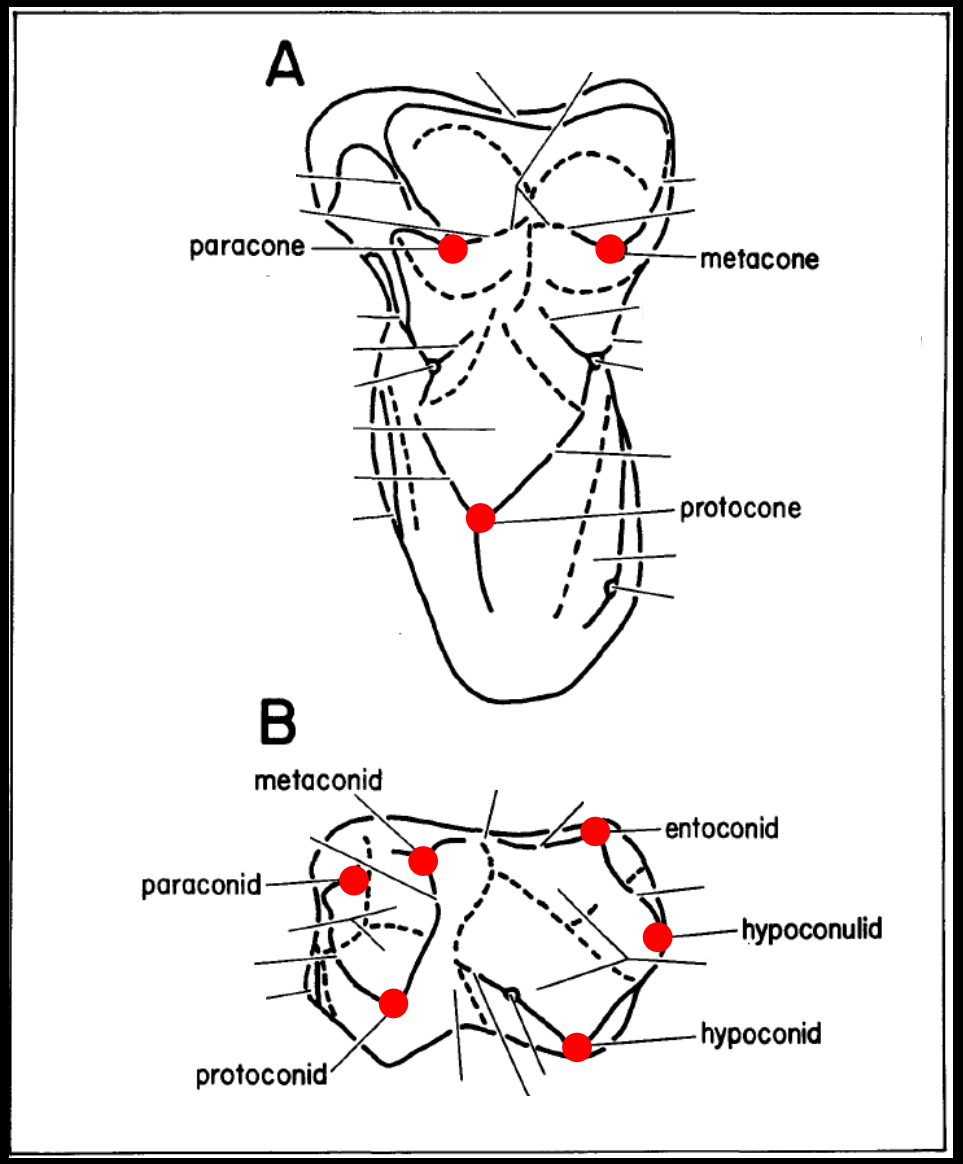
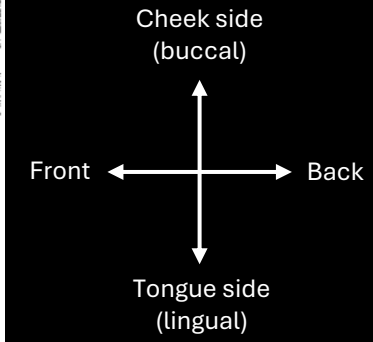
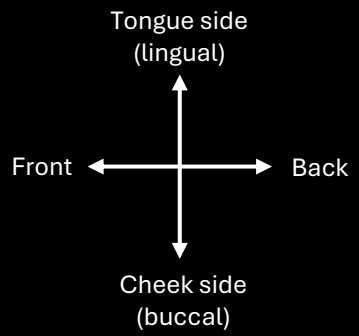


Figure credit: Bown and Kraus 1979; Ravel et al. 2014

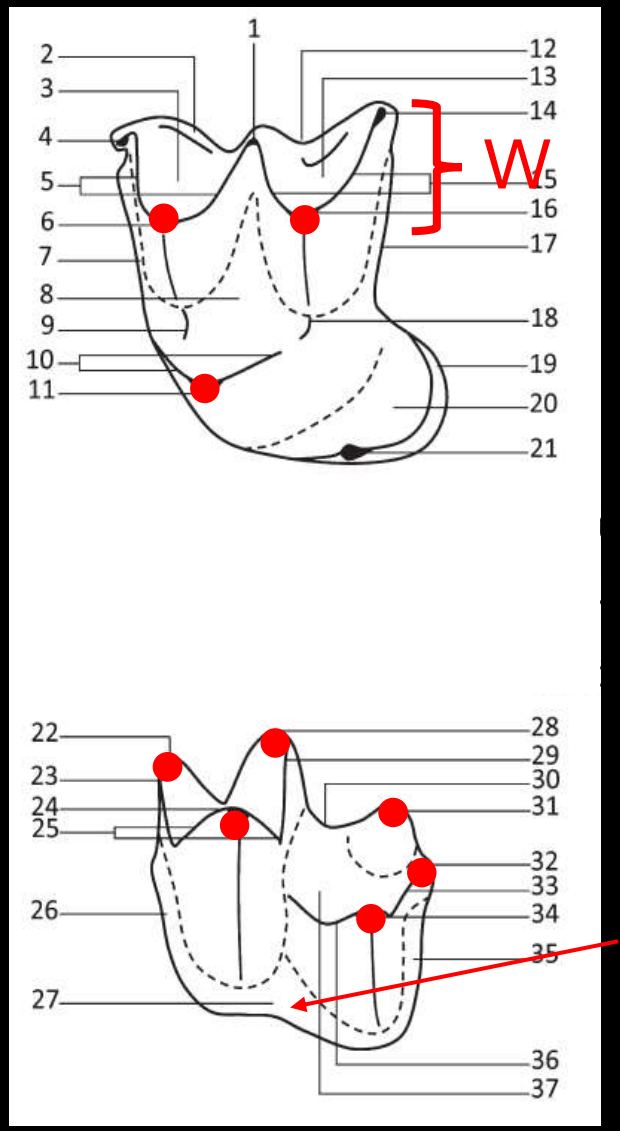
Upper Molar



Lower Molar

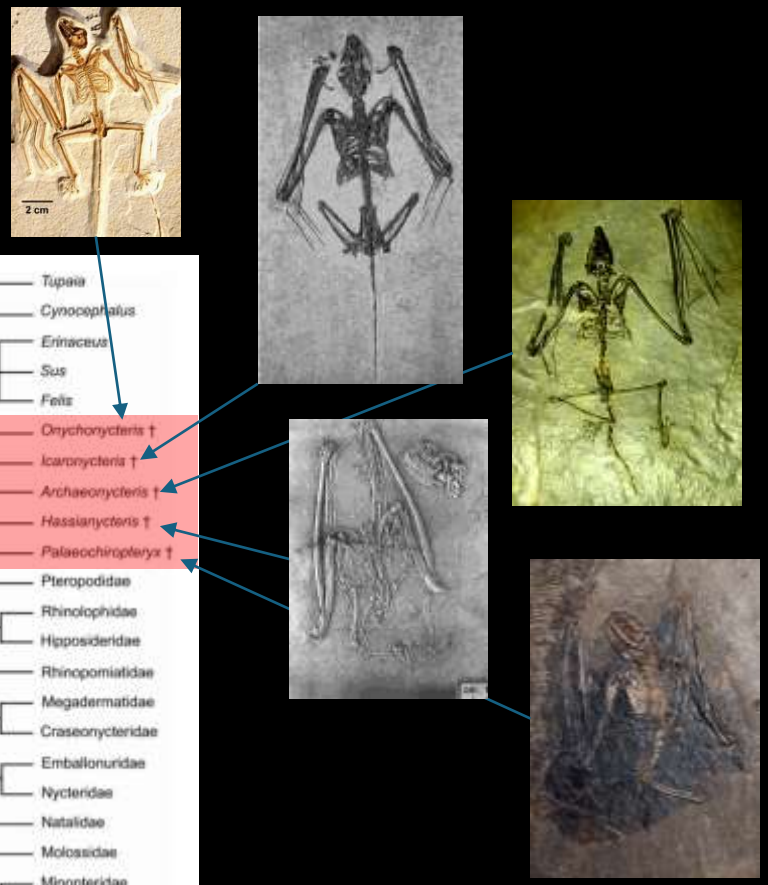


Bat molars



Understanding relationships of fossil bats

Most studies of fossil bat relationships only include species known from complete skeletons



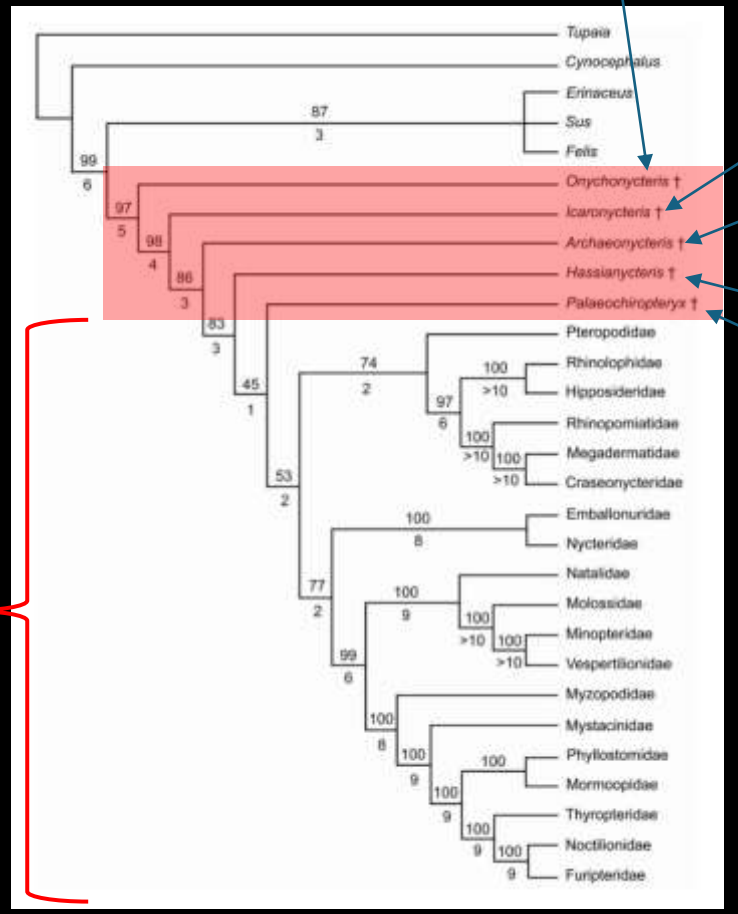


Figure credit: Simmons et al. 2008

Understanding relationships of fossil bats

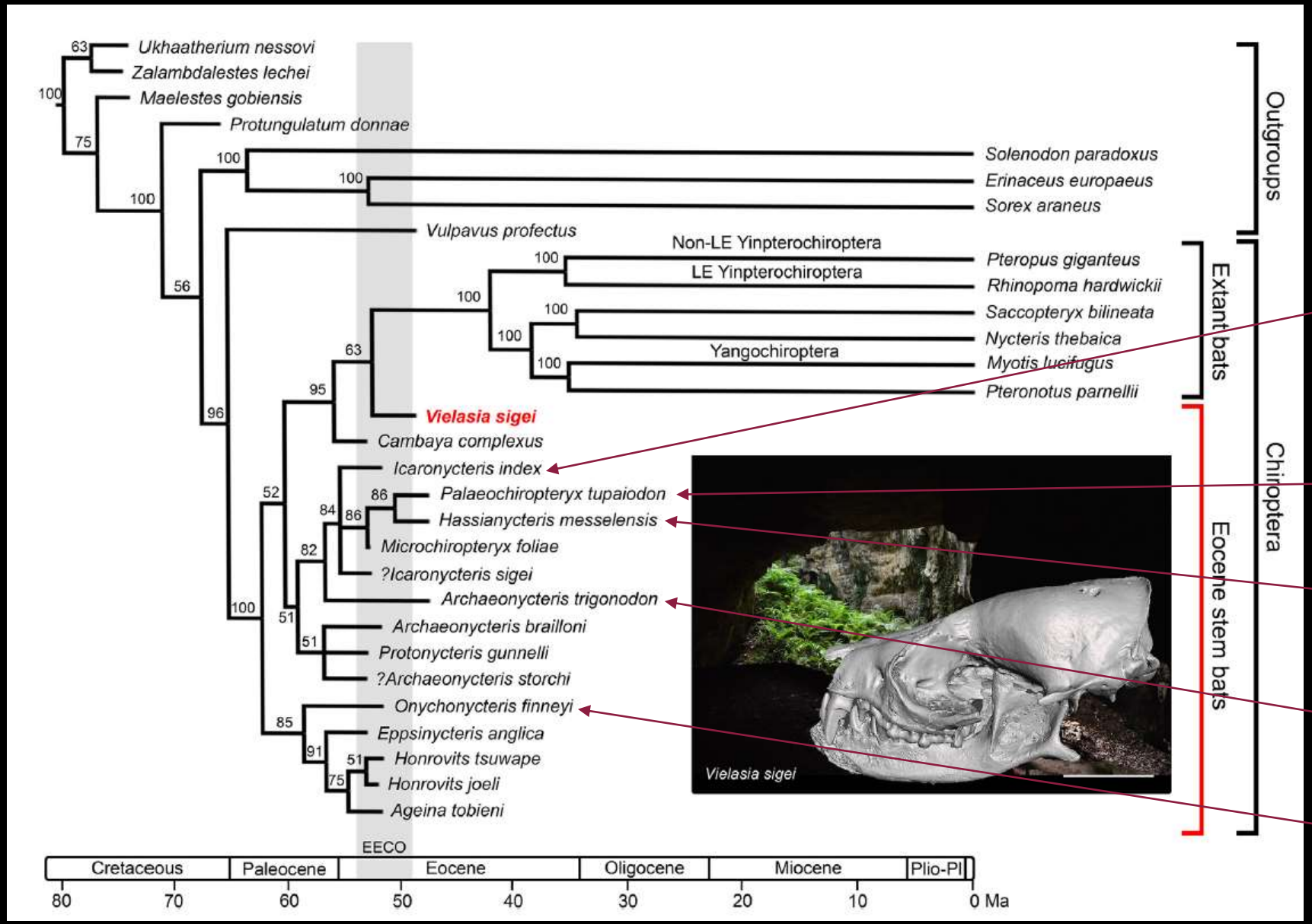
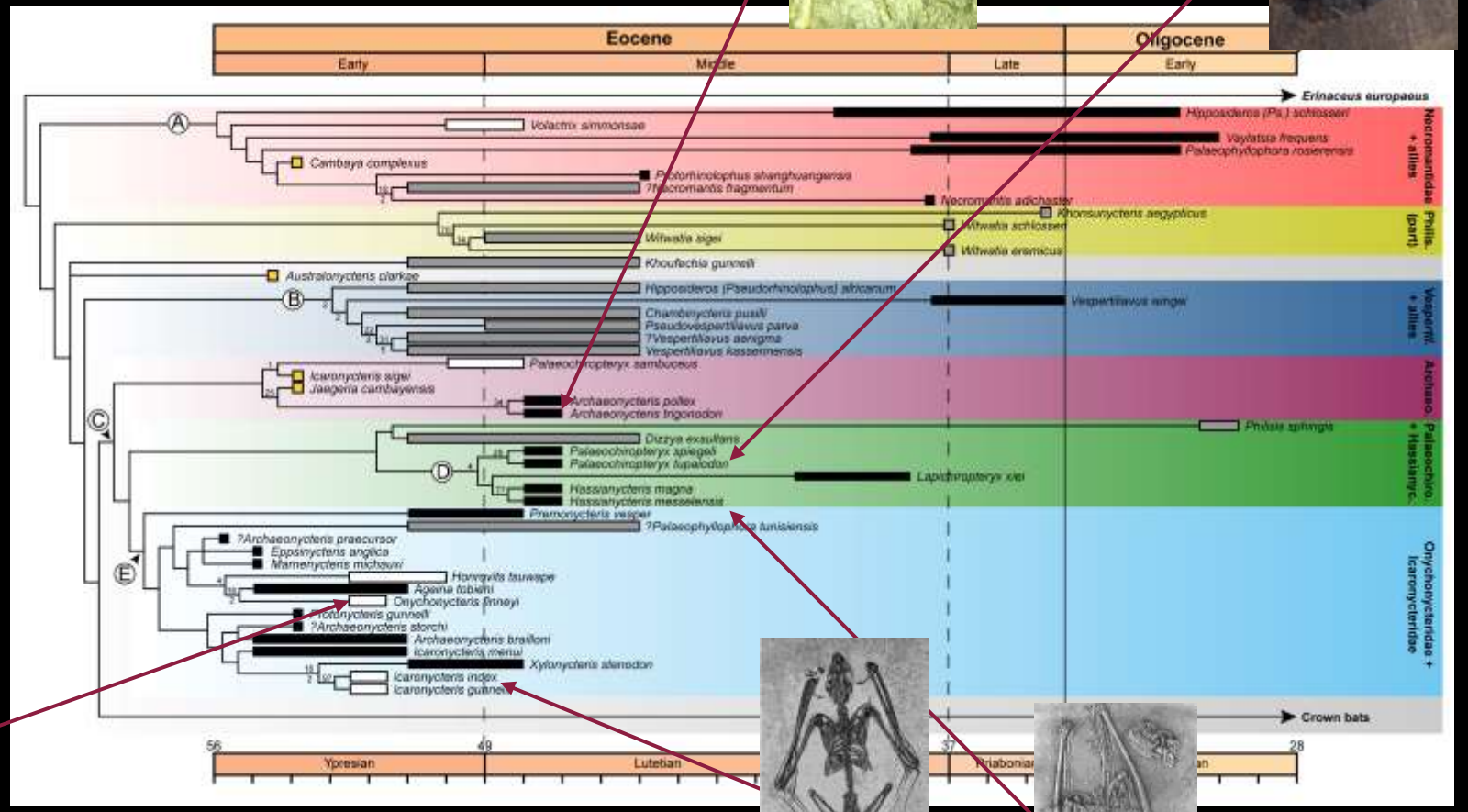


Figure credit: Hand et al. 2023

Understanding relationships of fossil bats

Including fragmentary fossil bats recovers more complex relationships



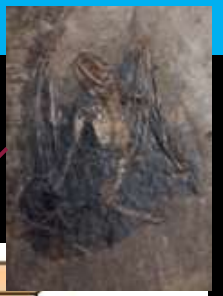
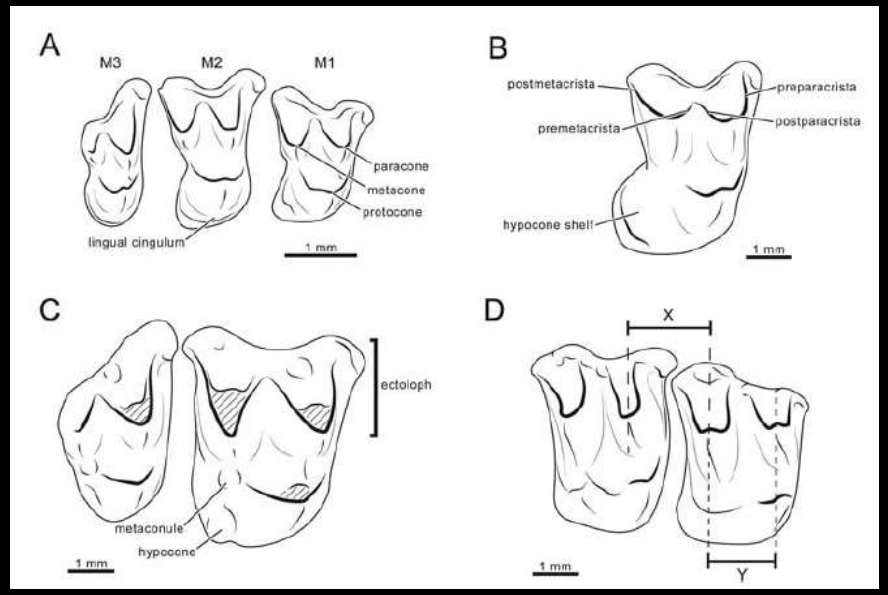


Figure credit: Jones et al. 2024

Ecological signal in bat dentition

Teeth inform ecology

Shape of bat teeth (especially molars) varies with diet



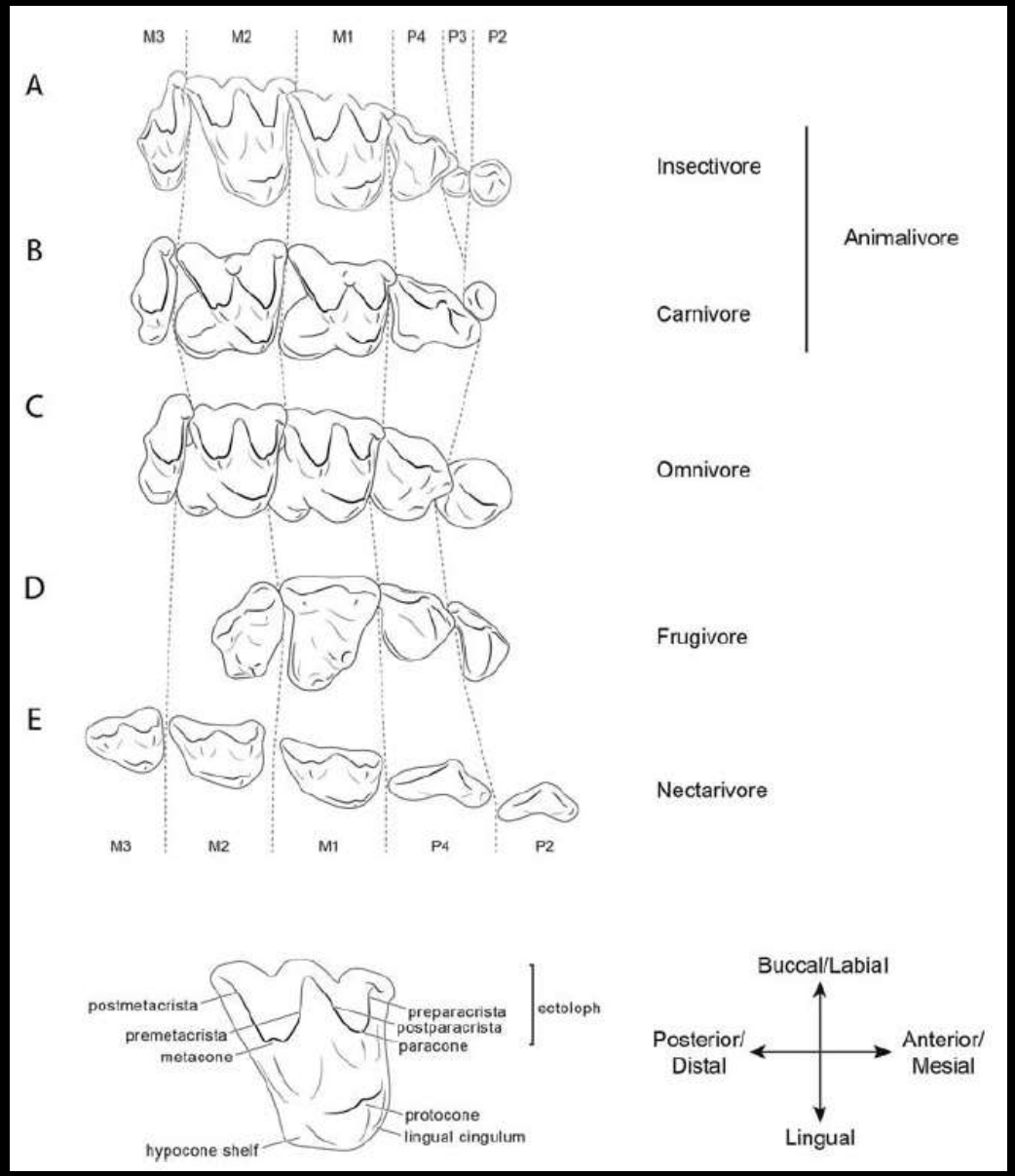
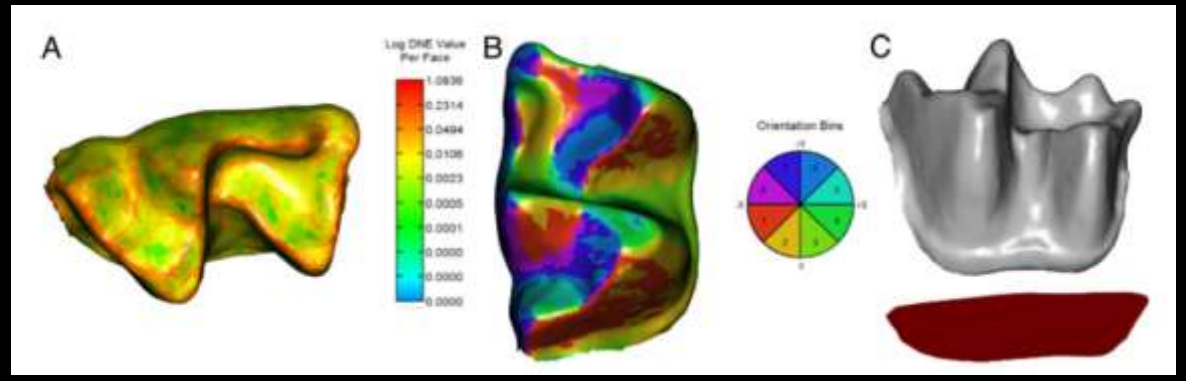


Figure credit: Simmons and Jones 2024

Ecological signal in bat dentition

Miocene bat from South America ***Notonycteris*** (13 mya) apparently was an insectivore/omnivore



Spectral bat, *Vampyrum spectrum* (Marco Tschapka)

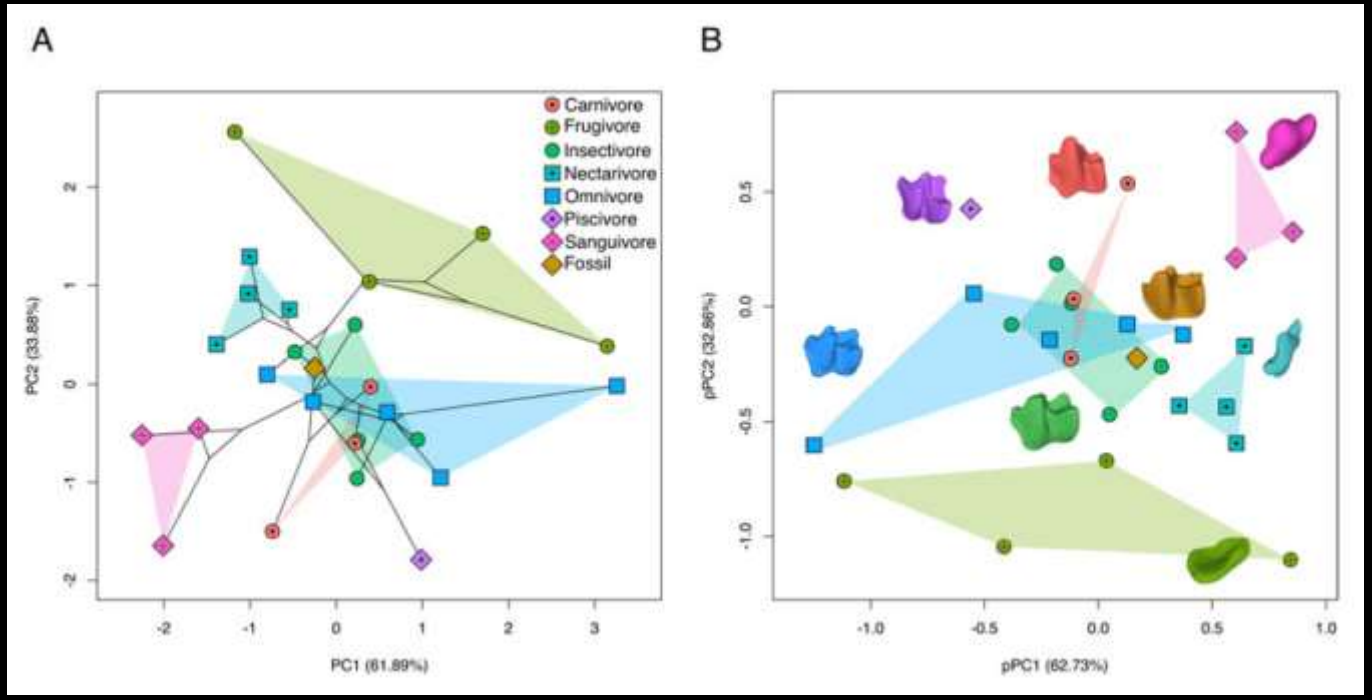
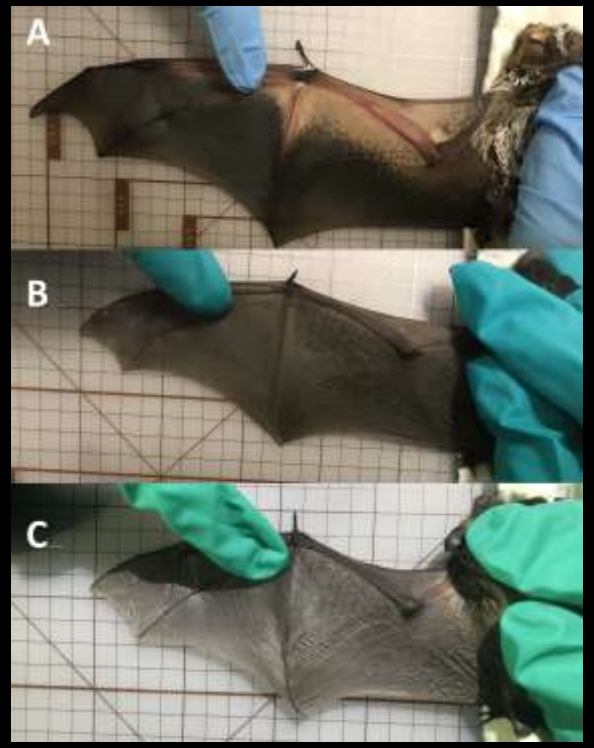


Figure credit: López-Aguirre et al. 2022

Post-cranial bones of ancient bats

Comparing wing dimensions and size helps inform how fossil bats flew

- Aspect ratio – wing length/wing width
- Wing loading – body mass/wing area



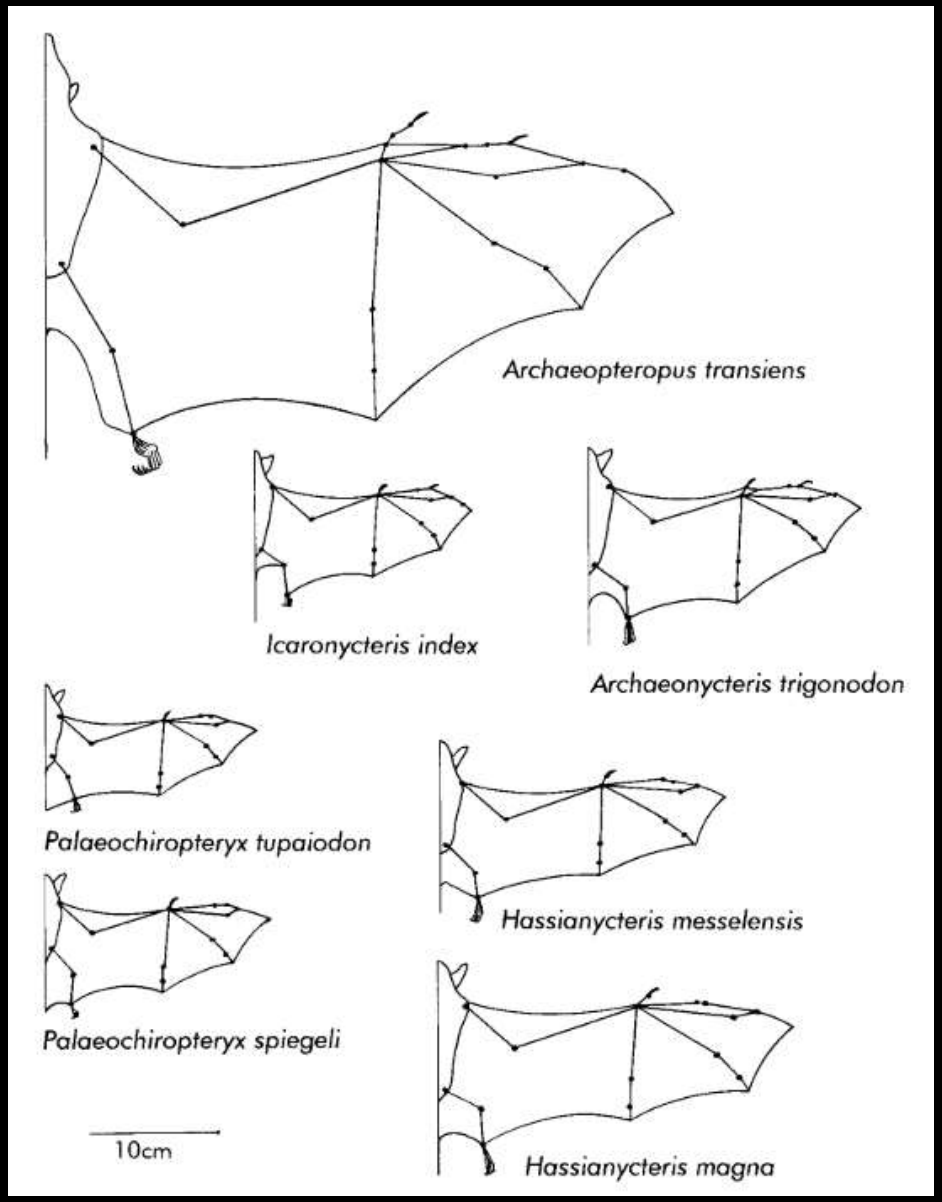
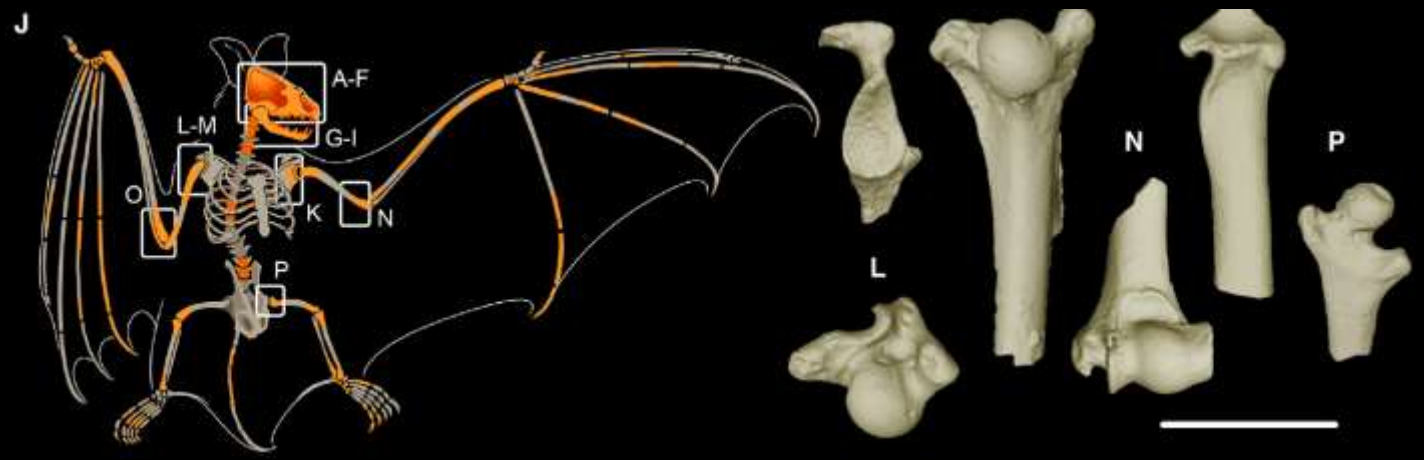


Figure credit: Simmons and Geisler 1998; Dana Green

Post-cranial bones of ancient bats

Isolated postcranial bones have been studied much less frequently



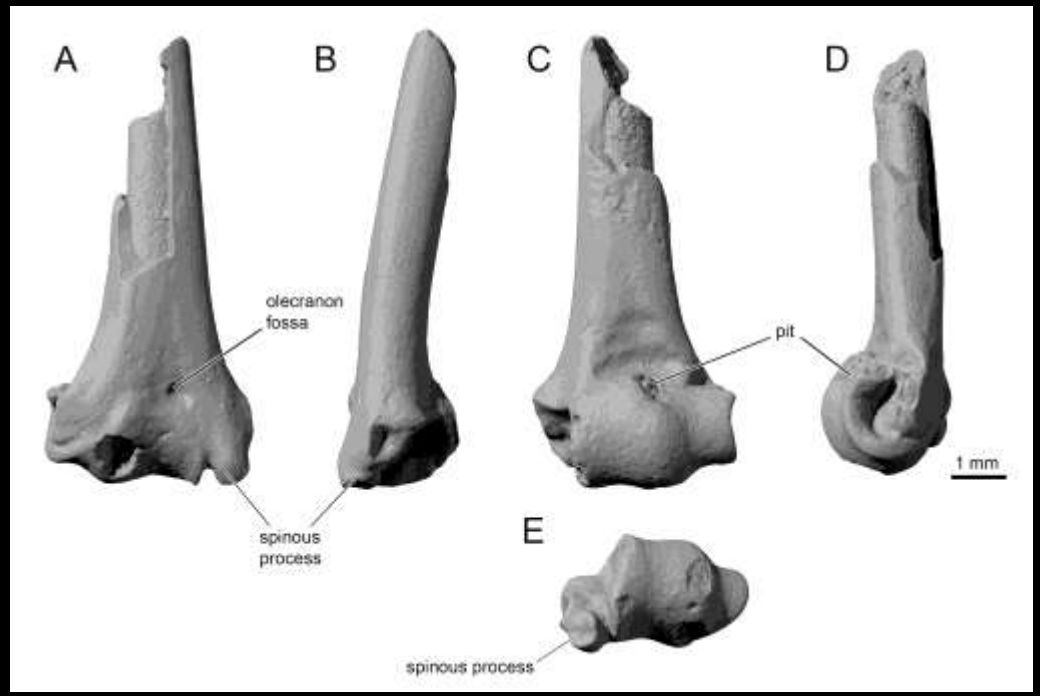
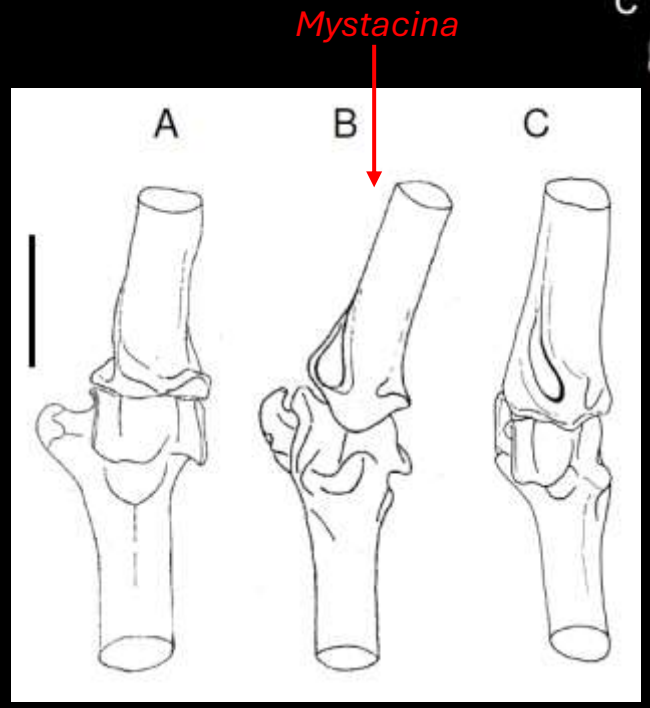


Figure credit: Hand et al. 2023; Sims et al., in review

Post-cranial bones of ancient bats

Comparison to living New Zealand short-tailed bats suggests ***Icarops*** (20 mya, Australia) was capable of terrestrial locomotion before isolation in New Zealand!

NZ short-tailed bat, *Mystacina tuberculata* (Rod Morris)



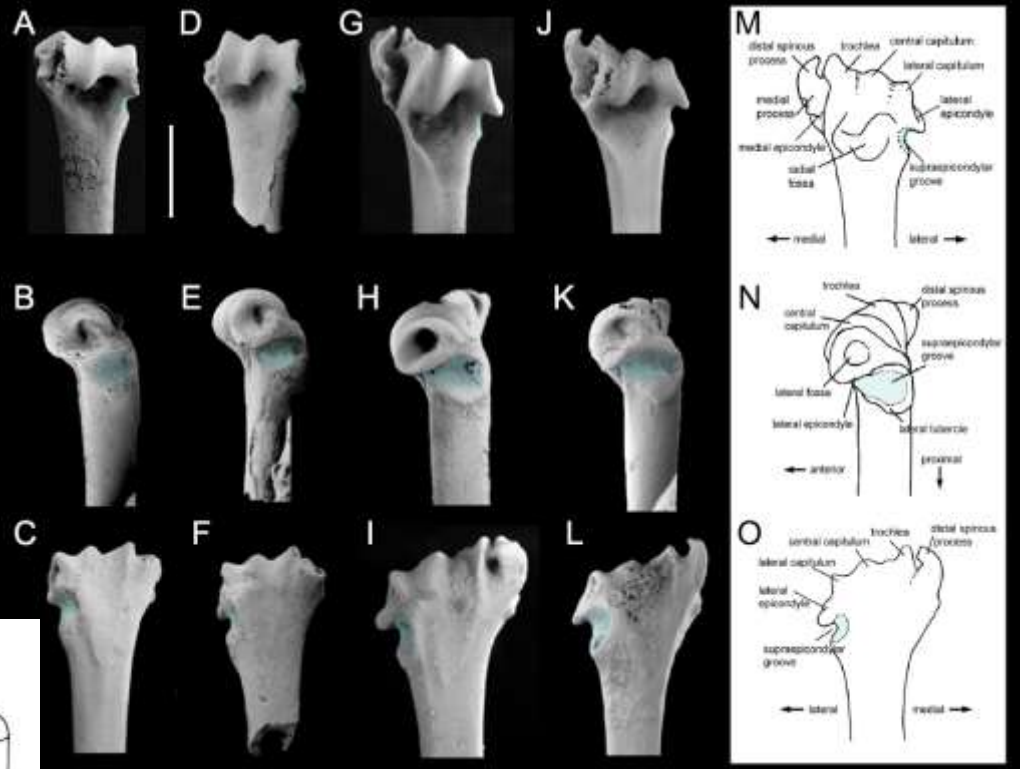
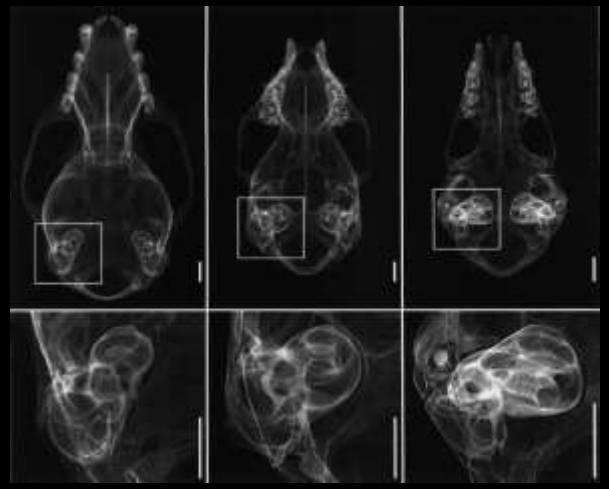


Figure credit: Hand et al. 2009

Could early bats echolocate?

Skull bones provide insight into echolocation ability of fossil bats



Non-echolocating bat

Echolocating bat

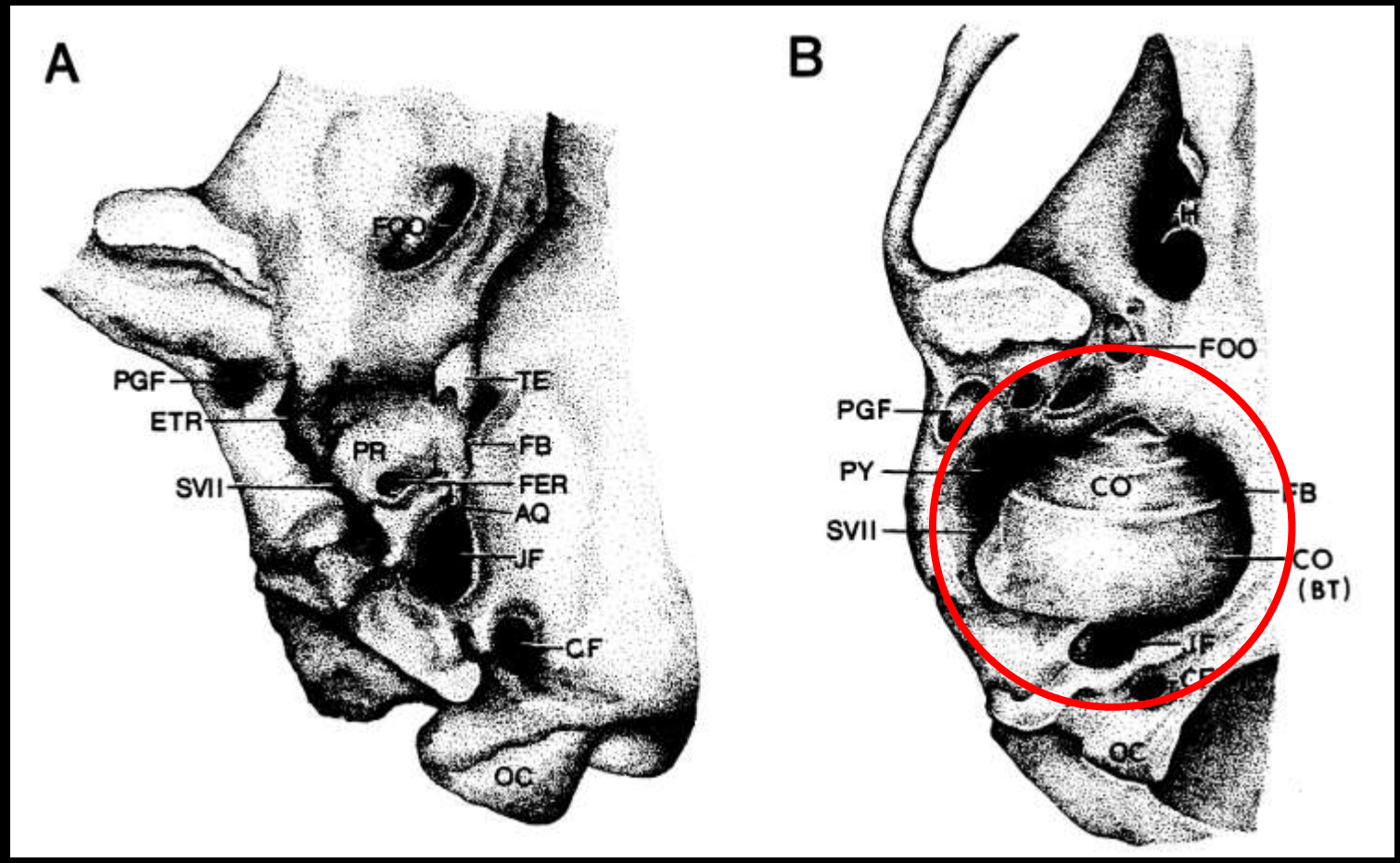
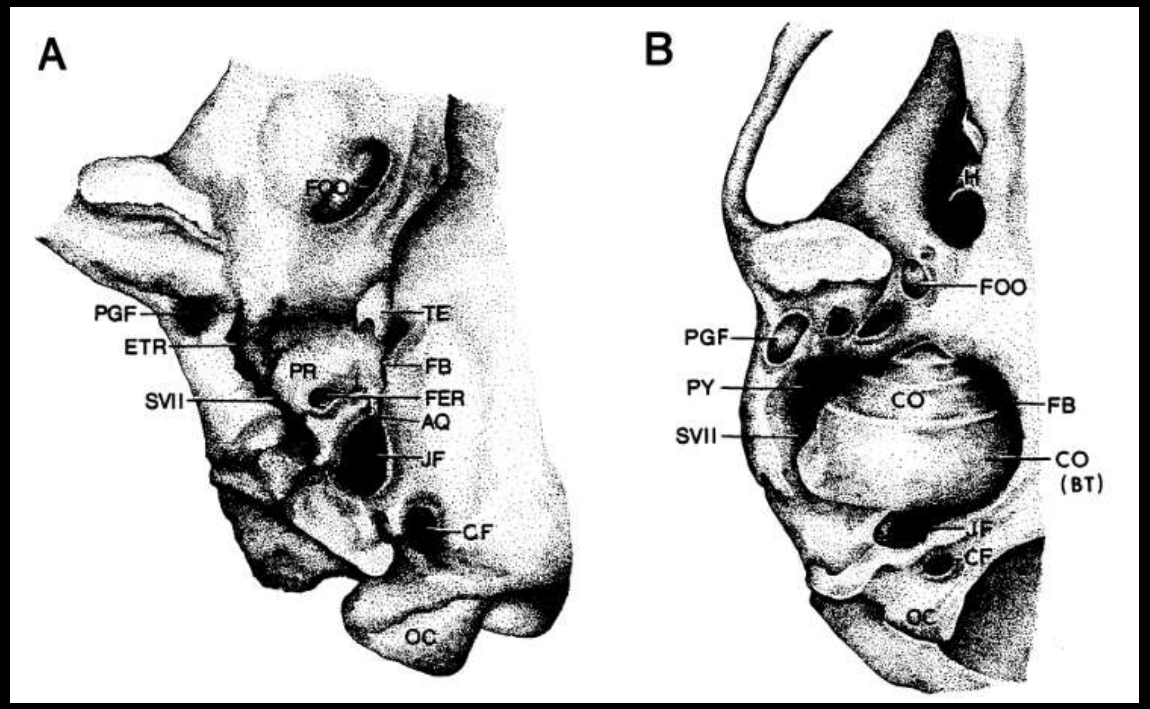


Figure credit: Novacek 1987; Habersetzer et al. 2017

Could early bats echolocate?



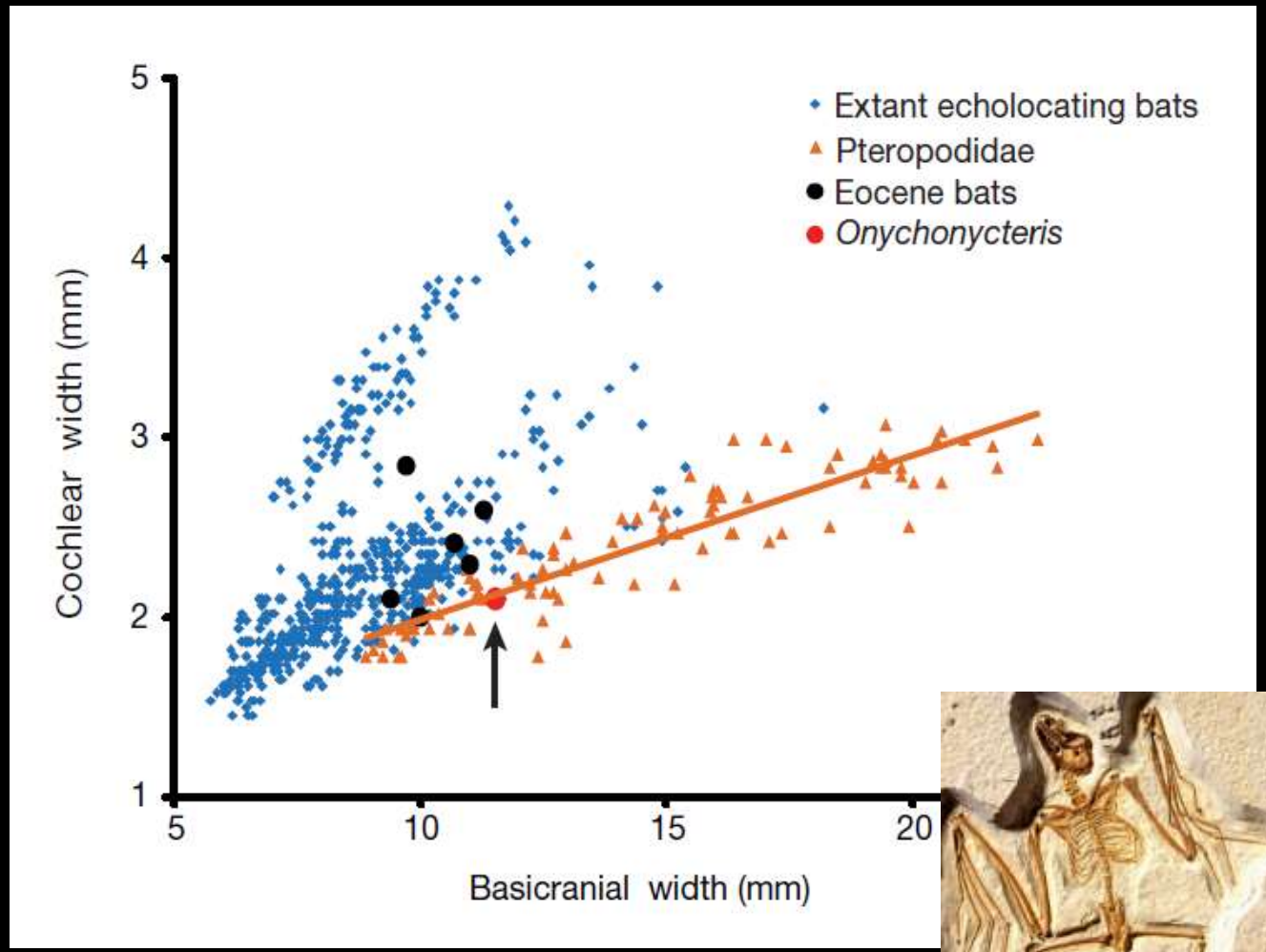


Figure credit: Novacek 1987; Simmons et al. 2008

Understanding early bat faunas

- Dentition
- Wing morphology
- Gut contents
- Echolocation

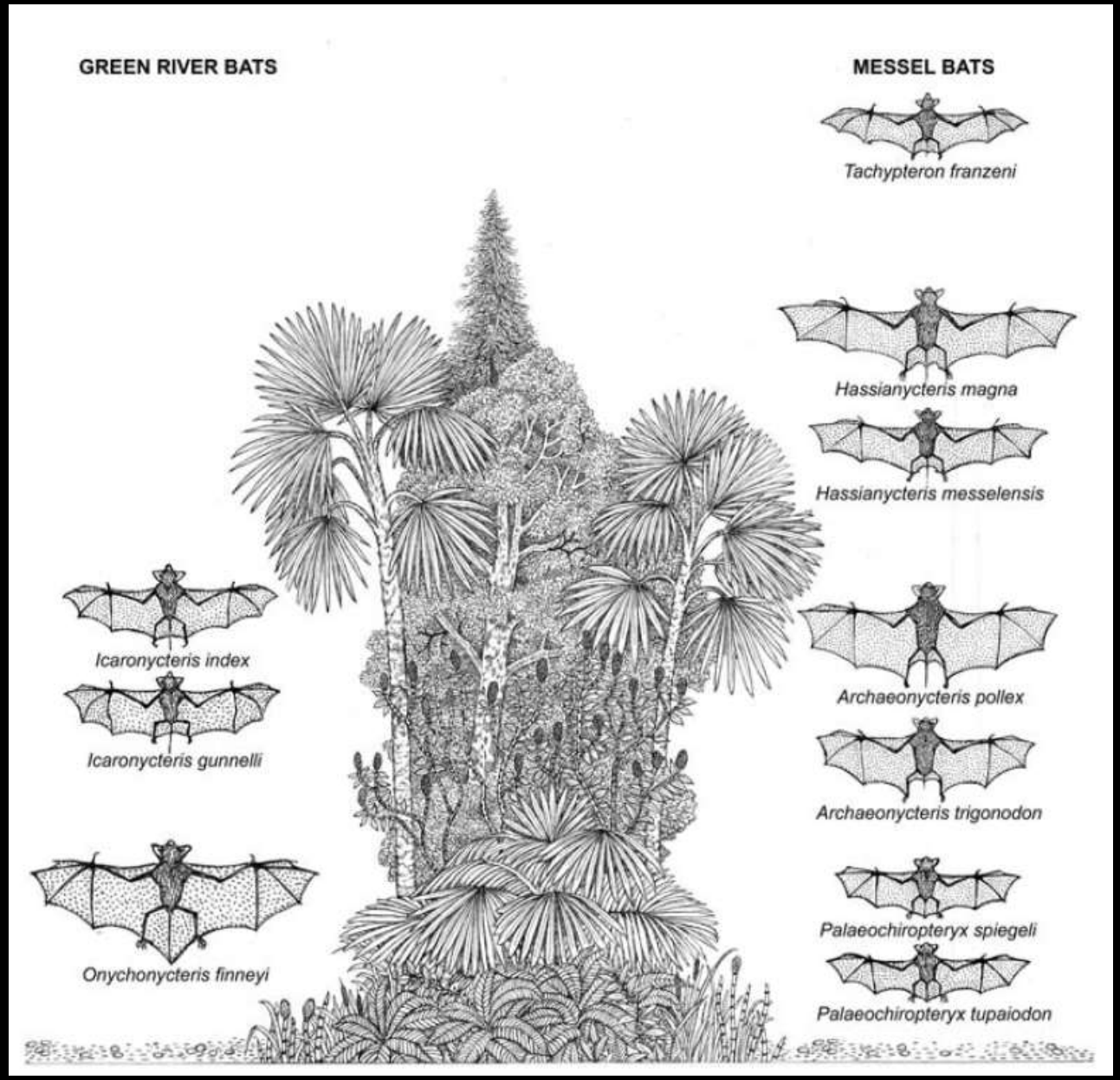
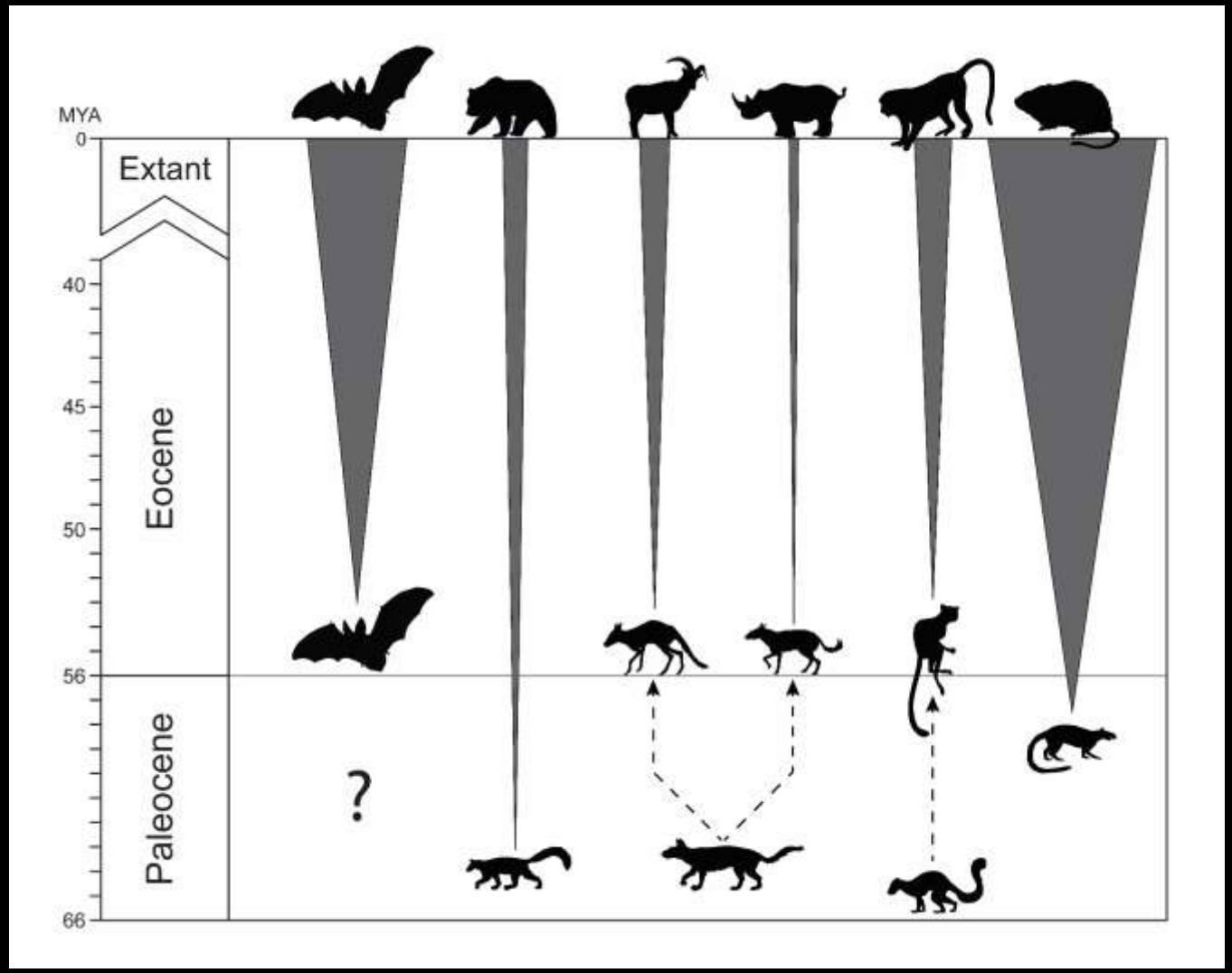


Figure credit: Simmons and Jones 2024

But where did they
come from?

Where did bats come from?

Bats lack transitional forms or obvious close relatives in the fossil record



Where did bats come from?

Laurasiatheria

Closest living relatives of bats are very morphologically diverse

...but,

Laurasiatheria traces origins to northern continents (Asia, Europe, North America)

Artiodactyla

Carnivora

Eulipotyphla

Perissodactyla

Pholidota

Where did bats come from?

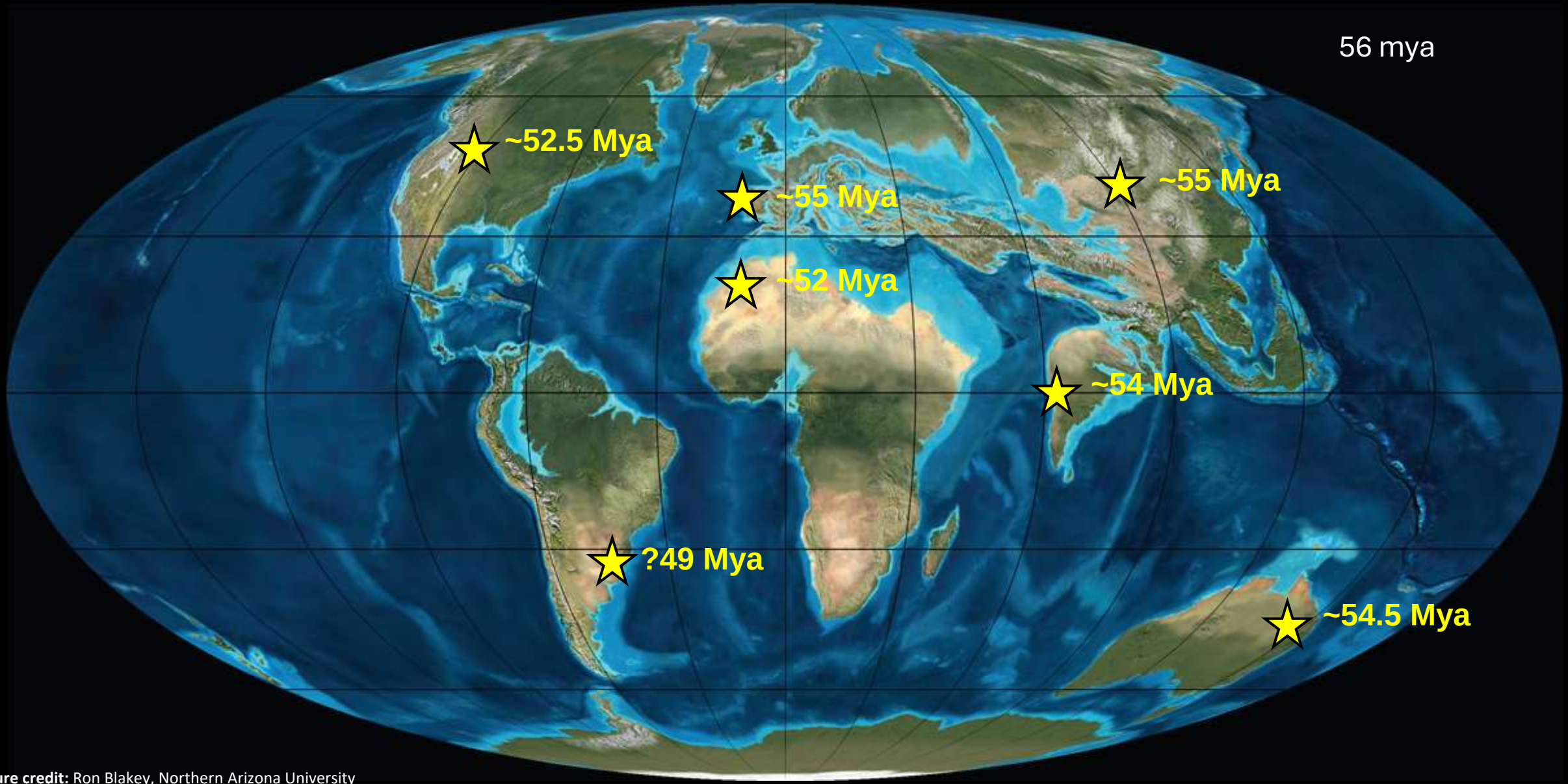


Figure credit: Ron Blakey, Northern Arizona University

Where did bats come from?

Nyctitheres?

Enigmatic early Cenozoic insectivores

Cambaya – described as a nyctithere, now thought to be a bat

Wyonycteris – described as a bat, now thought to be a nyctithere

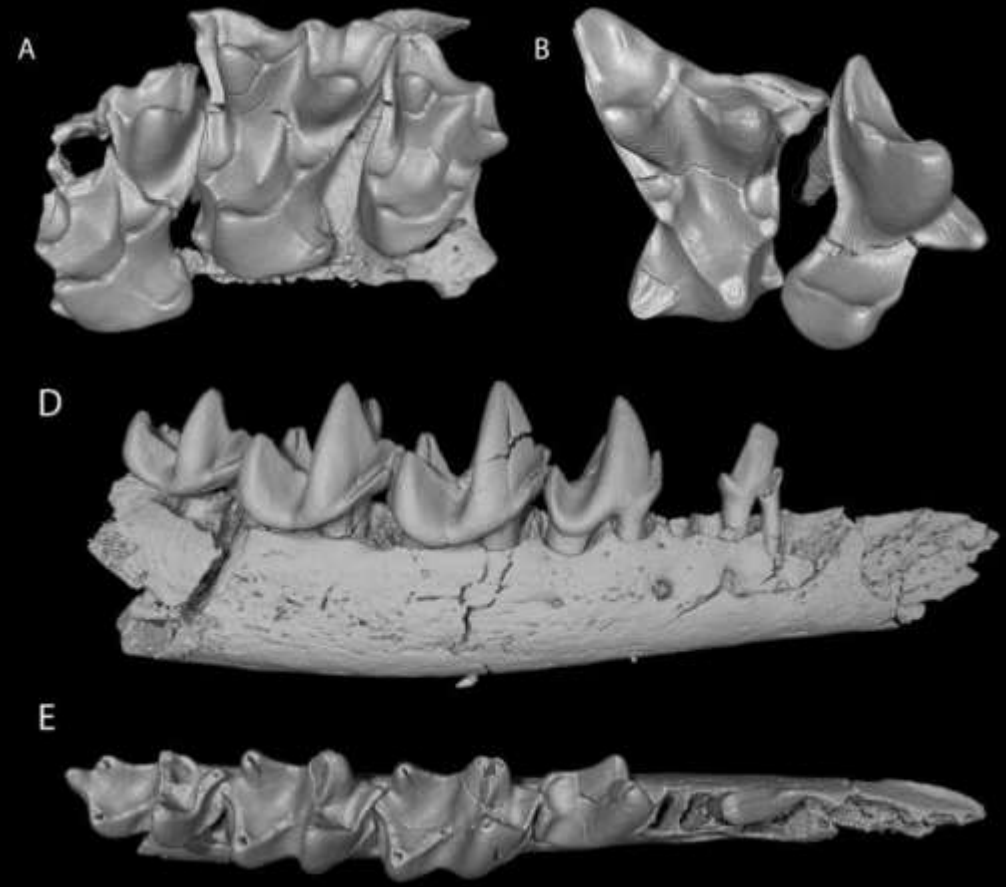
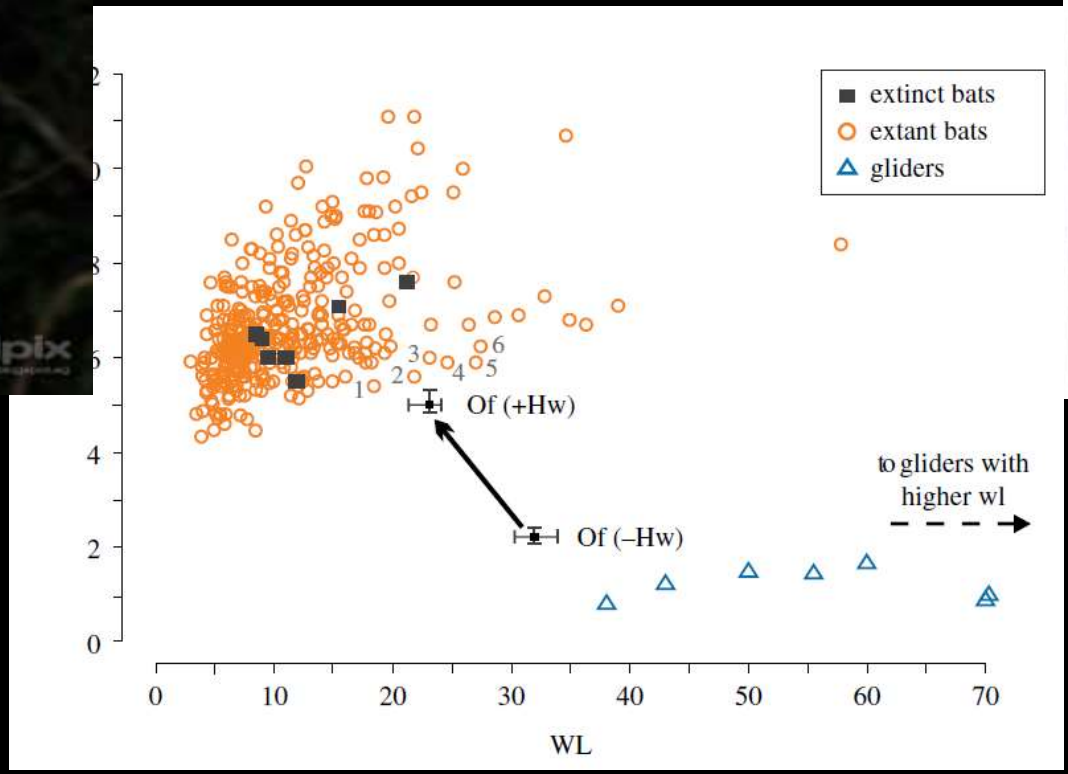


Figure credit: Smith et al. 2007; Jones and Beard 2023

Where did bats come from?

Gliders?



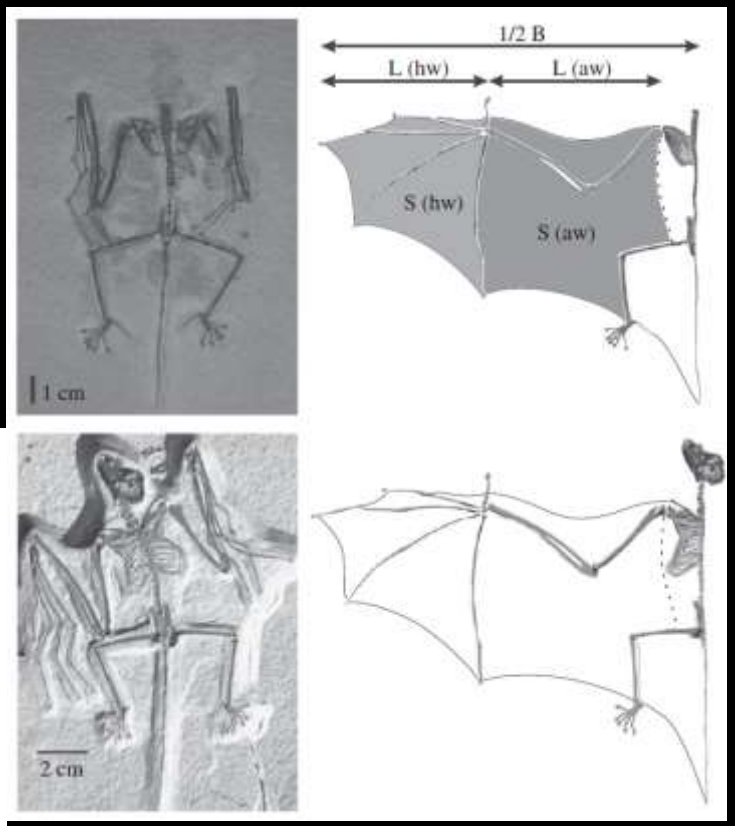


Figure credit: Amador et al. 2019

Why study bat paleontology?

- More complete picture of bat evolution
- Informs evolution of morphology, behavior, and ecology of early bats
- Vital to understanding bat origins

Check out:

- Amador, L.I., Simmons, N.B., and Giannini, N.P., 2019. **Aerodynamic reconstruction of the primitive fossil bat *Onychonycteris finneyi* (Mammalia: Chiroptera)**. Biology Letters 15:20180857.
- Hand, S.J., Weisbecker, V., Beck, R.M.D., Archer, M., Godthelp, H., Tennyson, A.J.D., and Worthy, T.H., 2009. **Bats that walk: a new evolutionary hypothesis for the terrestrial behaviour of New Zealand's endemic mystacinids**. BMC Evolutionary Biology 9:169.
- Hand, S.J., Maugoust, J., Beck, R.M.D., and Orliac, M.J., 2023. **A 50-million-year-old, three-dimensionally preserved bat skull supports an early origin for modern echolocation**. Current Biology 33:1-17.
- Jones, M.F., Beard, K.C., and Simmons, N.B., 2024. **Phylogeny and systematics of early Paleogene bats**. Journal of Mammalian Evolution 31:18.
- López-Aguirre, C., Czaplewski, N.J., Link, A., Takai, M., and Hand, S.J., 2022. **Dietary and body-mass reconstruction of the Miocene neotropical bat *Notonycteris magdalenensis* (Phyllostomidae) from La Venta, Colombia**. Paleobiology 48:137-153.
- Simmons, N.B., Seymour, K.L., Habersetzer, J., and Gunnell, G.F., 2008. **Primitive early Eocene bat from Wyoming and the evolution of flight and echolocation**. Nature 451:818-822.
- Simmons, N.B., and Jones, M.F., 2024. **Foraging in the fossil record: Diet and behavior of the earliest bats**. Pp 7-39 *in* A Natural History of Bat Foraging: Evolution, Physiology, Ecology, Behavior, and Conservation (Russo, D., and Fenton, B., eds.), Academic Press.
- And many others!