Hot Science Cool Talks

UT Environmental Science Institute

106

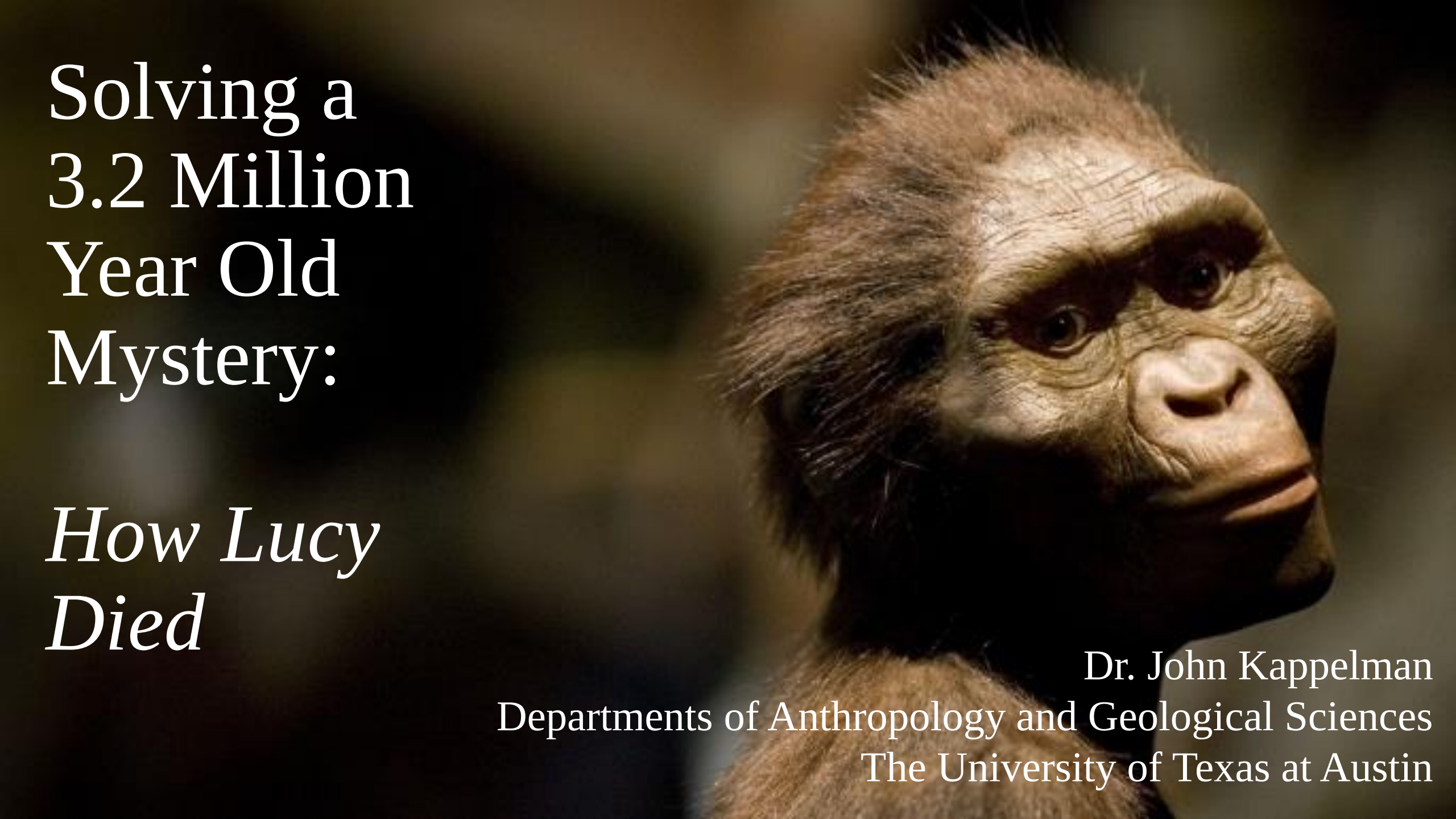
Solving a 3.2-Million-Year-Old Mystery: How Lucy Died

Dr. John Kappelman

March 24, 2017

Solving a 3.2 Million Year Old Mystery:

How Lucy Died



Dr. John Kappelman
Departments of Anthropology and Geological Sciences
The University of Texas at Austin

Paleontology: study of ancient life

Why study human evolution?

How did natural selection shape our ancestors, and us, across 7 million years (Ma)?

Characteristic features:

Big brains: ~2 Ma

Tool use: ~2.5 Ma, maybe older?

Bipedal: walking on two legs instead of four (quadrupedal): certainly in Lucy at > 3 Ma, and perhaps as old as 7 Ma

http://www.brainfacts.org/brain-basics/evolution/

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https://blogs.scientificamerican.com/thoughtful-animal/for-chimps-tool-choice-is-a-weighty-matter/

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http://humanorigins.si.edu/evidence/human-fossils/fossils/al-288-1/

Why study Lucy?

Fossil has been studied for > 40 years

What else is there to discover?

Lesson in how science works

Science builds upon past work, brings new approaches and new perspectives to future work

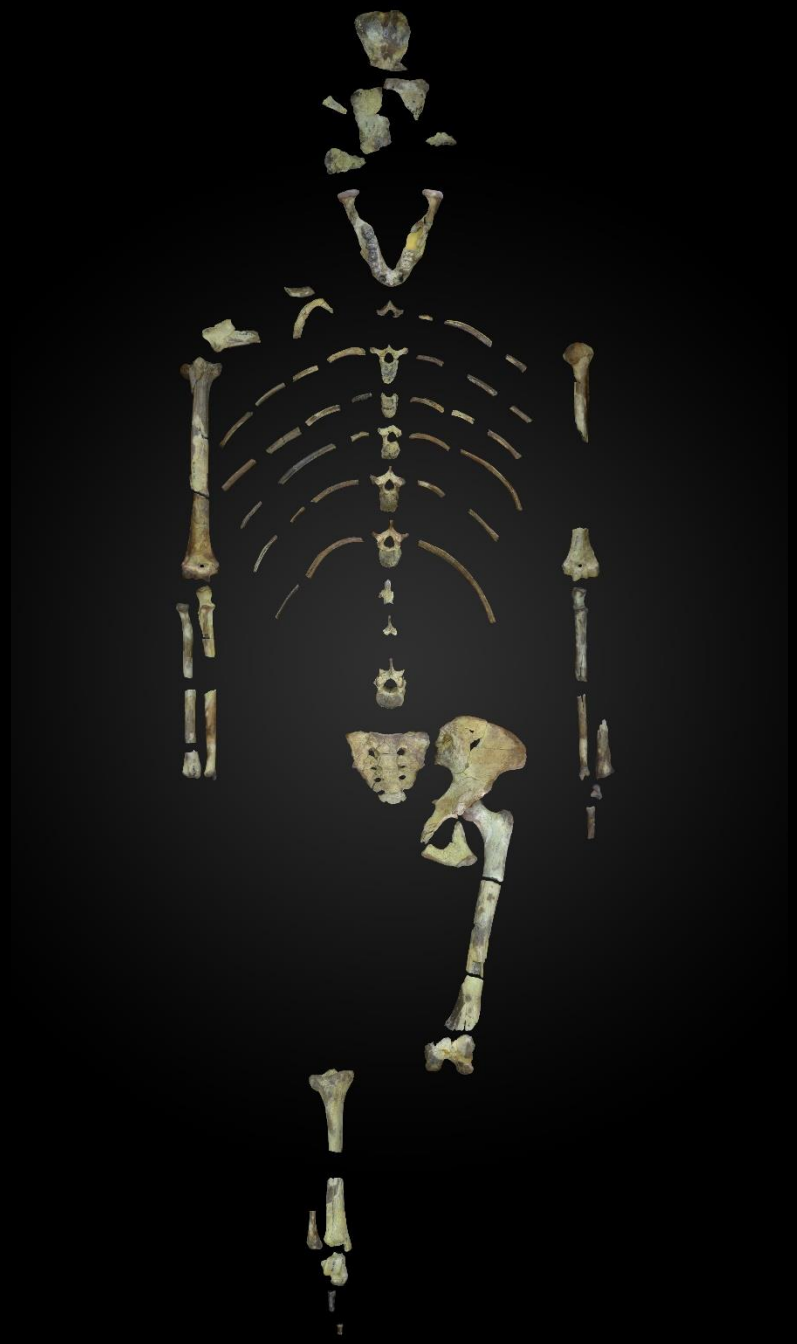
Egalitarian: anyone can do it!

Lucy, the most famous fossil on our planet

President Obama and Lucy
Addis Ababa, Ethiopia, 2015

Lucy: young adult female of *Australopithecus afarensis*

Place: Hadar, Afar Depression, Ethiopia; also Kenya & Tanzania
Age: 3.18 Ma; range 3.9 – 2.9 Ma
Sample: >400 specimens
Paleobiology: males larger than females (more like gorillas than humans)
Paleohabitat: wooded savanna mosaic
Locomotion: walked on two legs (bipedal) when on the ground; debated whether she climbed trees



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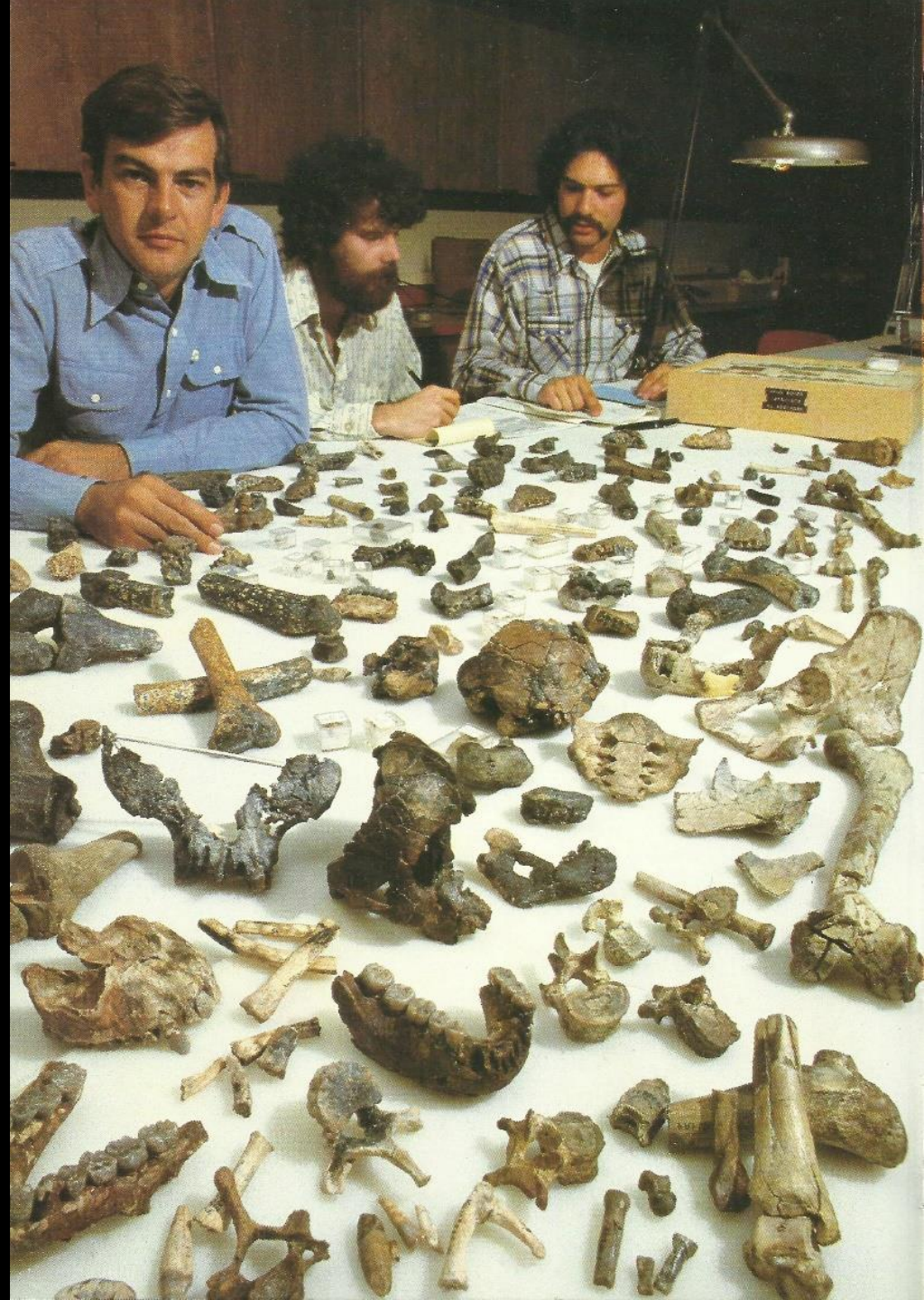

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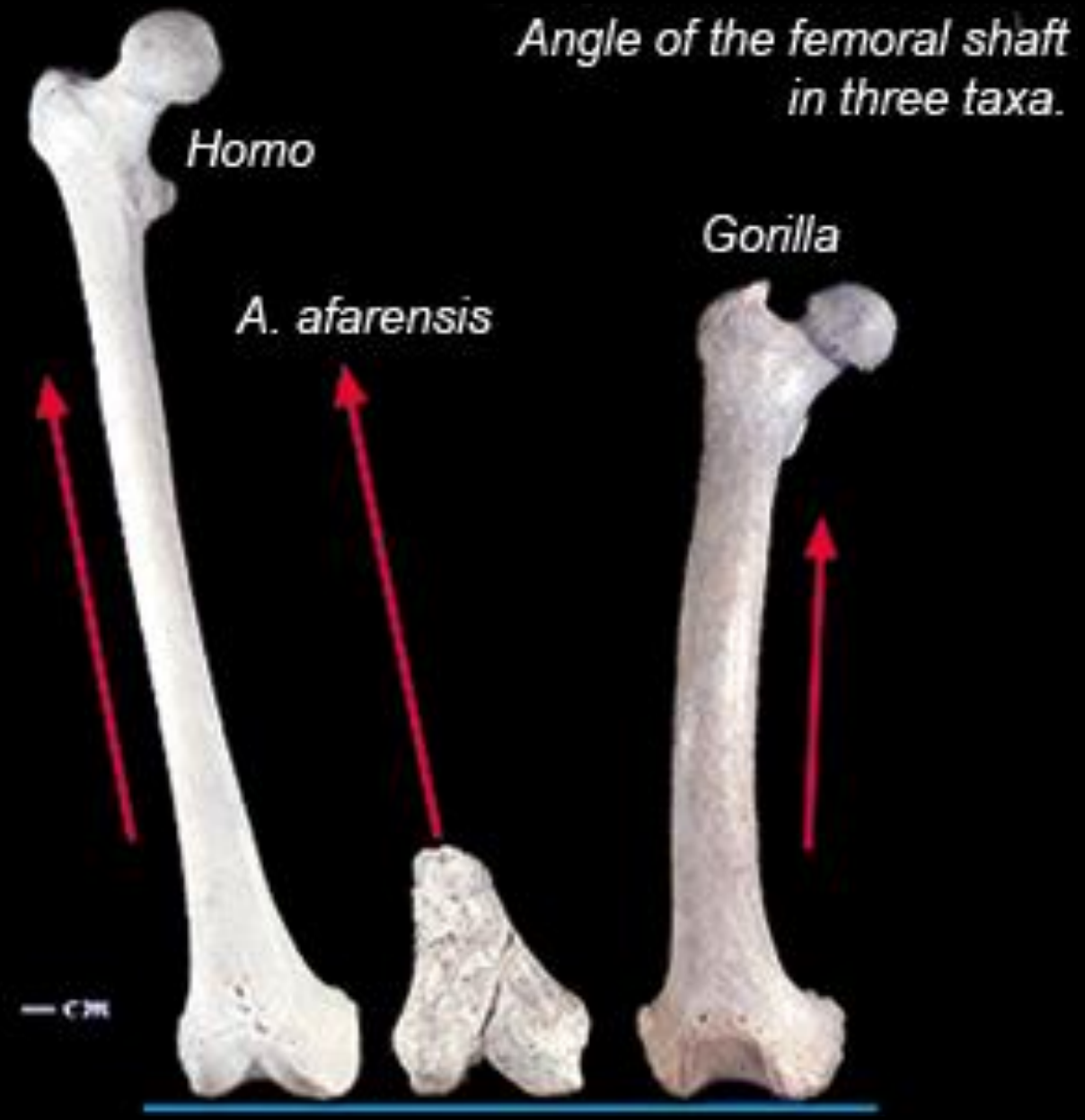
Basis for the debate:

how to interpret the anatomy?

Femur (thighbone)

Bipeds: *hips apart, knees close together*

Quadrupeds: *knees apart*



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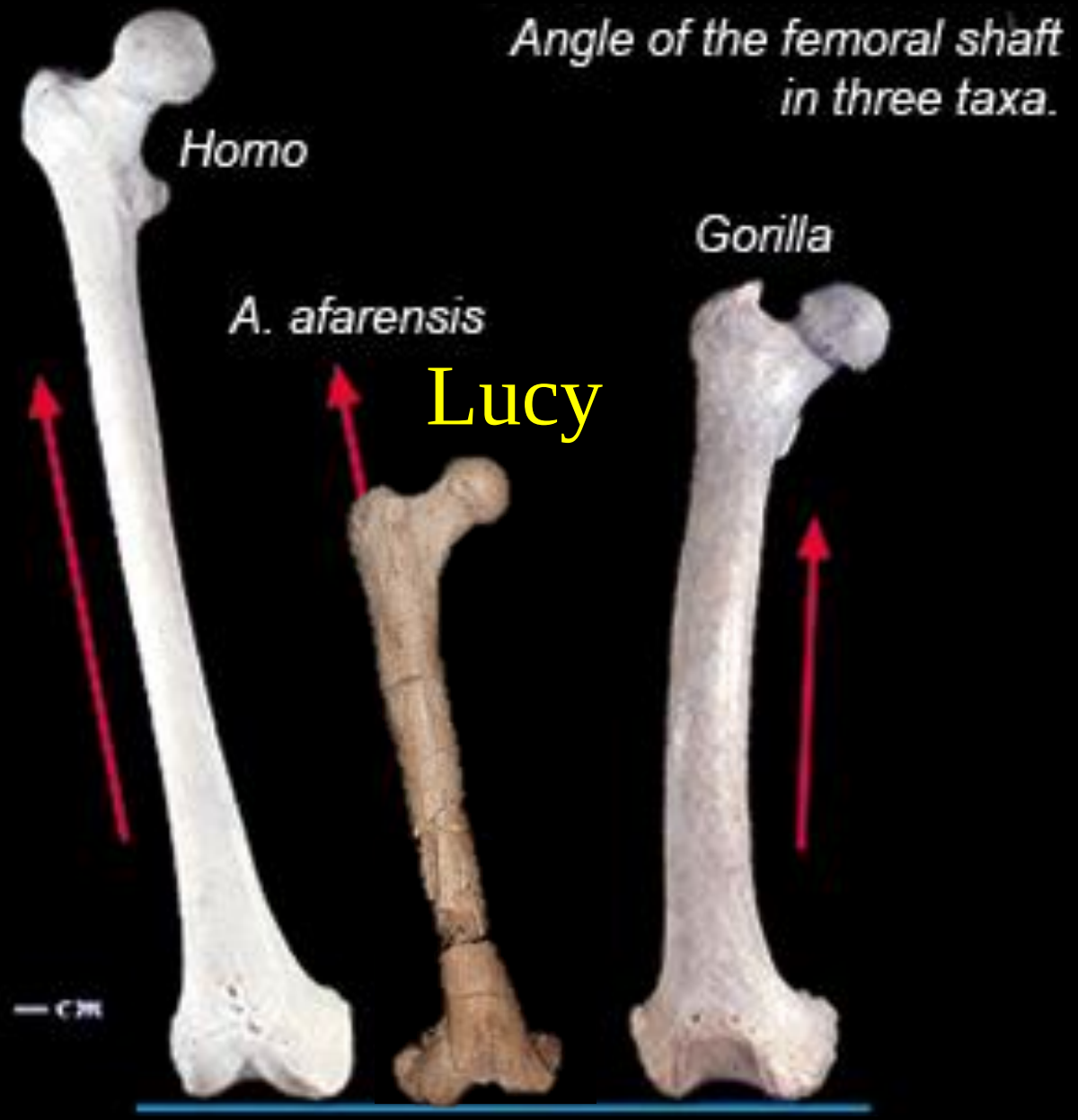

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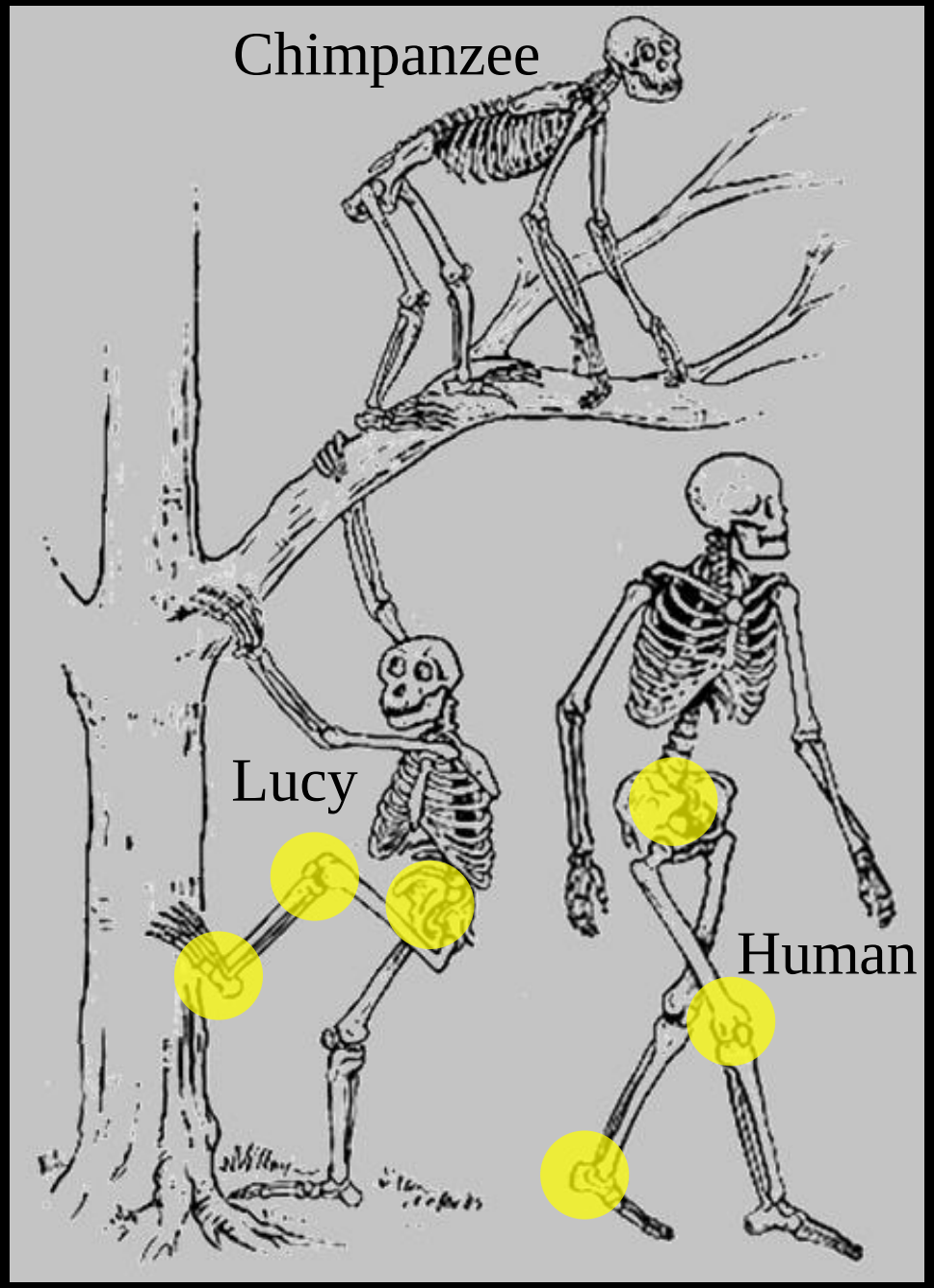
Comparative anatomy:

- *shared similarities with bipedal humans*

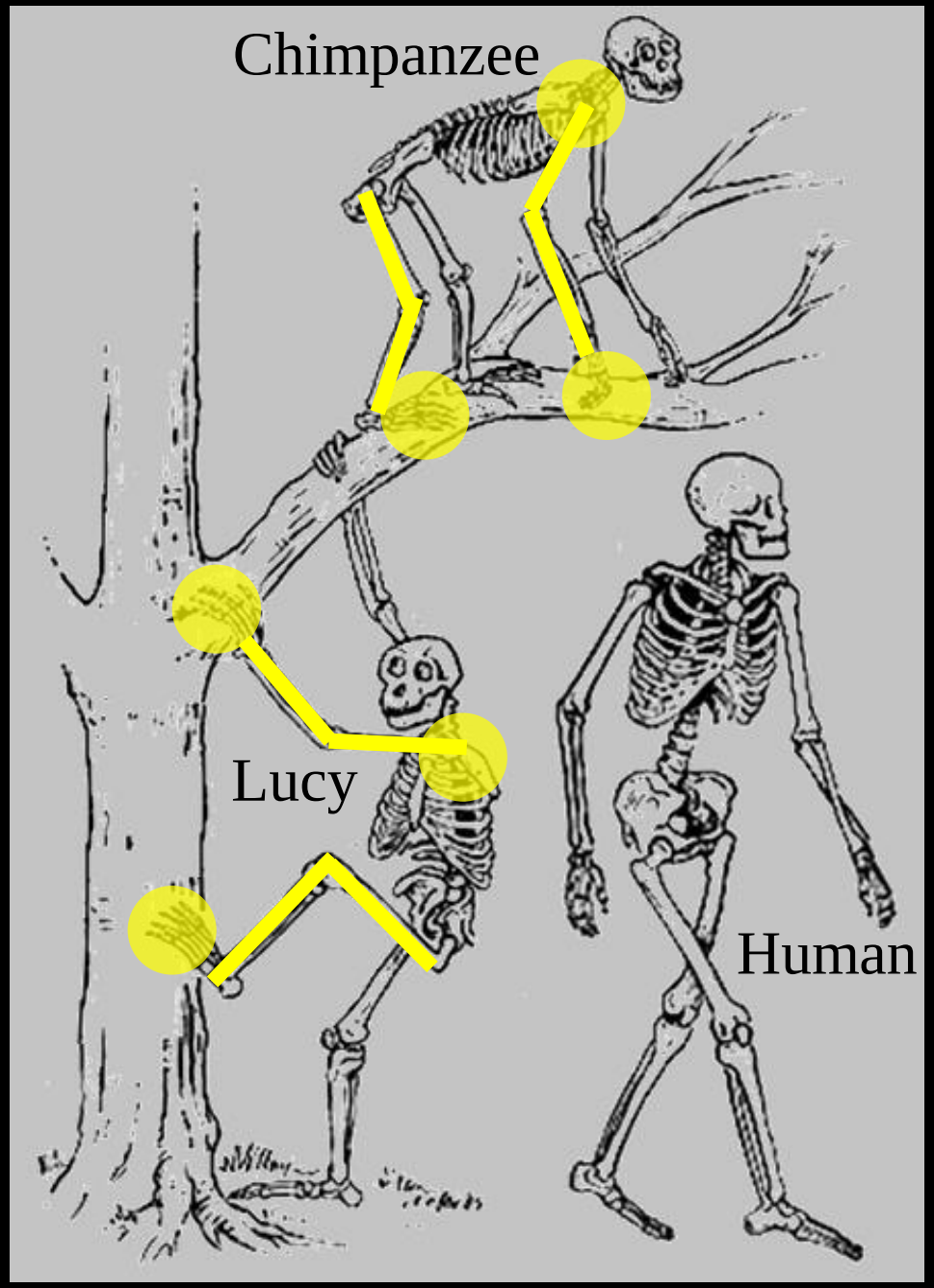


Fleagle. *Primate Evolution and Adaptations.*

Basis for the debate:
how to interpret the anatomy?

Comparative anatomy:

- *shared similarities with climbing chimpanzees*



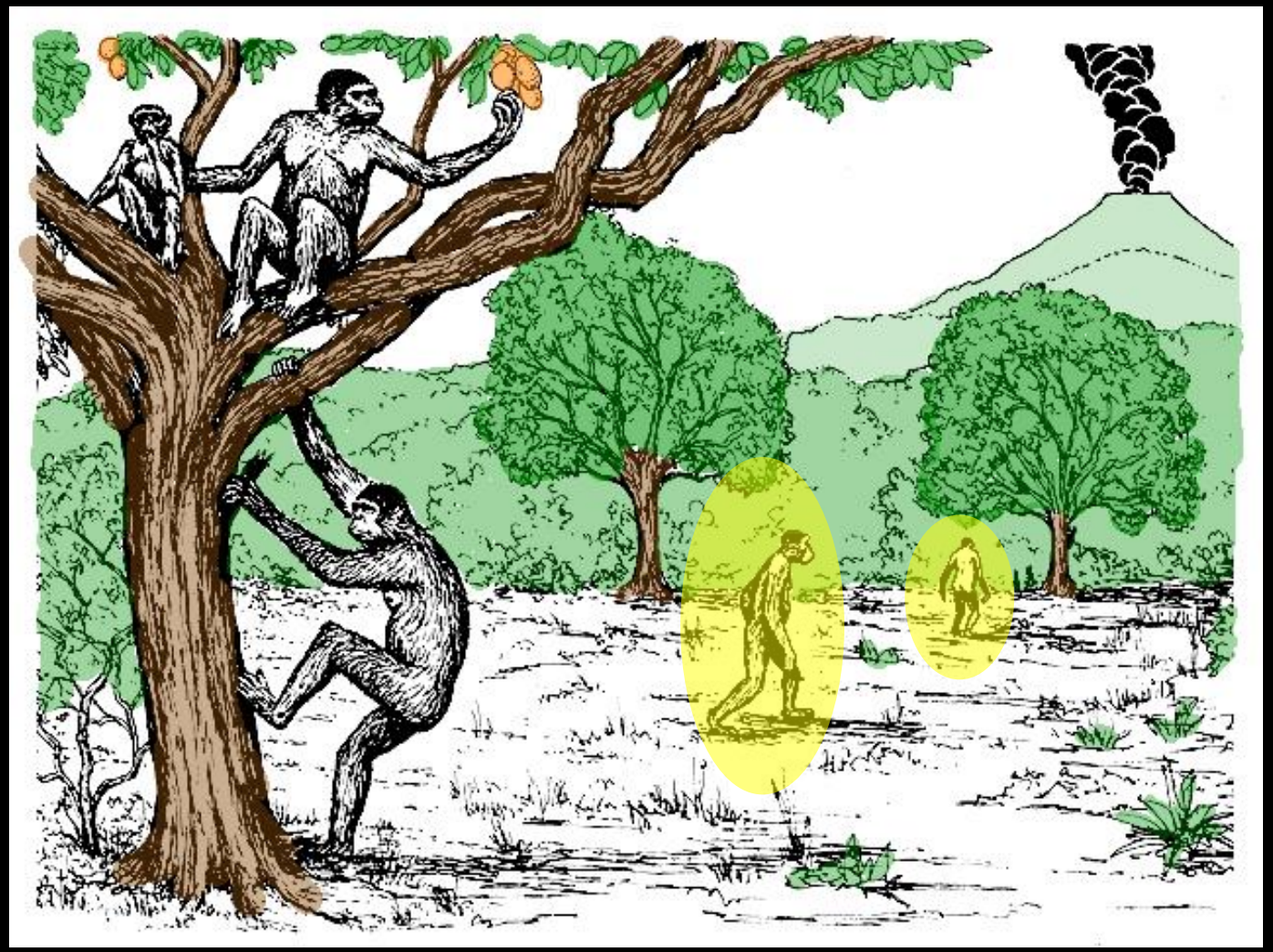
Fleagle. *Primate Evolution and Adaptations.*

How did Lucy and other early human ancestors move?

Two sides of a vigorous debate:

1) On two legs (bipedal) only; climbing features no functional significance, only *inherited* from an ancestor who climbed

2) Bipedal, yes, but also climbed trees



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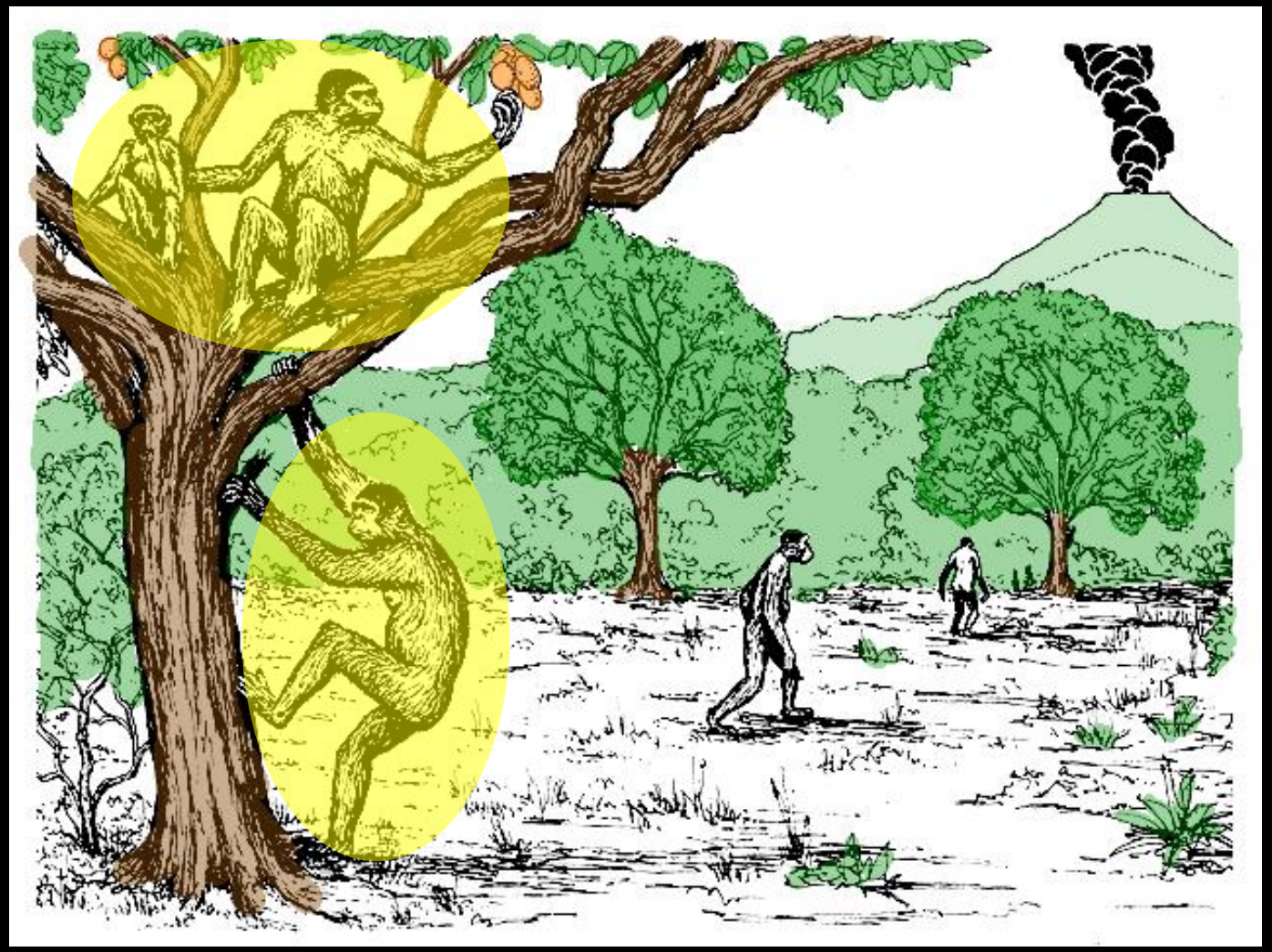

Debate stalled for 35 years.

Traditional methods for studying the skeleton:

- Calipers (measure size)
- Microscopes (examine fine detail)

Techniques told us about size and shape but did not answer the question of function.

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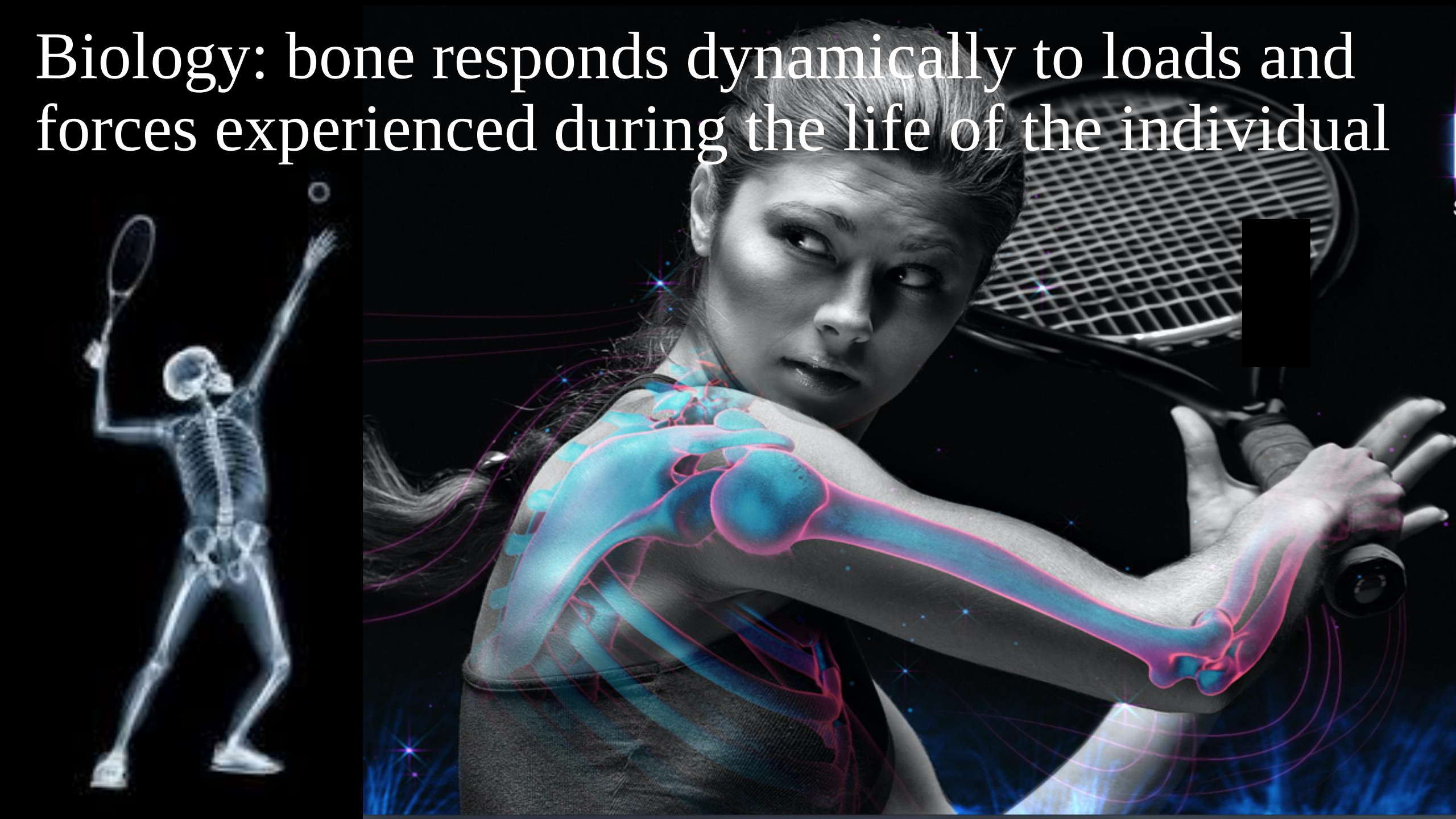
Techniques told us about size and shape but did not answer the question of function.

We needed a different approach, and different techniques, to test the question.

Biology: bone responds dynamically to loads and forces experienced during the life of the individual

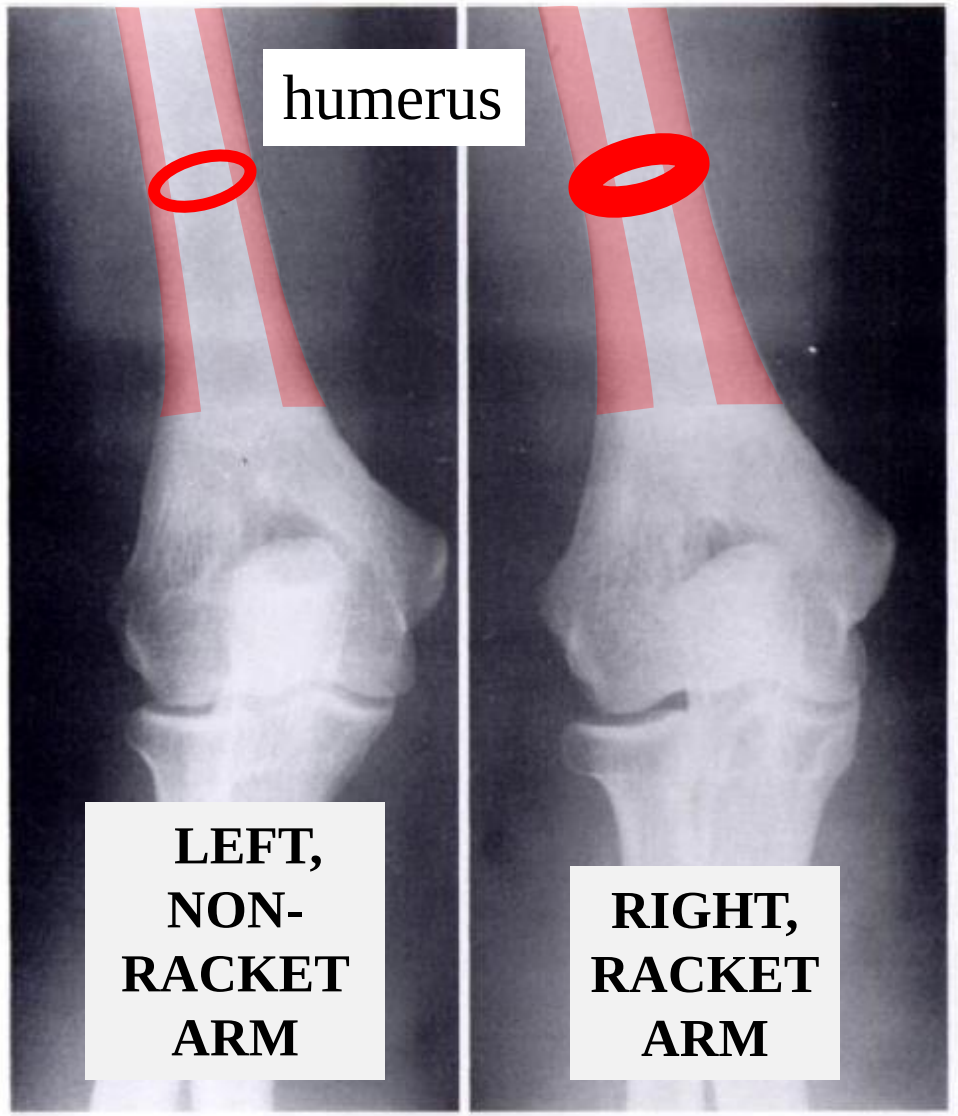


Use X-rays to look inside bones and study the cross-sectional geometries

Bone of the racquet arm (humerus) is thicker than non-racquet arm = greater strength

WHY? Bone responds dynamically to the loads and forces experienced ***DURING*** the life of the individual

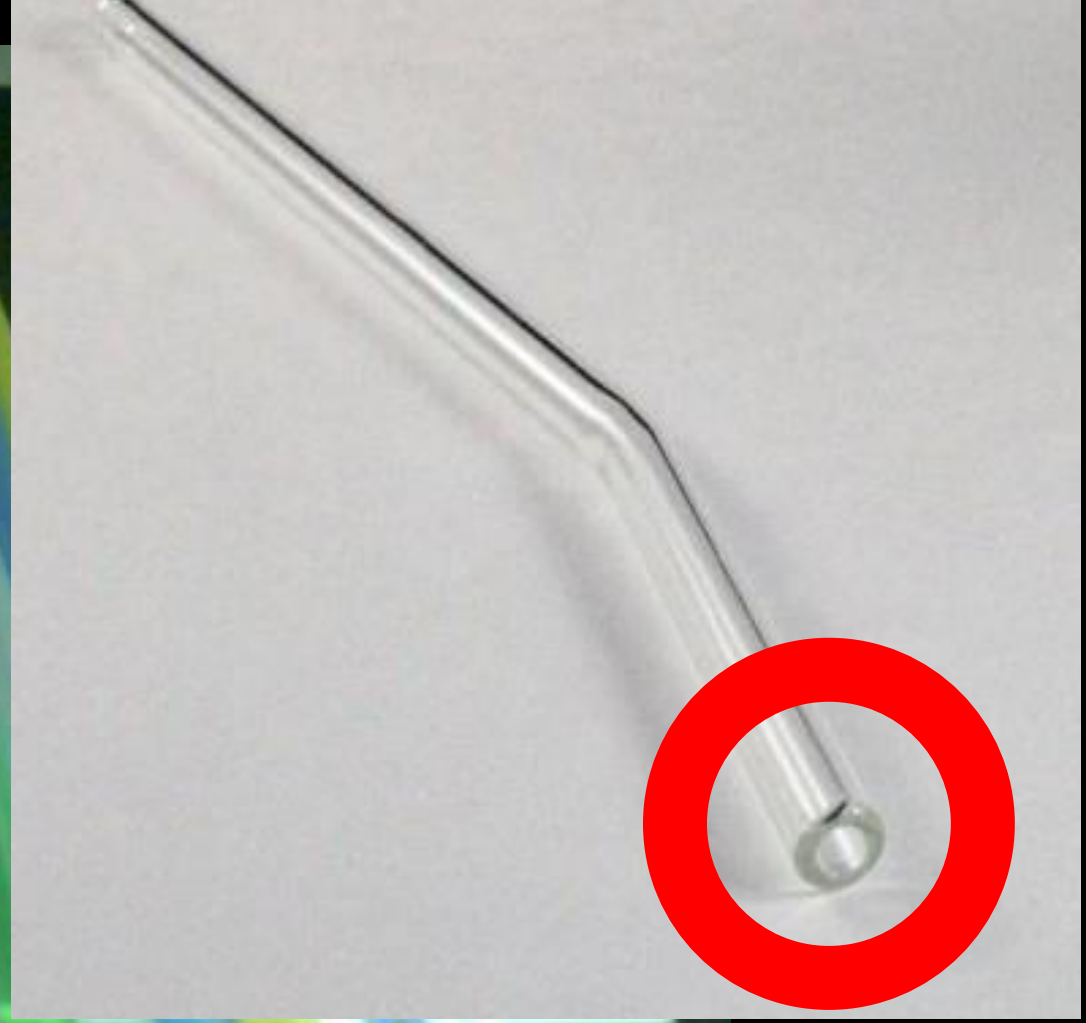
The arm is ***STRONG*** because it developed through use, NOT because it was inherited from a parent who had one arm that was strong than the other



Upper arms of 23 year old right-handed tennis player who started at age 9.

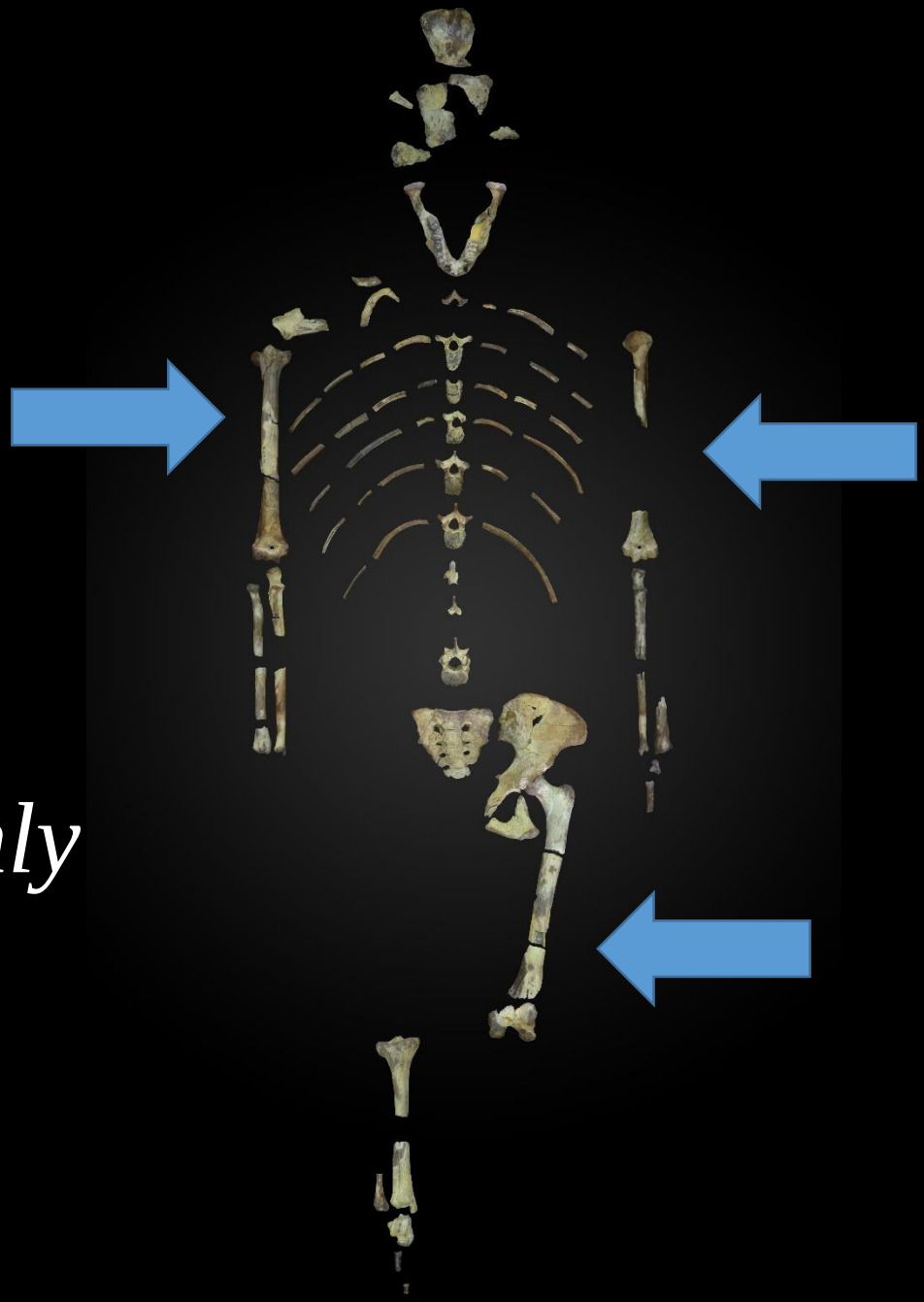
Cross-sectional geometry

Greater wall thickness
- greater strength
- more resistance to bending



This of study of limb bone architecture requires elements from the same individual.

Lucy is one of the only early human fossils complete enough to permit this study.



Need X-rays to see inside the bones, and computed tomography (CT) is best because we can obtain 3D images.

Perhaps your pet has had a CT scan?

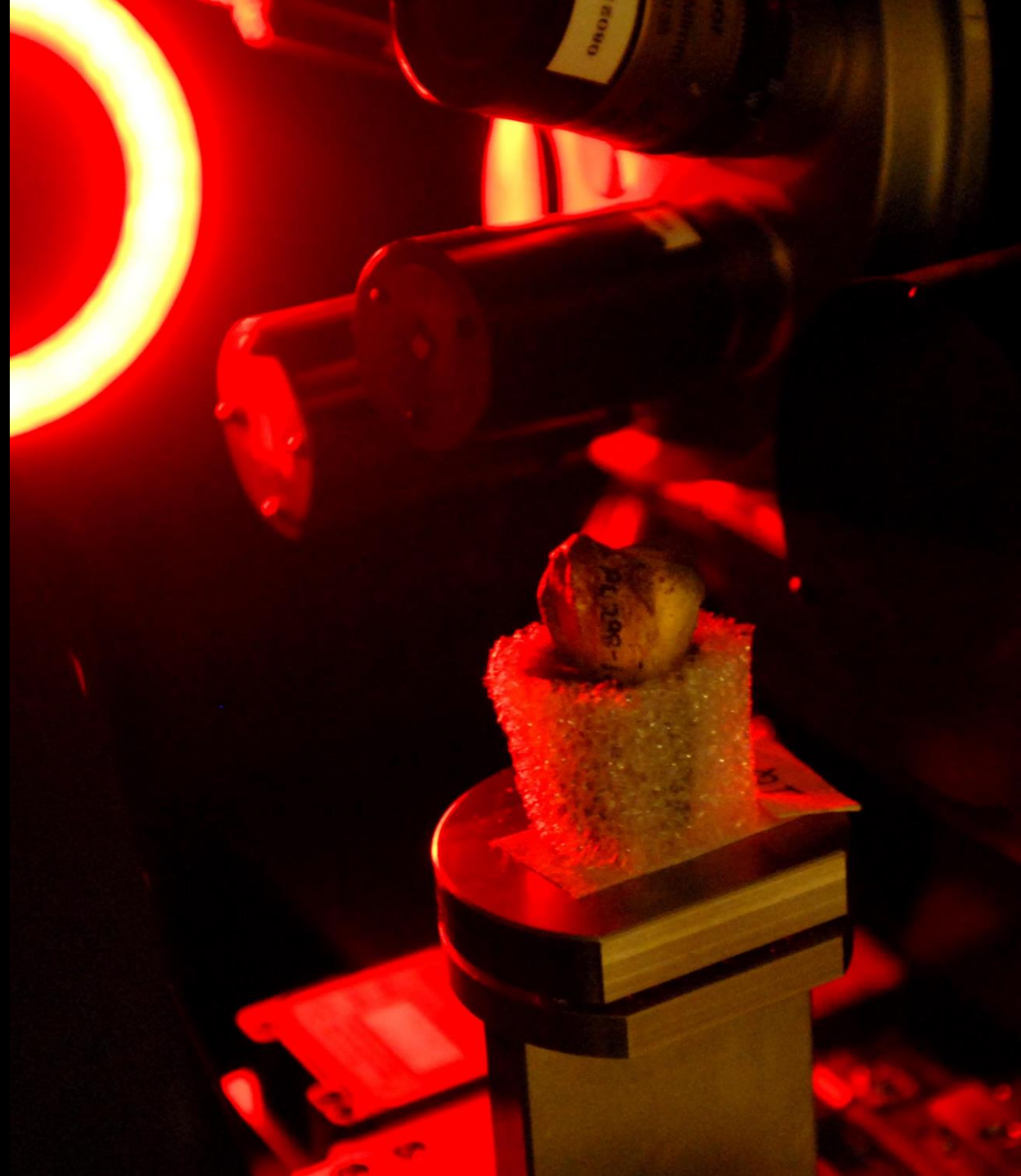
(“Rover: sit and stay!”)

High-resolution high-energy X-ray CT scanning

- Medical CT good for living people, not good for fossils

- Dream was to scan Lucy but room-sized 20 T lead box does not travel

- Lucy would have to come to UT Austin which was highly unlikely



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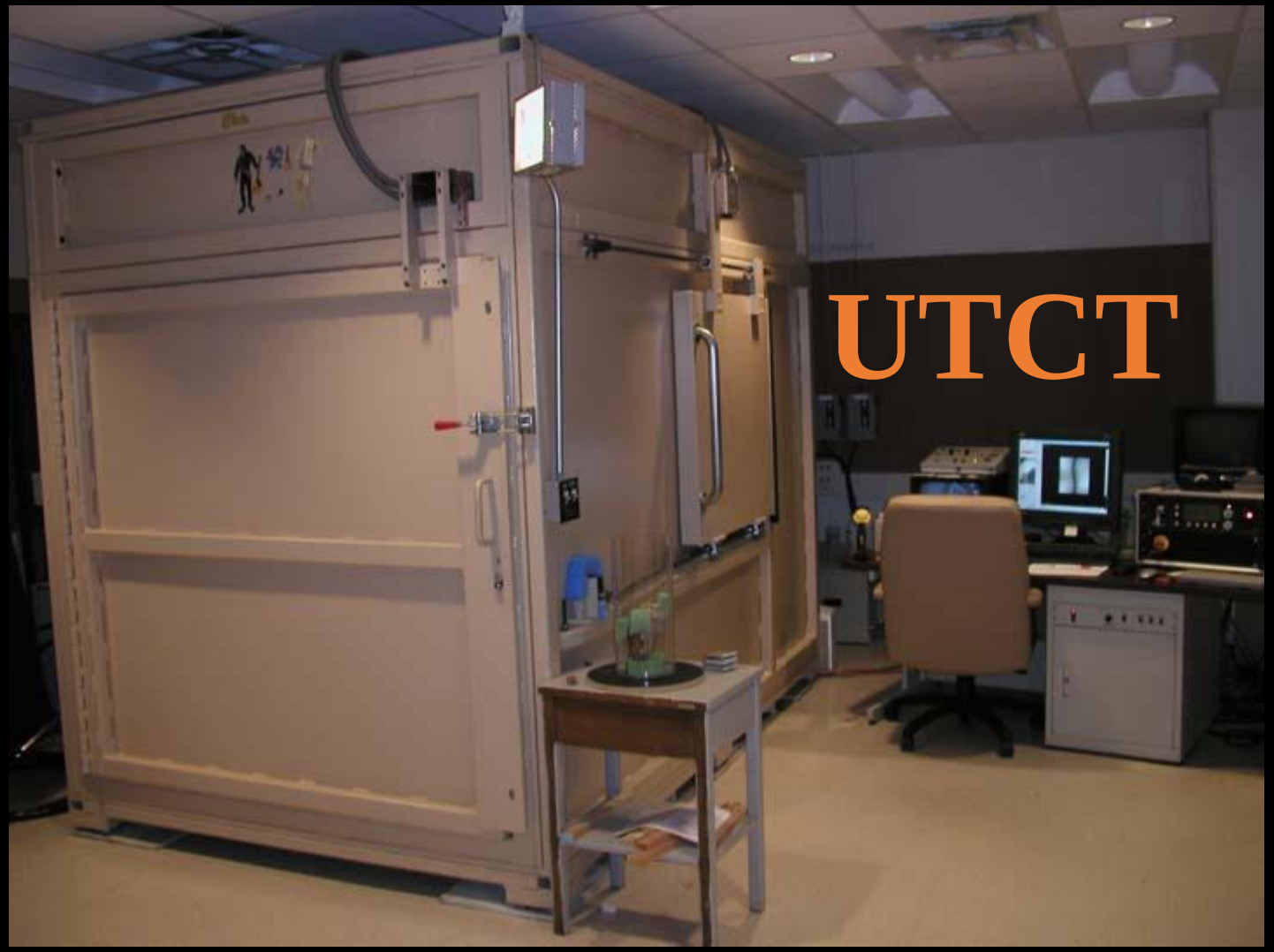

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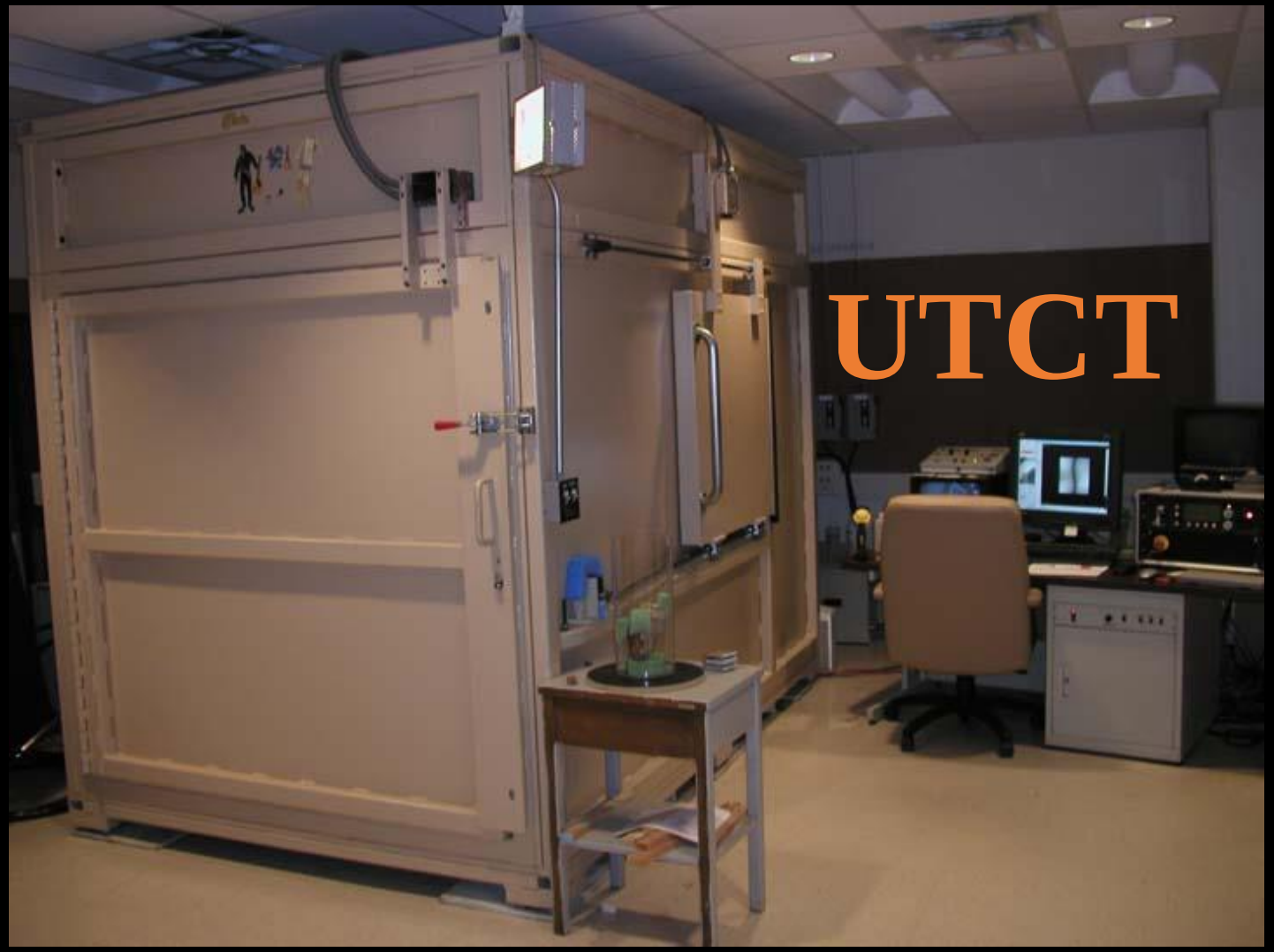


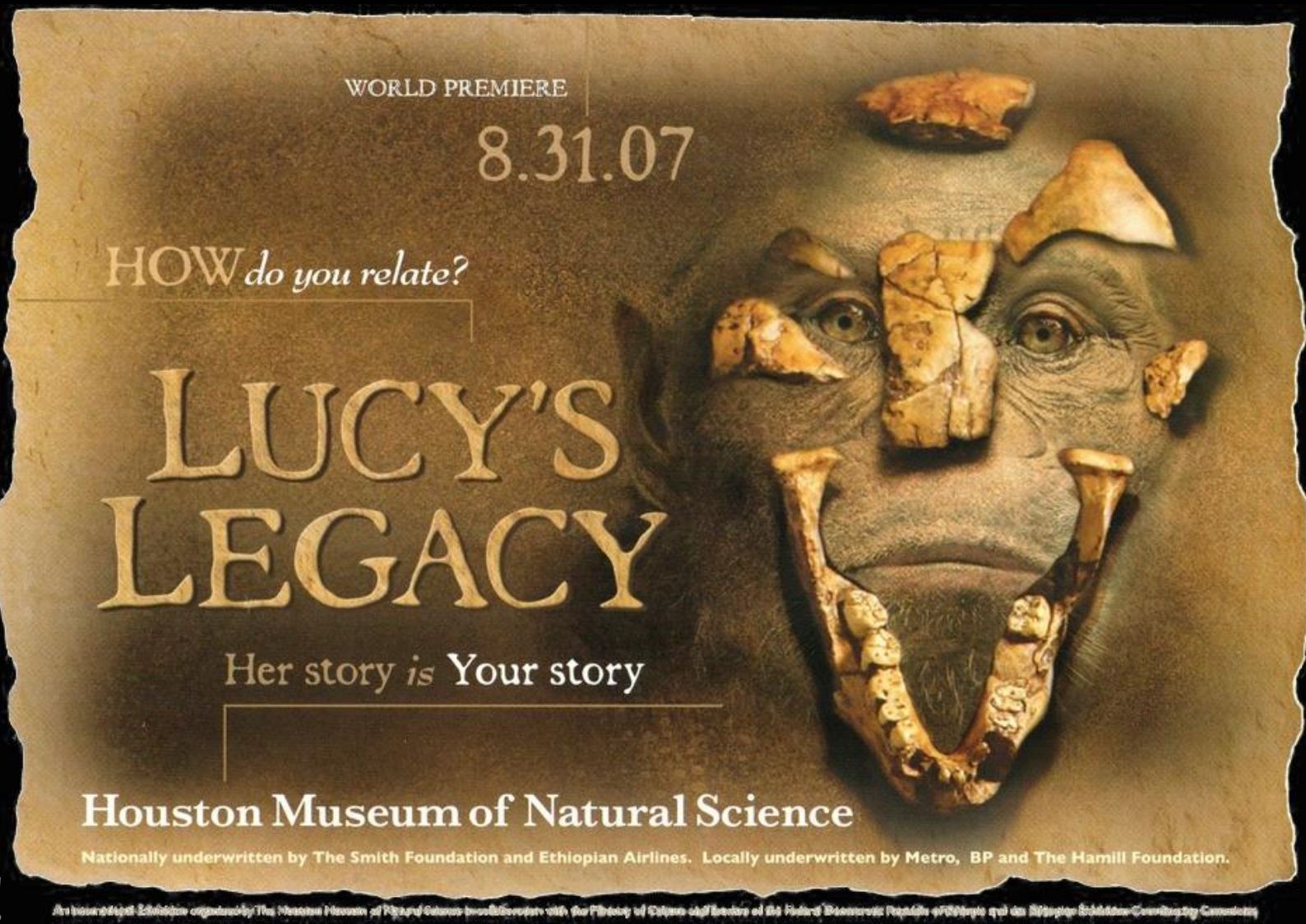
Be careful of the things you wish for…

- 2002: planning a US tour of Lucy and Ethiopian antiquities

- I began six years of negotiations to bring Lucy to UT Austin

- 2007: exhibit opened Houston Museum of Natural Science

- 2008: permission granted!



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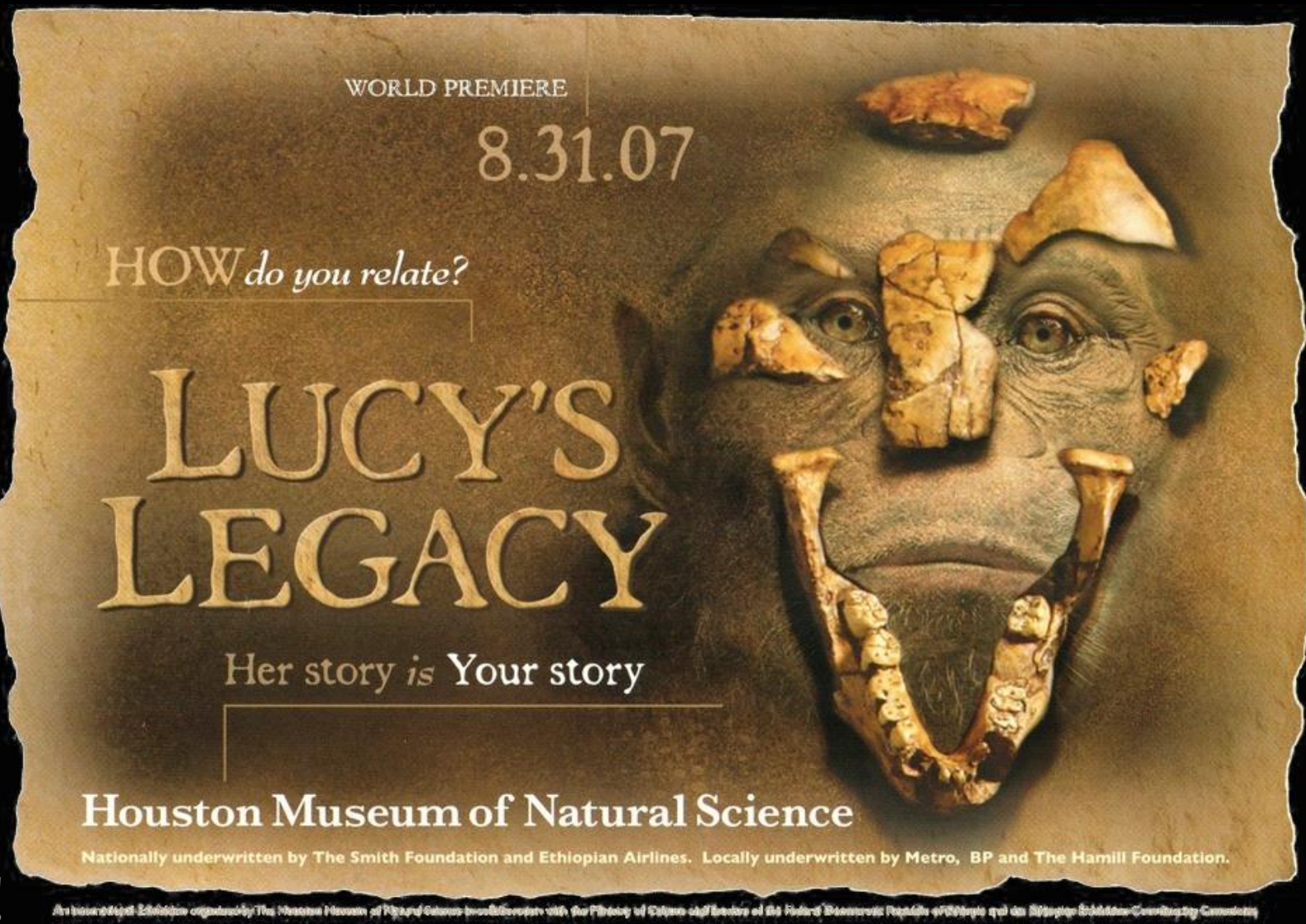

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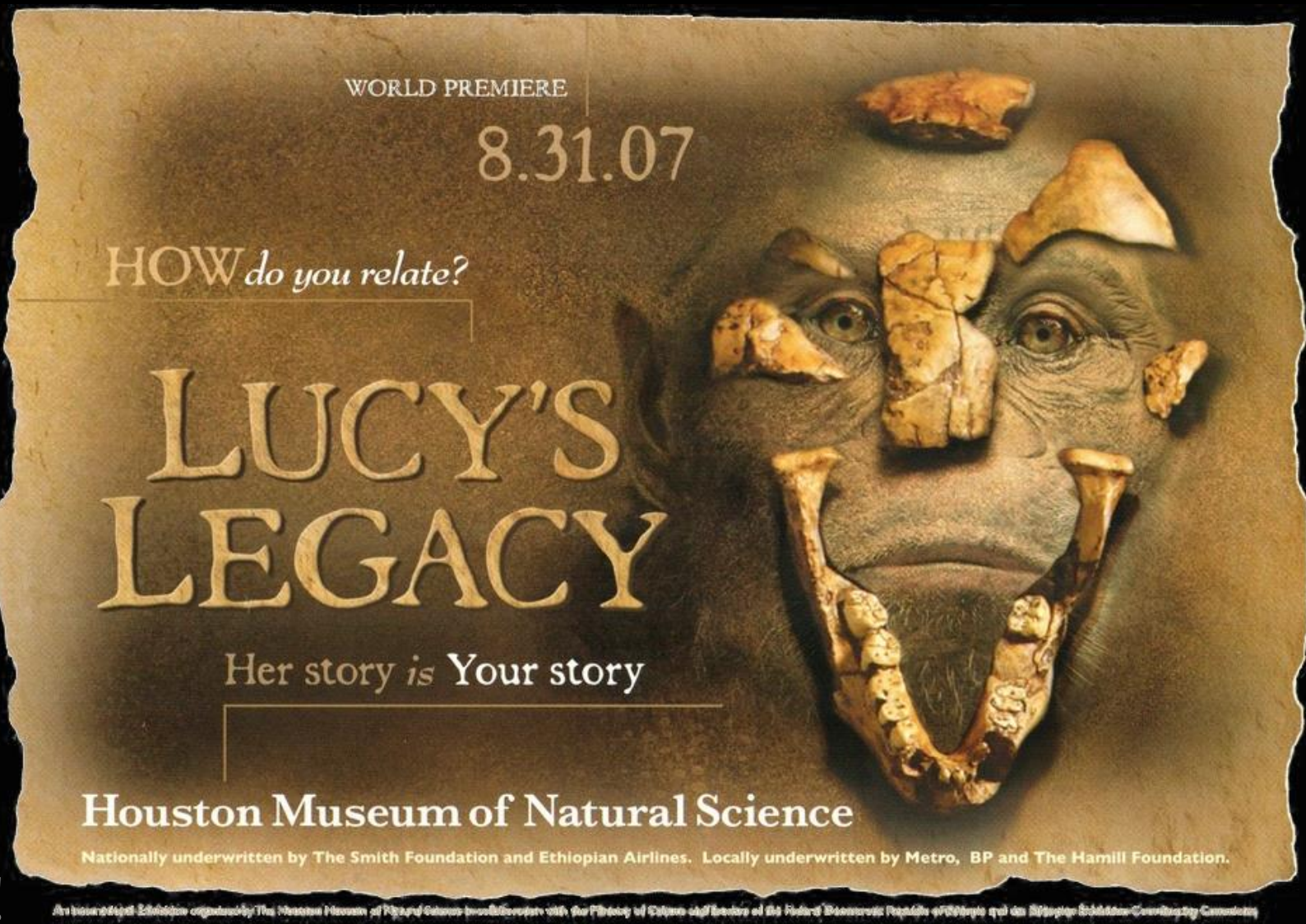

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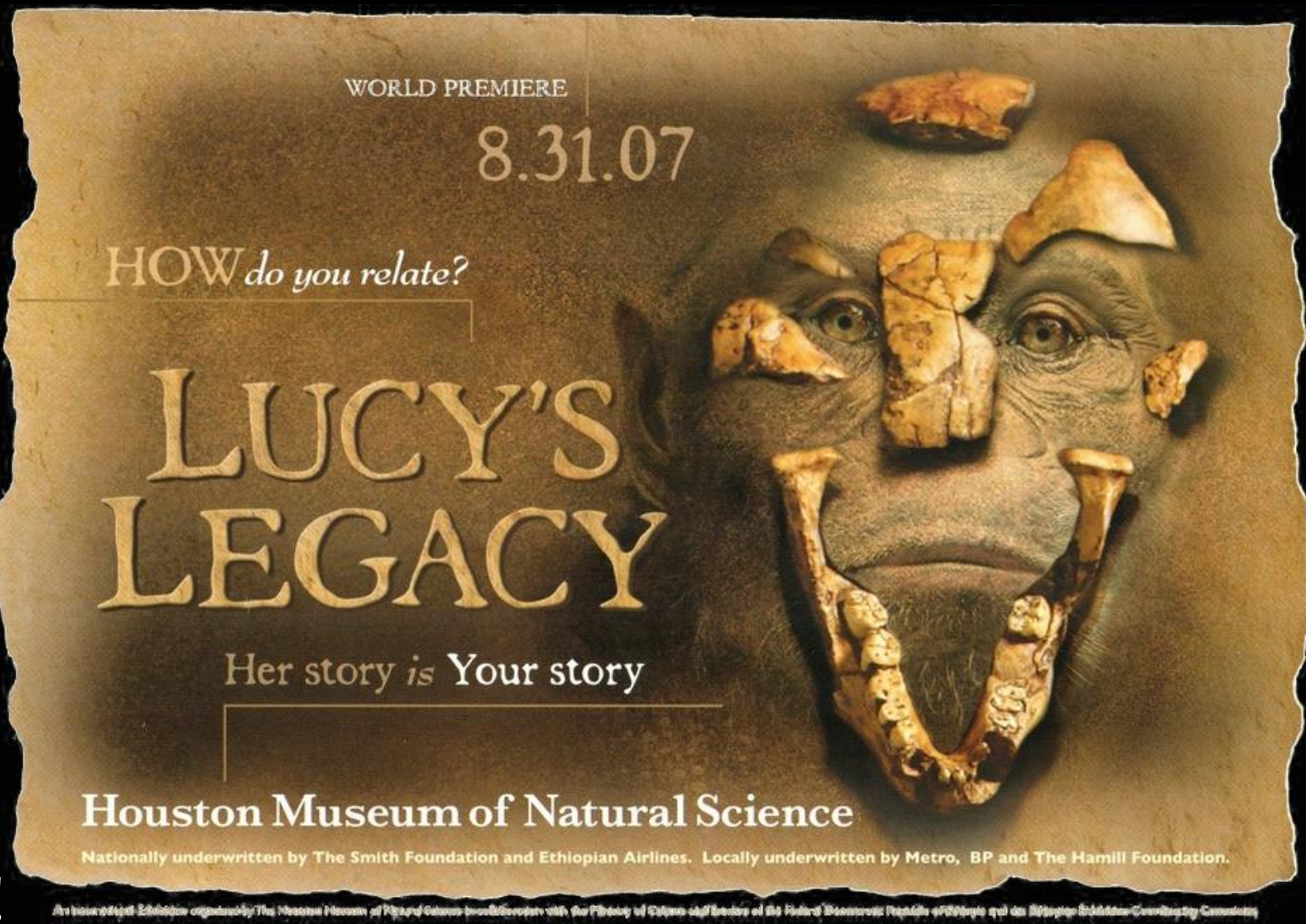

CT scan Lucy to learn in detail how she moved

- For 11 days and 24 hours per day we scanned every fragment of Lucy's skeleton
- Only Alemu Ademassu touched the actual fossil
- Every fragment was inspected before and after scanning by Ron Harvey, an independent conservator

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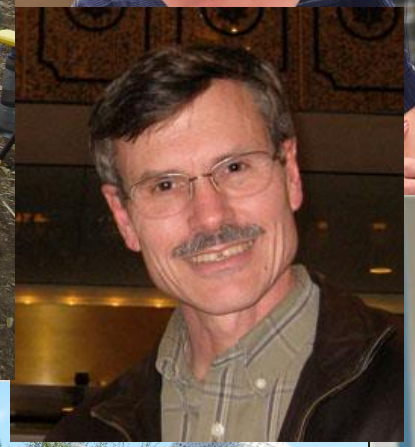


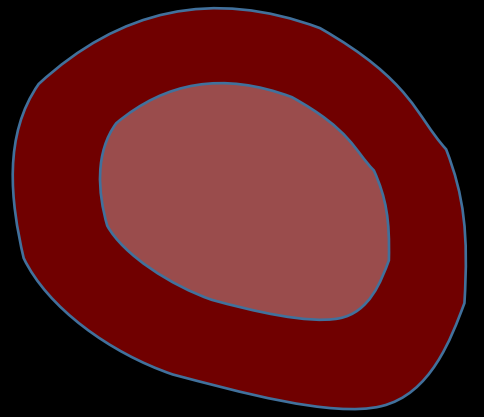

Team Lucy

Richard A. Ketcham
Stephen Pearce
Lawrence Todd
Wiley Akins
Matthew W. Colbert
Mulugeta Feseha
Jessica A. Maisano
Adrienne Witzel
Christopher Ruff
M. Loring Burgess

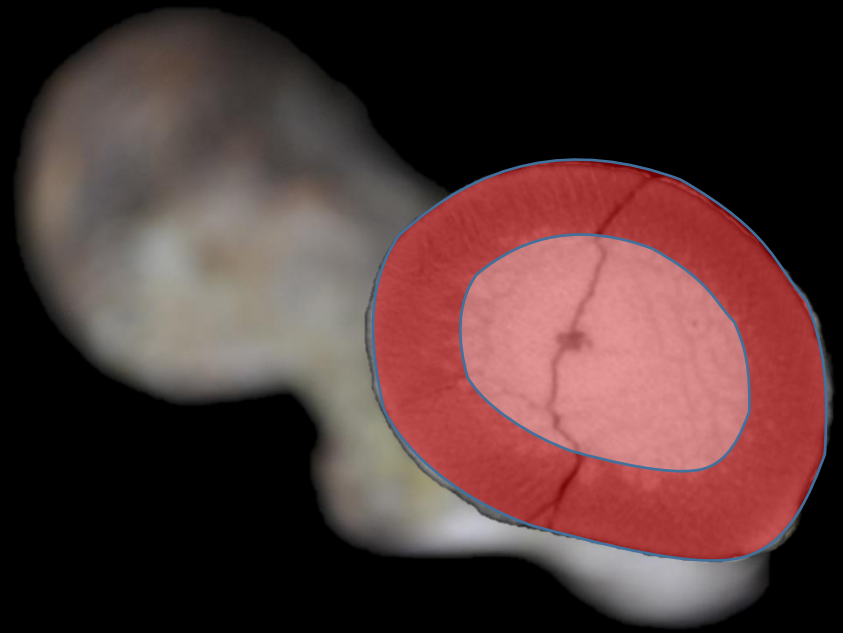


Results of high-resolution CT scanning

- Cross-section
  - Natural break in thigh bone (femur) shaft
  - High resolution CT scan



CT slice



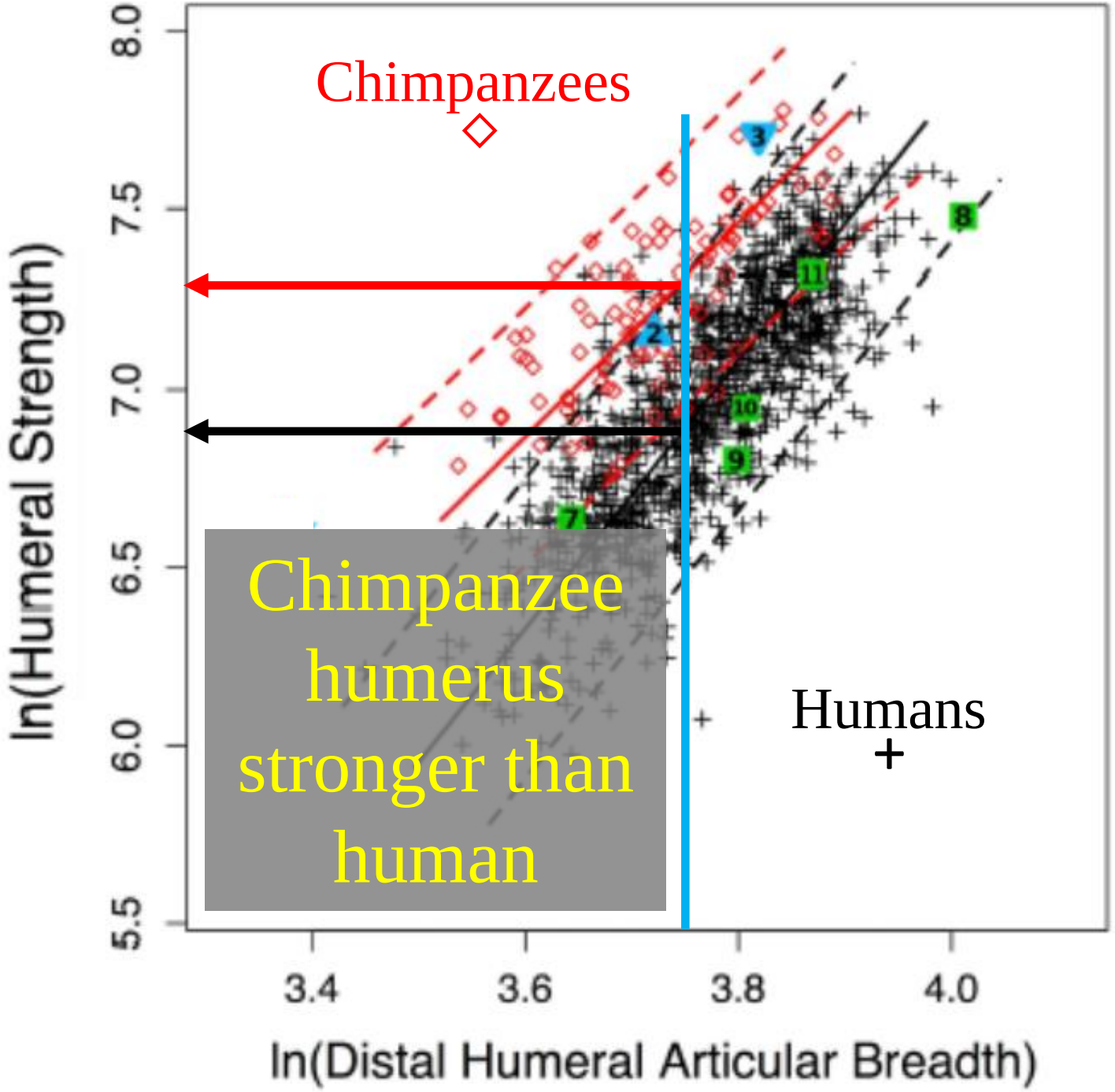
Bone

Humerus (upper arm bone)

Human
(n = 1756)

Chimpanzee
(n = 98)

Bones scaled to same length



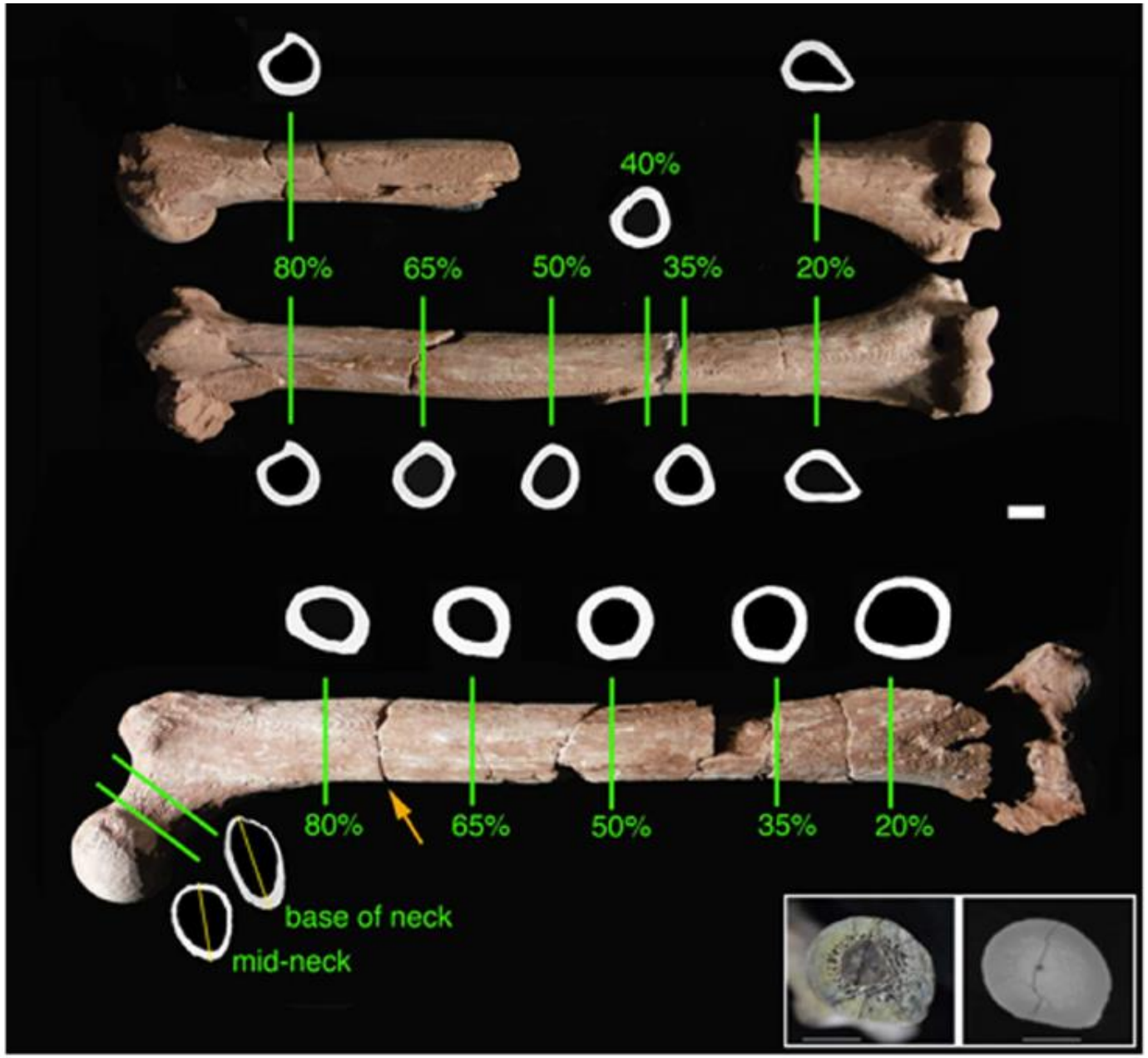


Fig 2. Section locations and cortical bone cross-sectional outlines for A.L. 288–1 humeri and femur, determined from CT scans. For diaphyseal sections, medial is to the left, anterior above; for femoral neck sections, anterior is to the left, superior above (medial and lateral orientations of (left) femur and left humerus reversed for consistency). Yellow lines through femoral neck sections indicate planes where superior and inferior cortical thicknesses were measured (as in [14]). Inset at lower right shows physical section (left) and CT image at an adjacent location (right) for a natural break in the femur at about 75% of length', indicated with an orange arrow in the main figure. Scale

Lucy's upper arm bone (humerus)

- thick internal bone

- very strongly built

Limb Bone Structural Proportions and Locomotor Behavior in A.L. 288-1 ("Lucy")

Christopher B. Ruff[1]*, M. Loring Burgess[1], Richard A. Ketcham[2], John Kappelman[2,3]

PLOS ONE | DOI:10.1371/journal.pone.0166095 November 30, 2016

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Lucy

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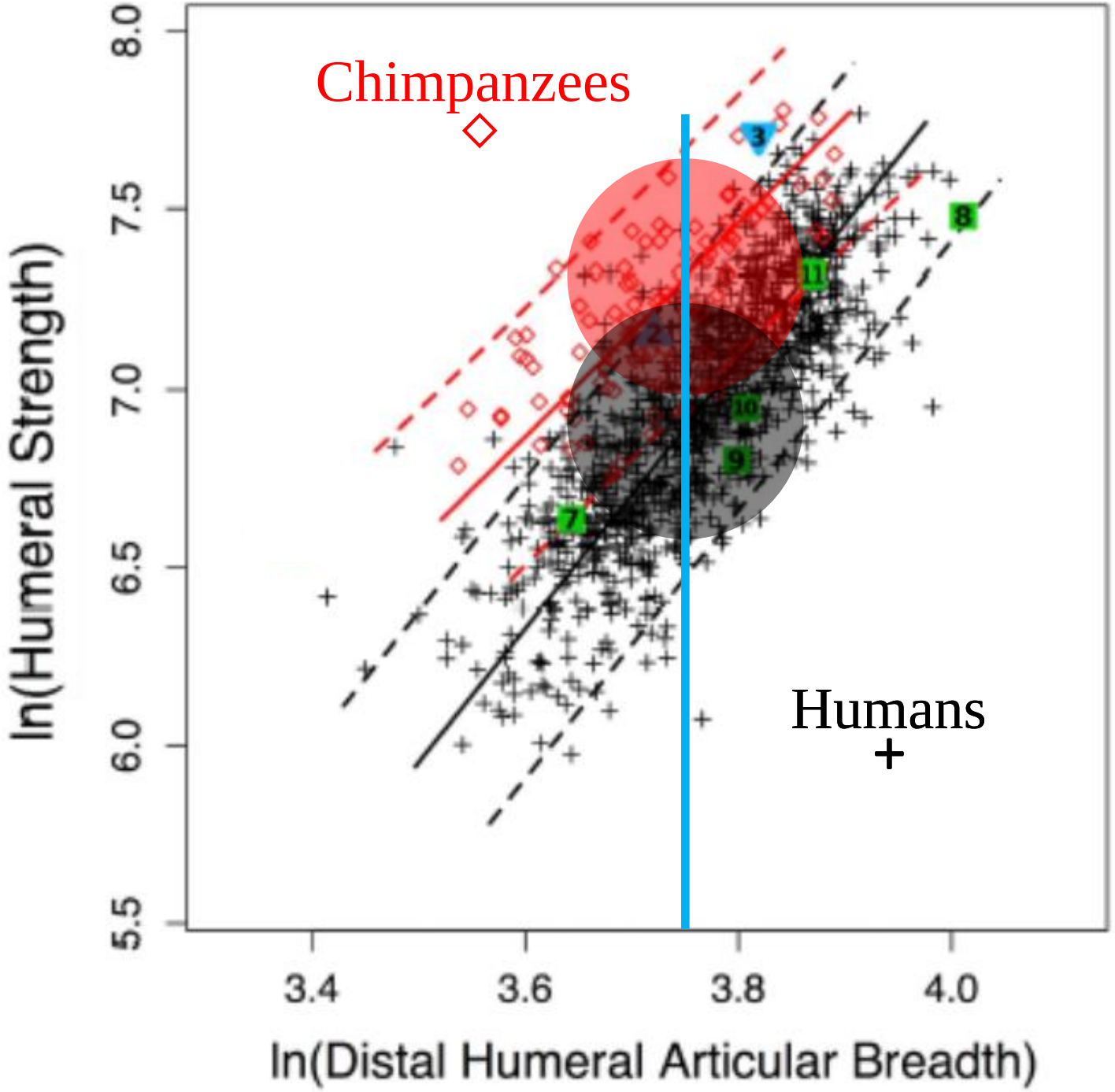
Bones scaled to same length



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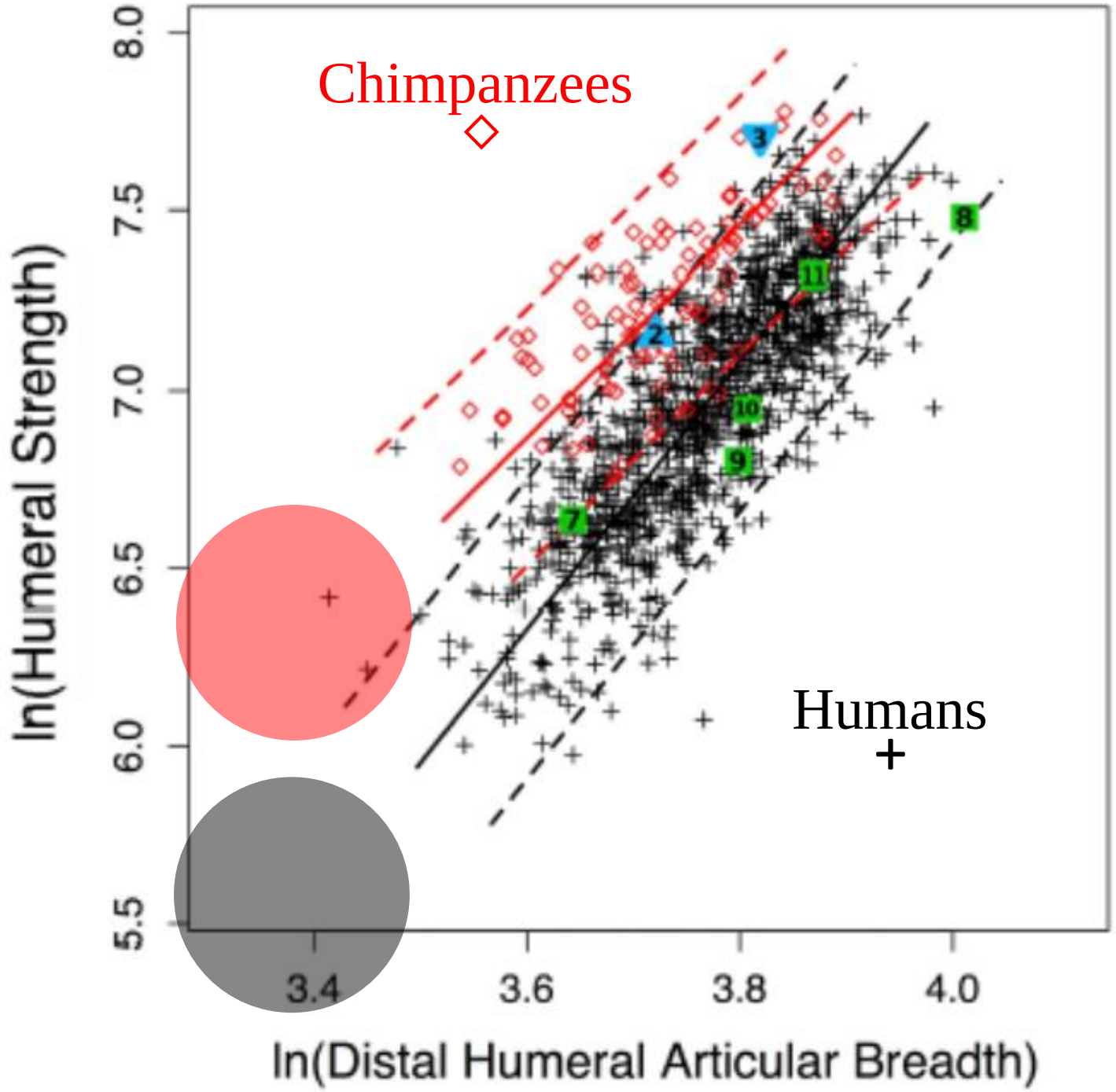

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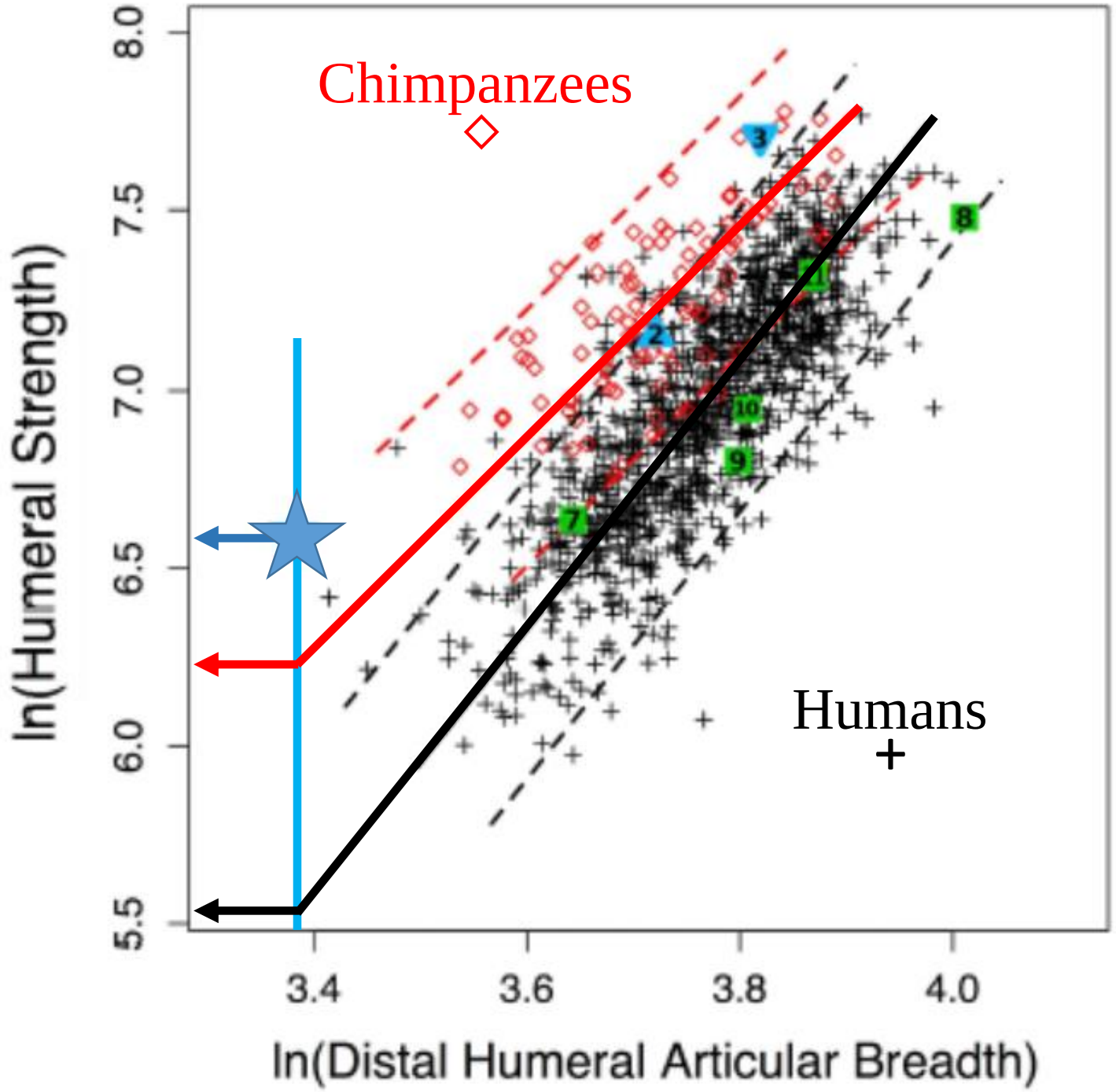
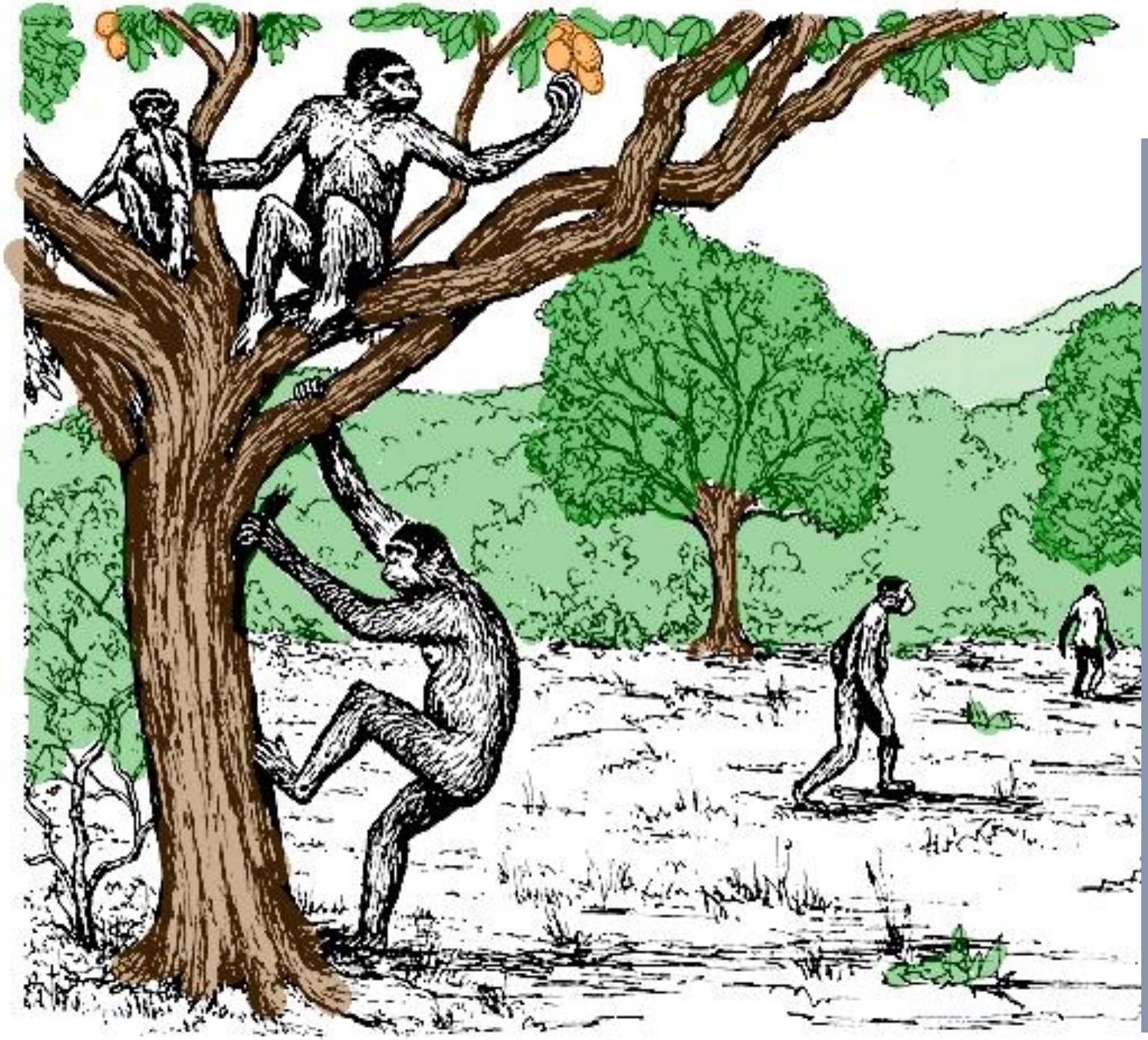
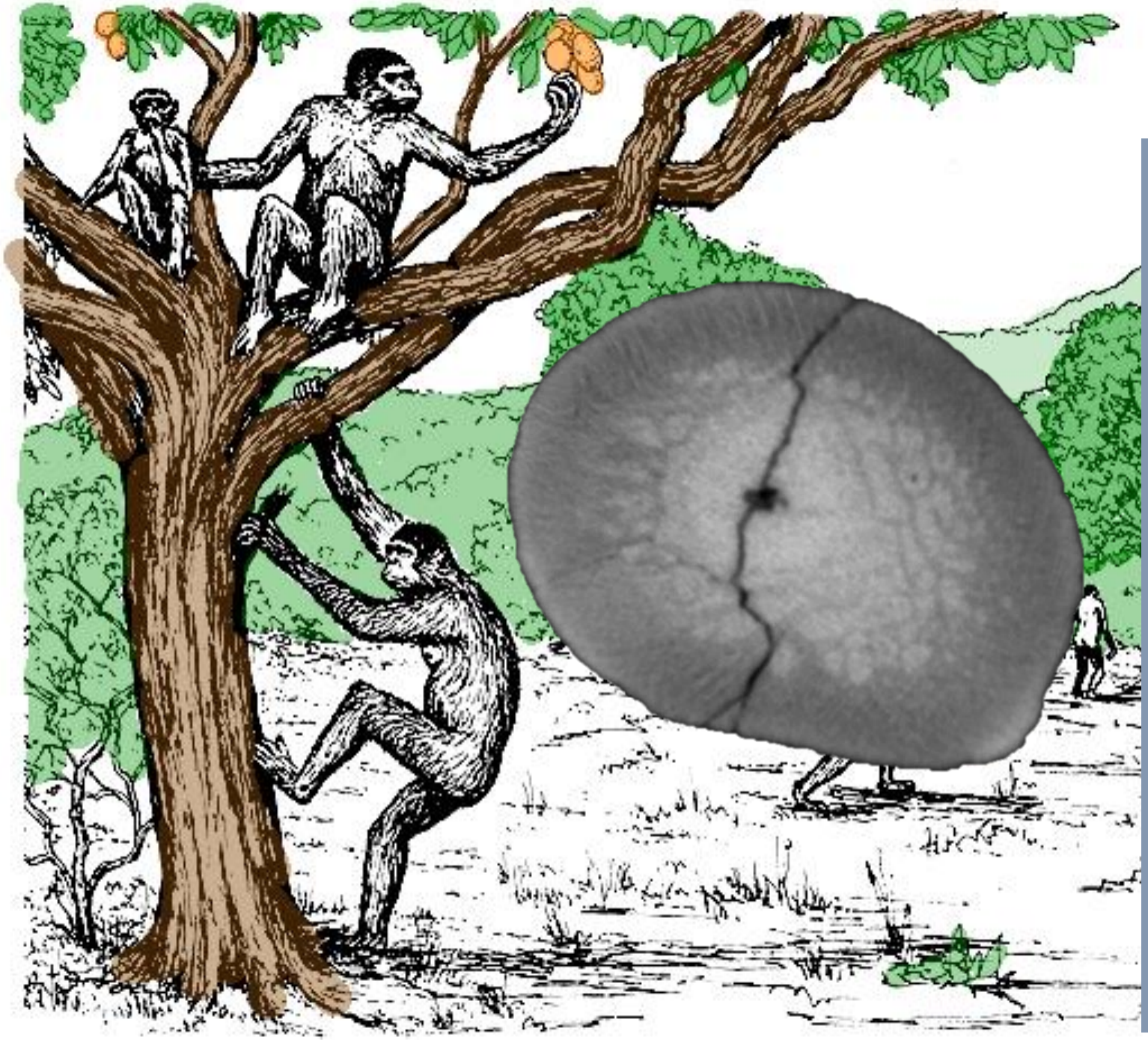




What did we discover about Lucy?

- Agree that she walked on two legs when she on the ground (bipedal)

- CT scans show that she *also* had very strong arms and probably spent a considerable amount of time climbing in the trees, probably foraging or nesting at night



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Saturday Night Live Weekend Update:

3 Dec 2016

R L

R L

Humerus

Tiny, sharp bone fragments

Anterior

Medial

Right humerus
~Posterior view

R L

R L

Humerus

Tiny, sharp bone fragments

Anterior

Medial

Right humerus
~Posterior view

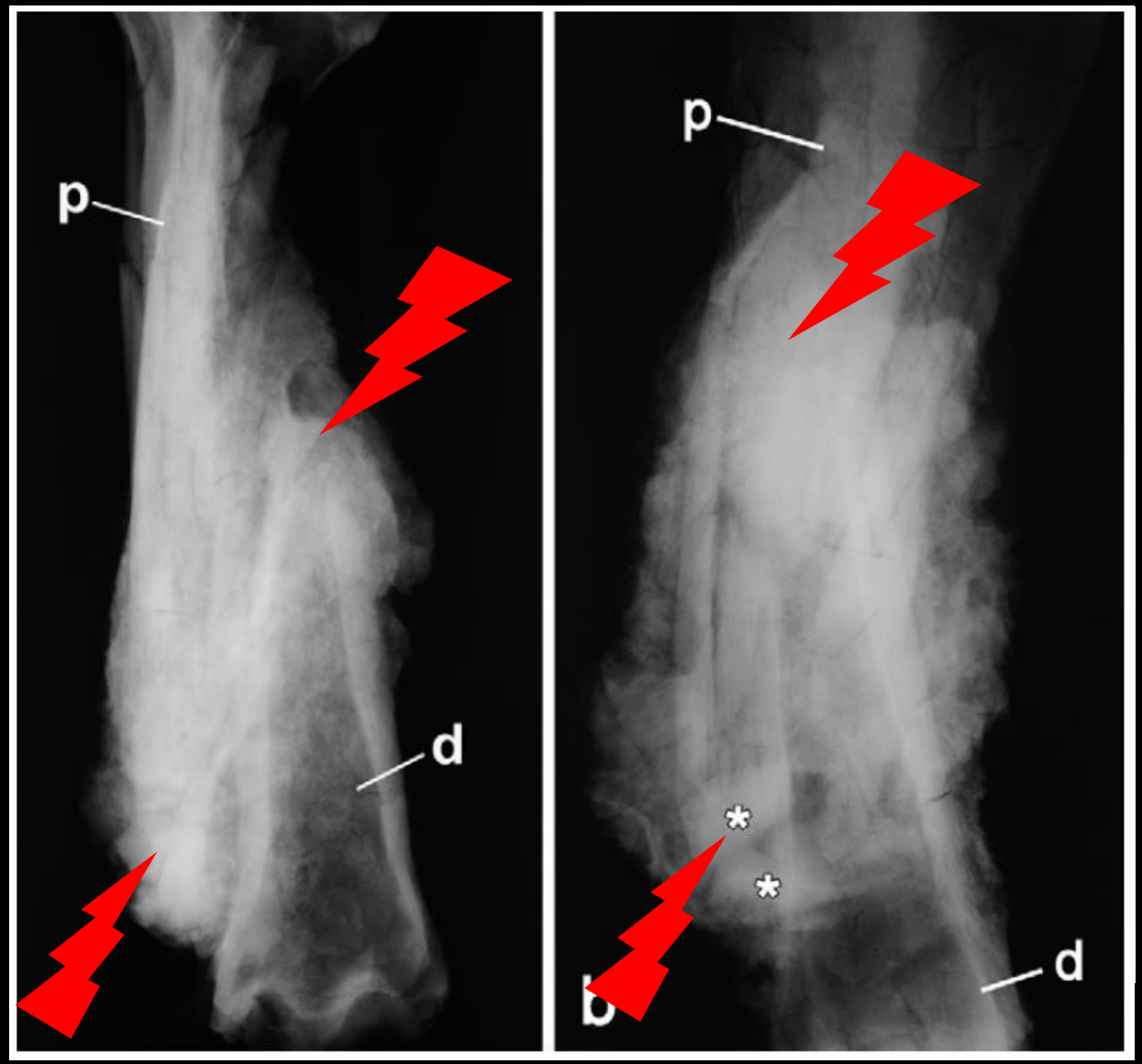
How do bones break?

Bone breakage

- Antemortem ("before death"): healed fracture contains fragments

- Postmortem ("after death"): often transverse to the length of the bone; dry breakage, fragments disperse on/into soil

- Perimortem ("at or near the time of death"): joint capsules and periosteum intact, fragments remain at injury site



Healed fracture (bison ~2 Ma)

International Journal of Paleopathology 2 (2012) 19–24

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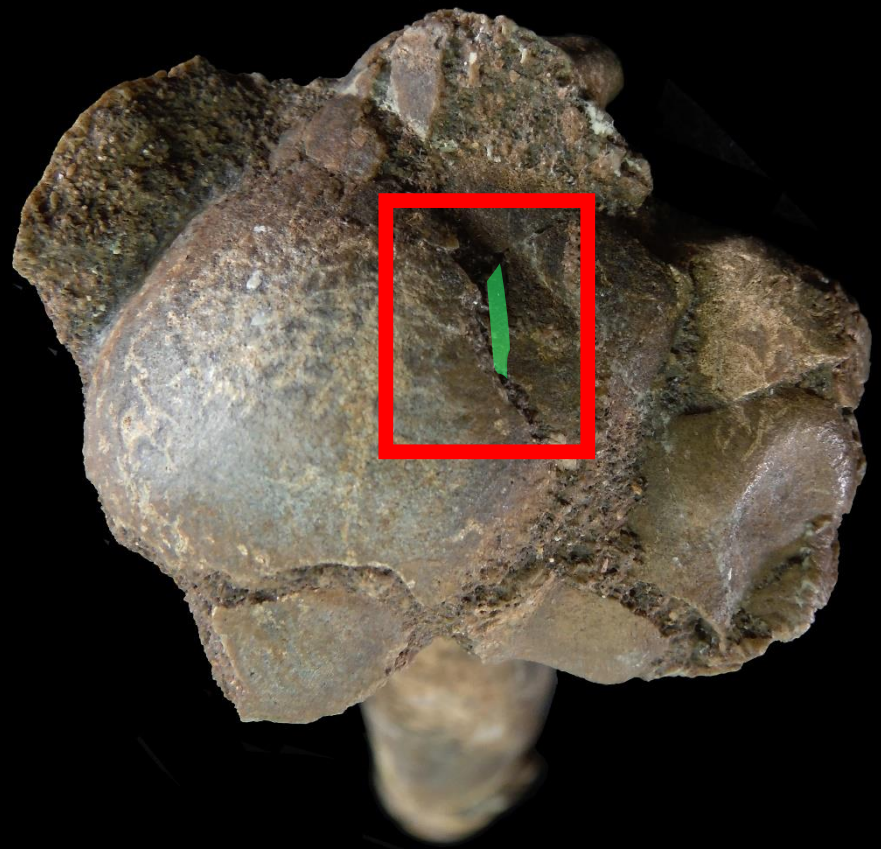
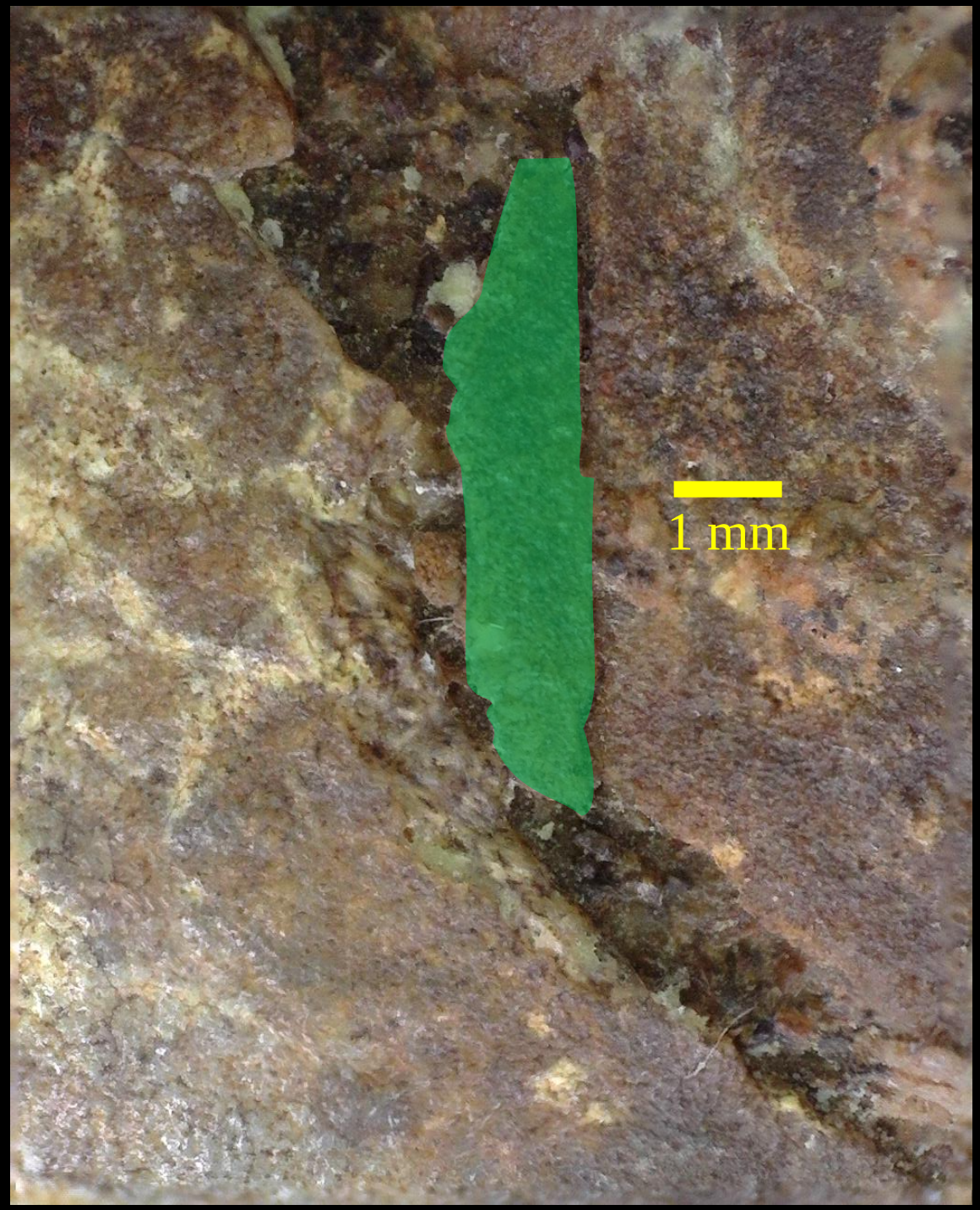
40 m fall from bridge, landed on face and front of body

Thali, M. J. & Oesterhelweg, L. D3. Incident-Specific Cases. In: *The Virtopsy Approach: 3D Optical and Radiological Scanning and Reconstruction in Forensic Medicine.* (eds. Thali, M. J., Dirnhofer, R., & Vock, P.) 219-387 (CRC Press, Boca Raton, Florida, 2009).

Right proximal humerus: numerous tiny bone fragments and slivers (<1 x 5 mm), bone compressed into itself





Larry Todd

Typical postmortem breakage patterns

Odocoileus hemionus

~24 months postmortem

One ***Tun***-dra of force

Fractured, but no compression

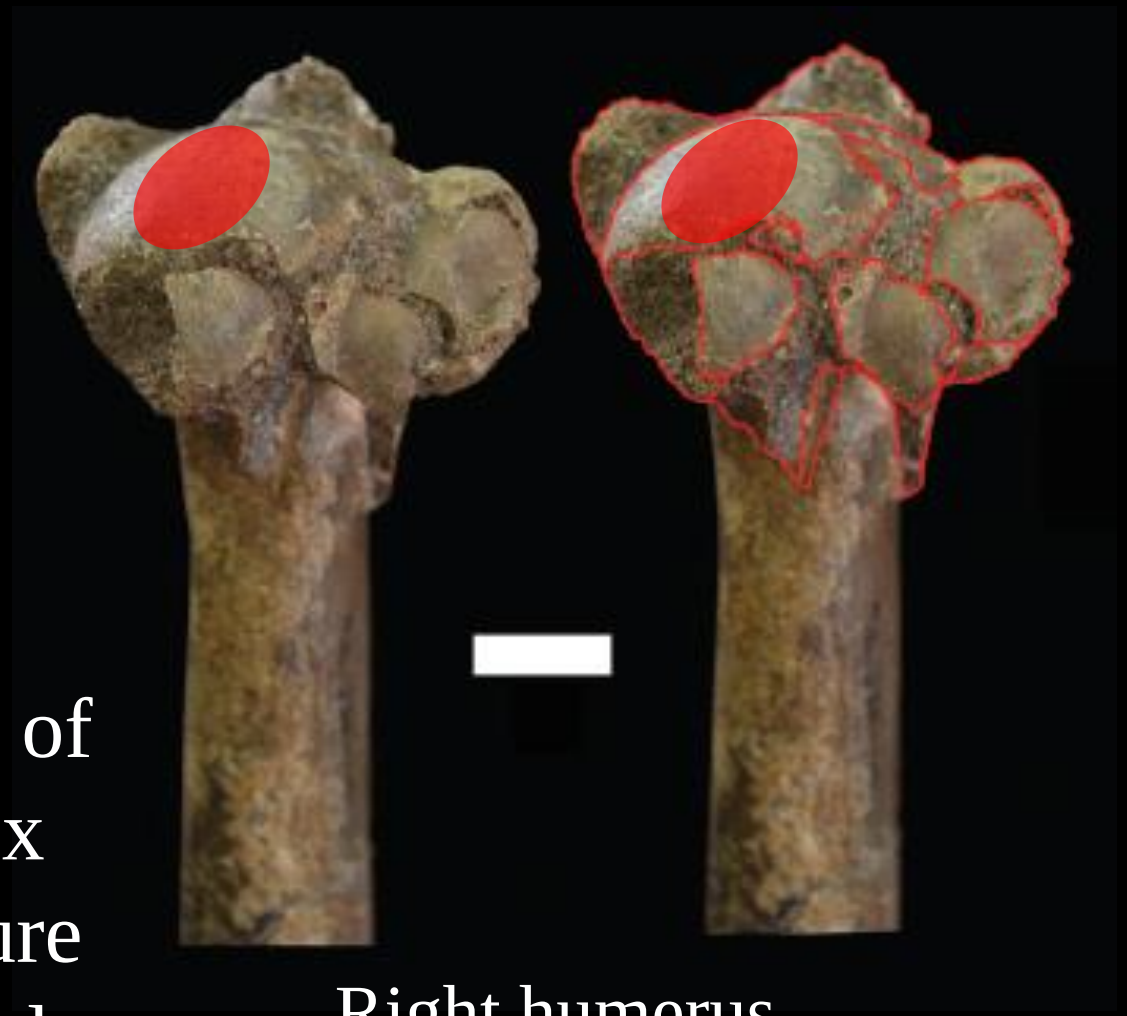
Typical postmortem breakage patterns

F-150

Multiple fragments & slivers preserved *in situ*: what sort of fracture is it?

Compressive perimortem fracture?

Portion of convex curvature of head preserved



Right humerus ~posterior, stereo view

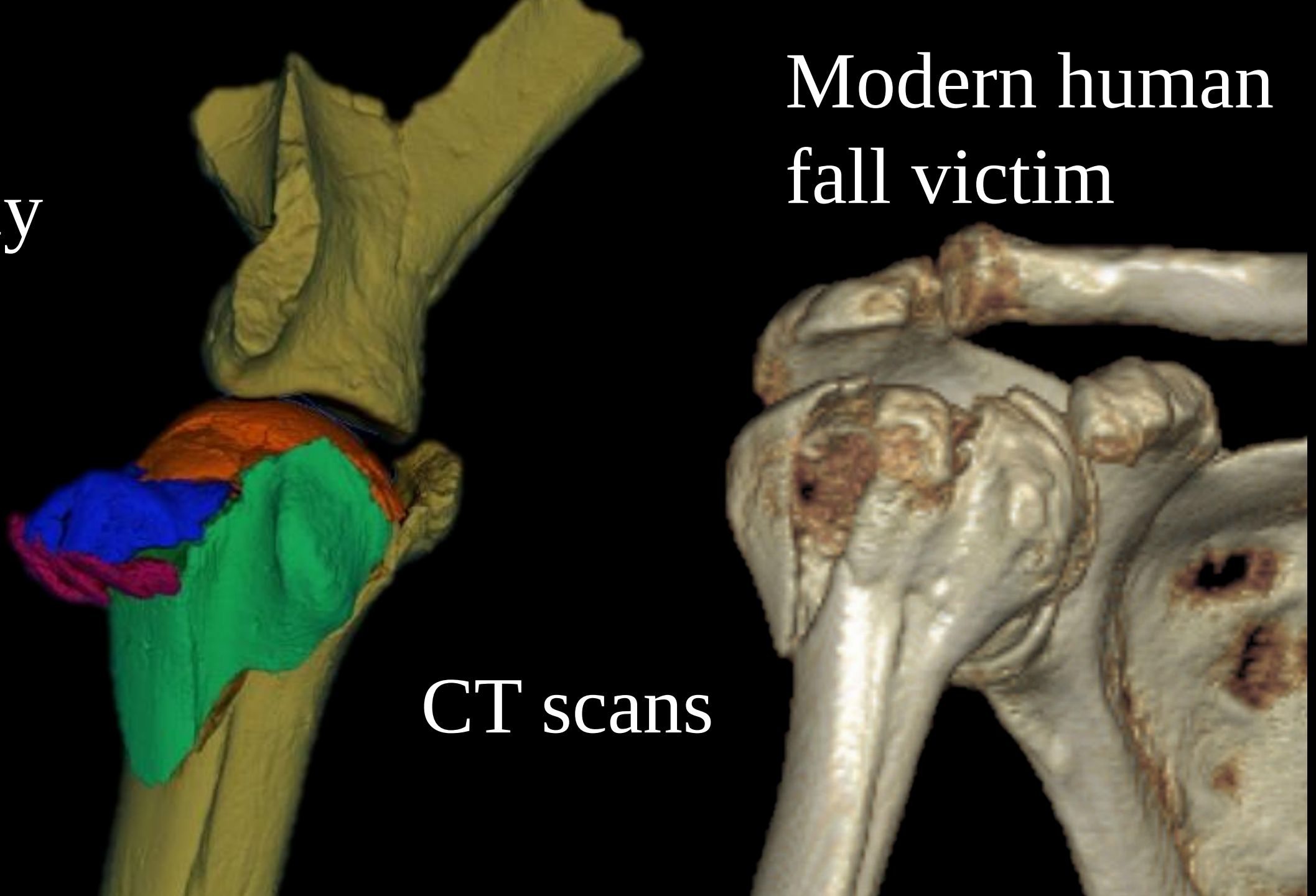
Four-part proximal humerus fracture:

Shoulder joint fracture:
impact following a fall – known as a ***vertical deceleration event –*** drives joint of shoulder blade (glenoid) into the upper arm joint (humeral head)

a unique signature of injury

Lucy

Modern human
fall victim



CT scans

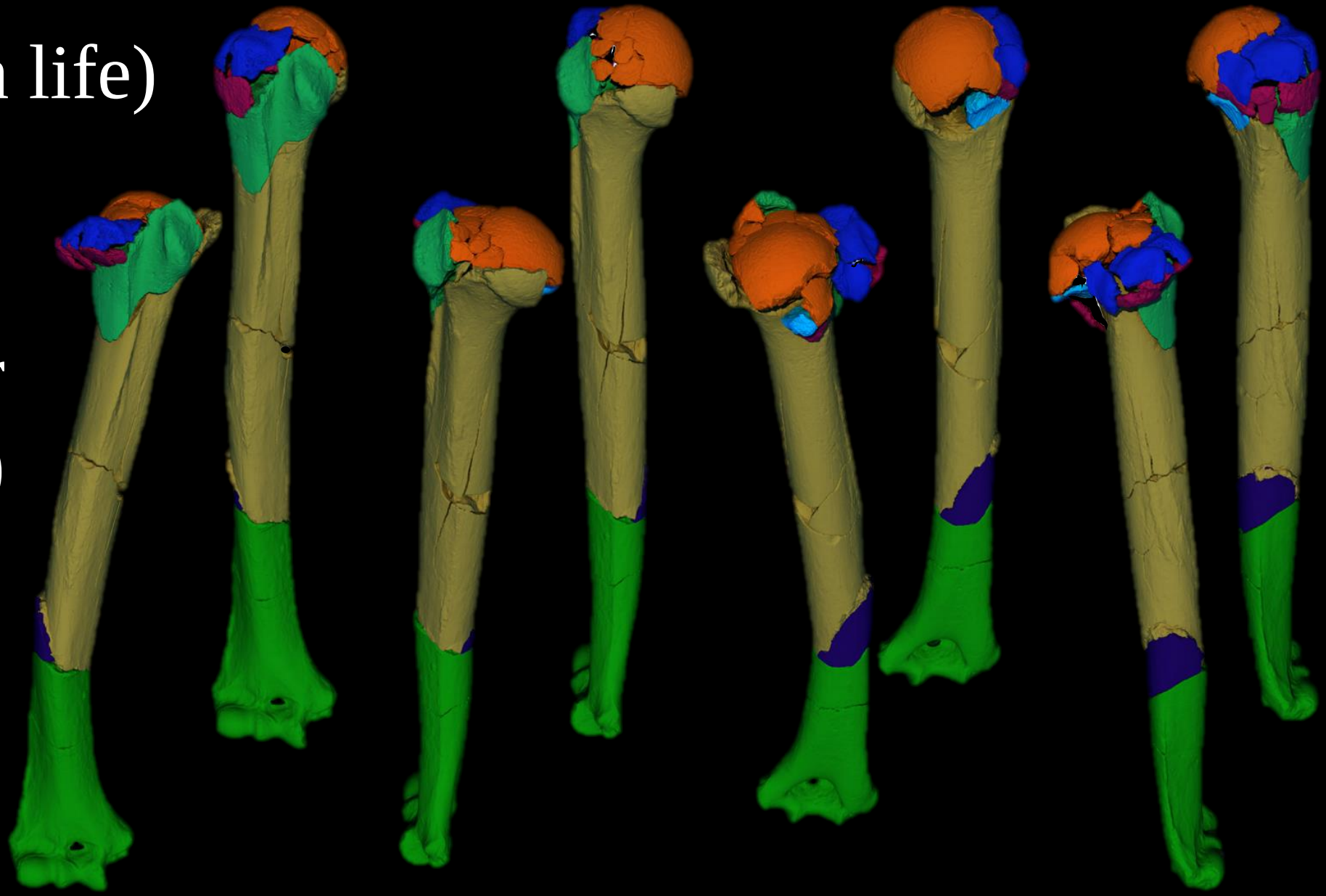
Lucy proximal humerus: ***supersized*** human-scale 3D printout

Dr. Stephen Pearce
Austin Bone and Joint Clinic
Austin, TX

Dr. Tom Helpenstell & Associates
Olympia Orthopaedic Associates, Seattle, WA

Before (in life)

After
(post-injury)



CT segmentation & reconstruction of right proximal humerus

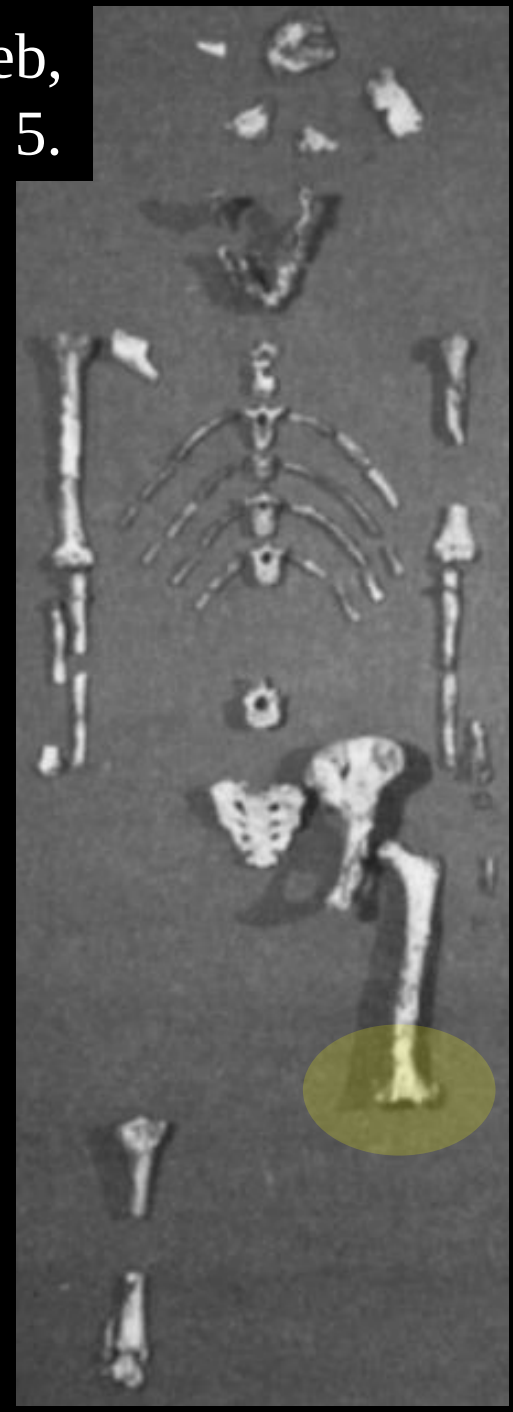
Four-part proximal humerus fracture

Compressive fracture of head by impact with shoulder blade

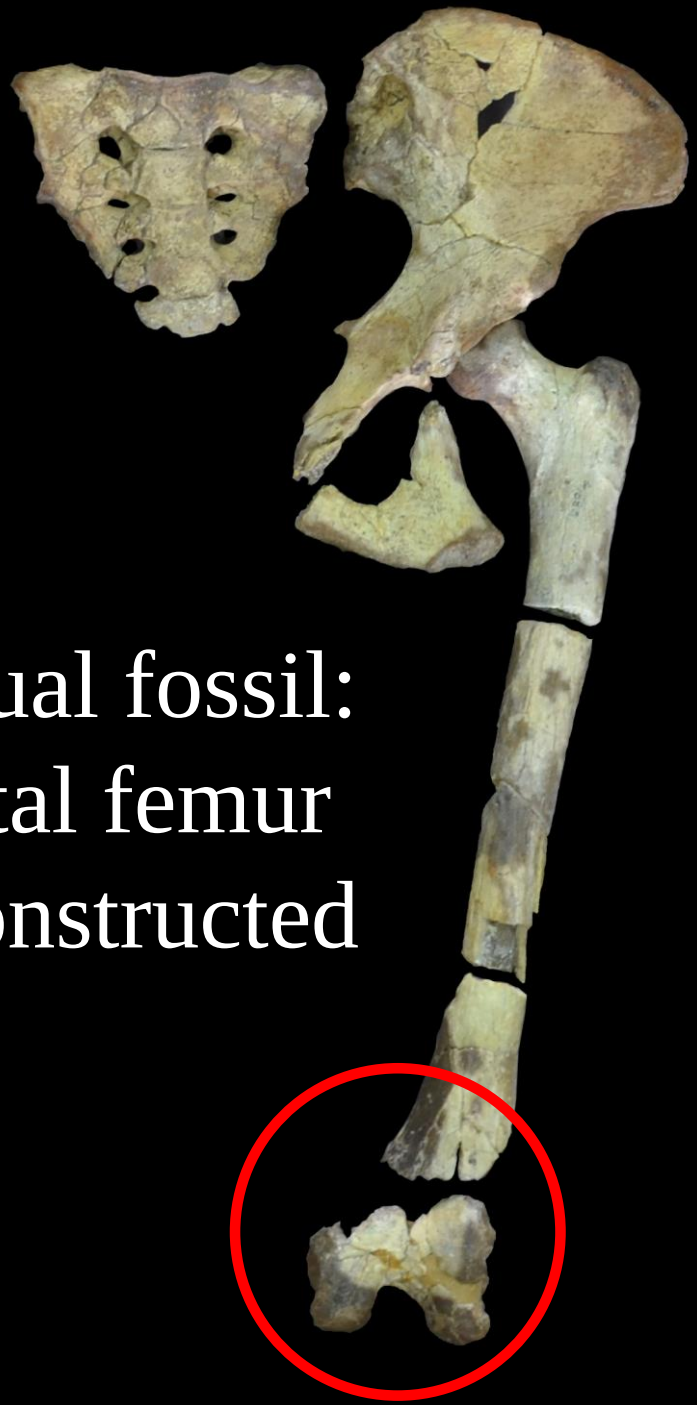
Spiral fracture of shaft

Johanson and Taieb,
Nature 1976: Fig. 5.

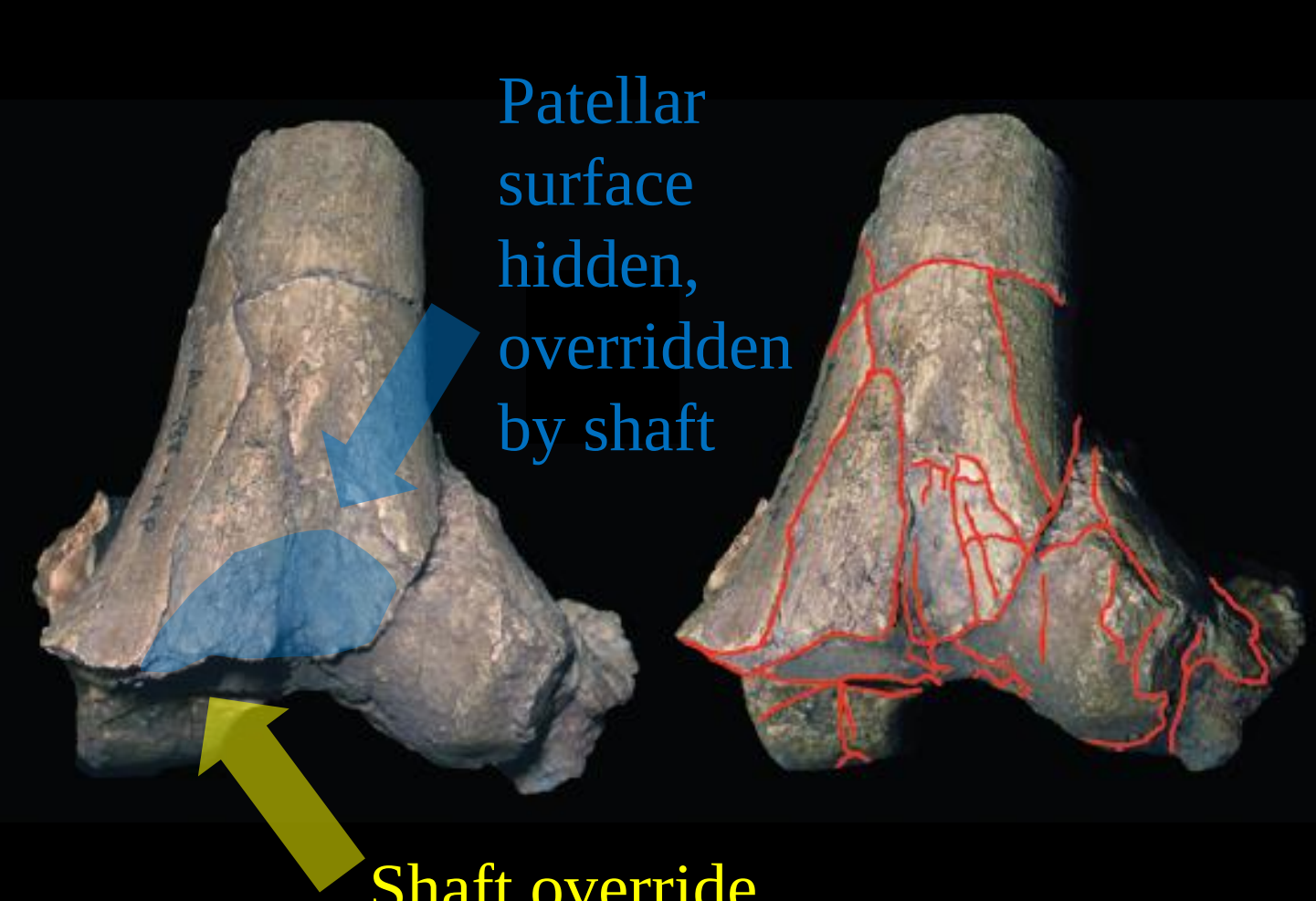
Lower end of
thighbone
(left knee)
[left distal femur]



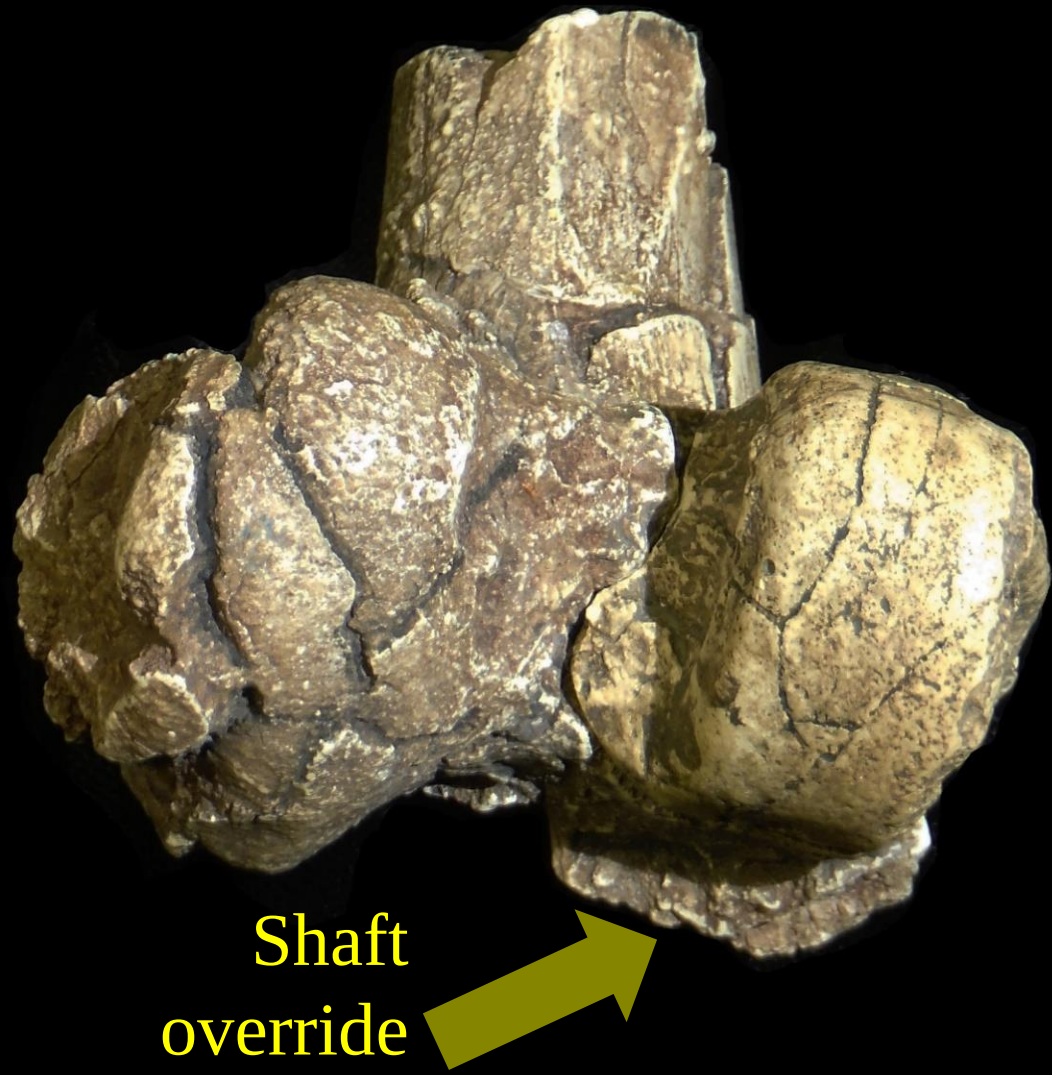
Actual fossil:
distal femur
reconstructed



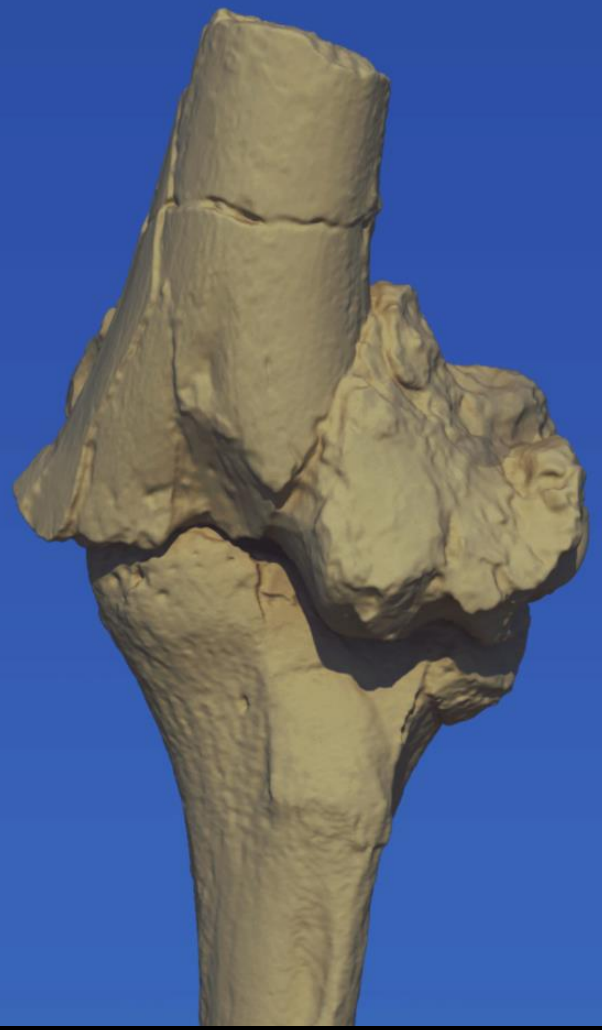
Cleveland casts + UT medial condyle (not to same scale)



ANTERIOR (stereo)



POSTERIOR



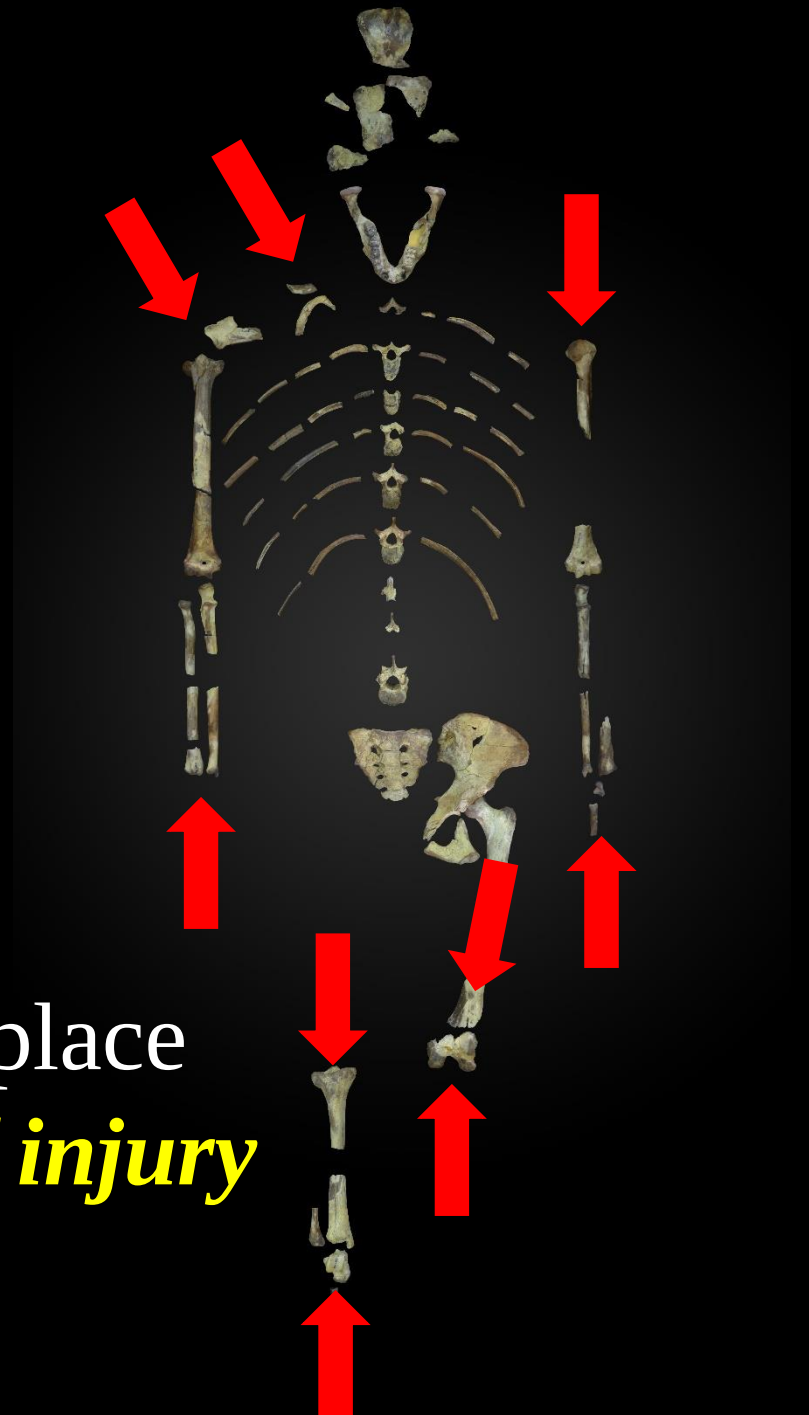
Compressive fracture by impact between femur and tibia dislocates the knee and drives it into the shaft.

X-ray of compressive fracture of knee produced by impact following a fall

http://z0mbie.host.sk/Fractures-of-the-Distal-Femur.html

Bone-to-bone compressive fractures are preserved at several major joints:

- Right (severe) and left shoulders
- Clavicle & first rib
- Right wrist
- Left knee
- Right knee
- Right ankle



Small, sharp bone fragments remaining at place of fracture along with ***unique signature of injury*** strongly suggest ***perimortem*** fractures

If perimortem, several mechanisms produce bone fractures:

- Lightning strikes or seizure-generated fractures (violent tetanic muscle contractions)
- Blunt force trauma by impact with debris during floods
- Injuries and fractures caused by animals

Link

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Yellowstone bison and visitor

If perimortem, several mechanisms produce bone fractures:

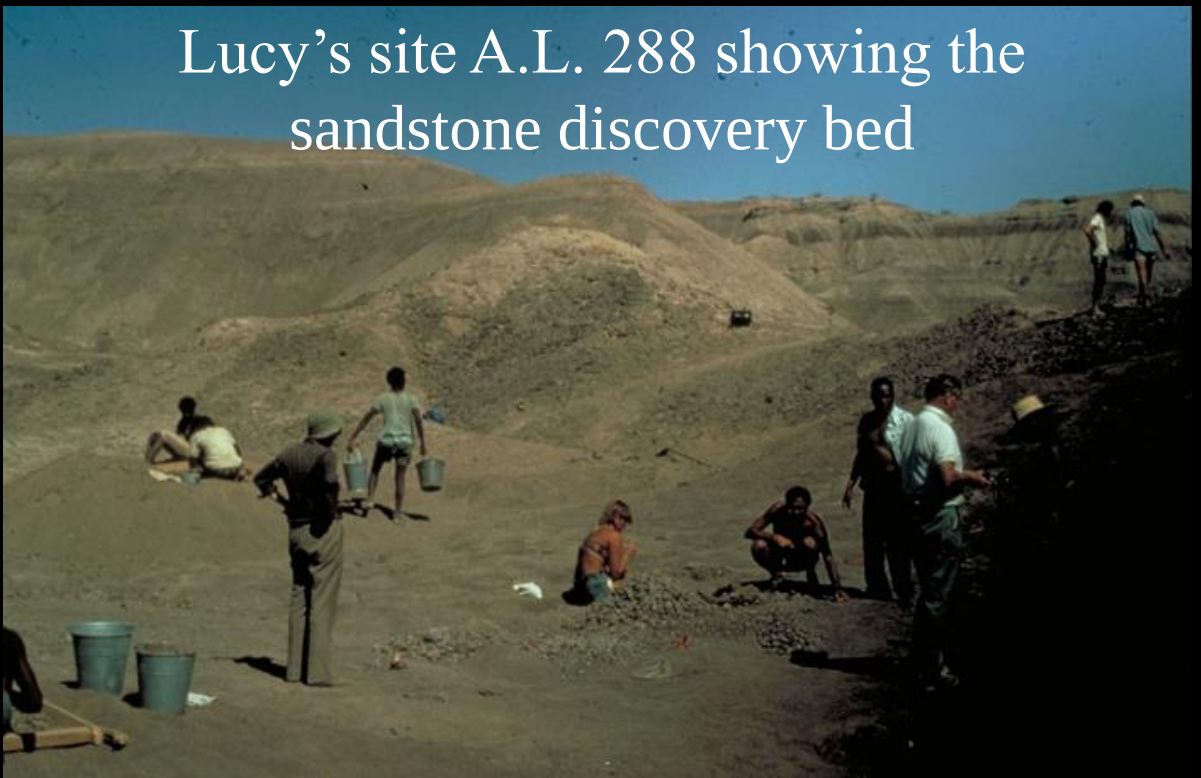
High energy vertical deceleration event (common in modern cases, documented by X-rays and CT scans shown earlier)

A unique signature of injury:

Lucy was conscious when she hit the ground, and stretched out her arms to try to break her fall

Does knowing where was Lucy discovered help us to untangle the mystery of her death?

- Thin (~0.5 m) sandstone deposited by a small stream with turtle and crocodile eggshells, crab claws, and rodent skulls
- Located on low-relief area of distal floodplain near lake
- Stream bank probably too low for a fall to produce high energy fractures



Lucy's site A.L. 288 showing the sandstone discovery bed

Modern Awash River and small streams

https://morenewsfromafar.wordpress.com/2012/02/27/awash-river-valley-afar-oasis/

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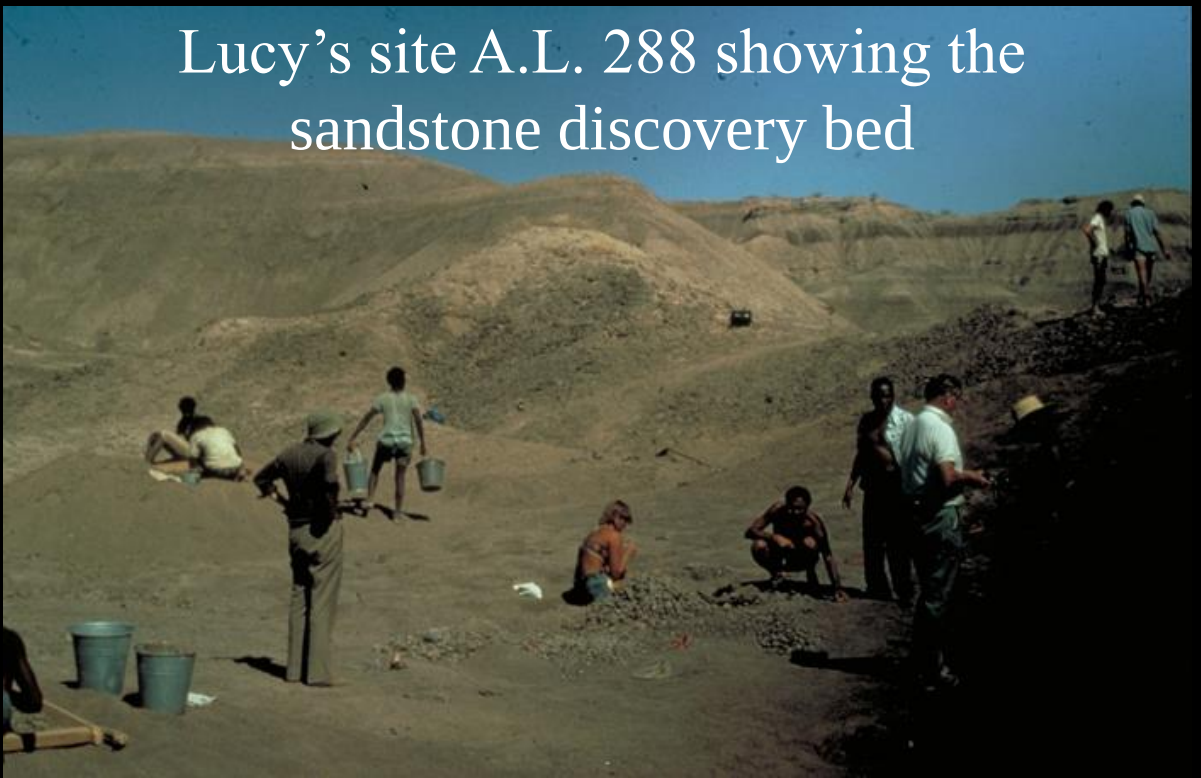

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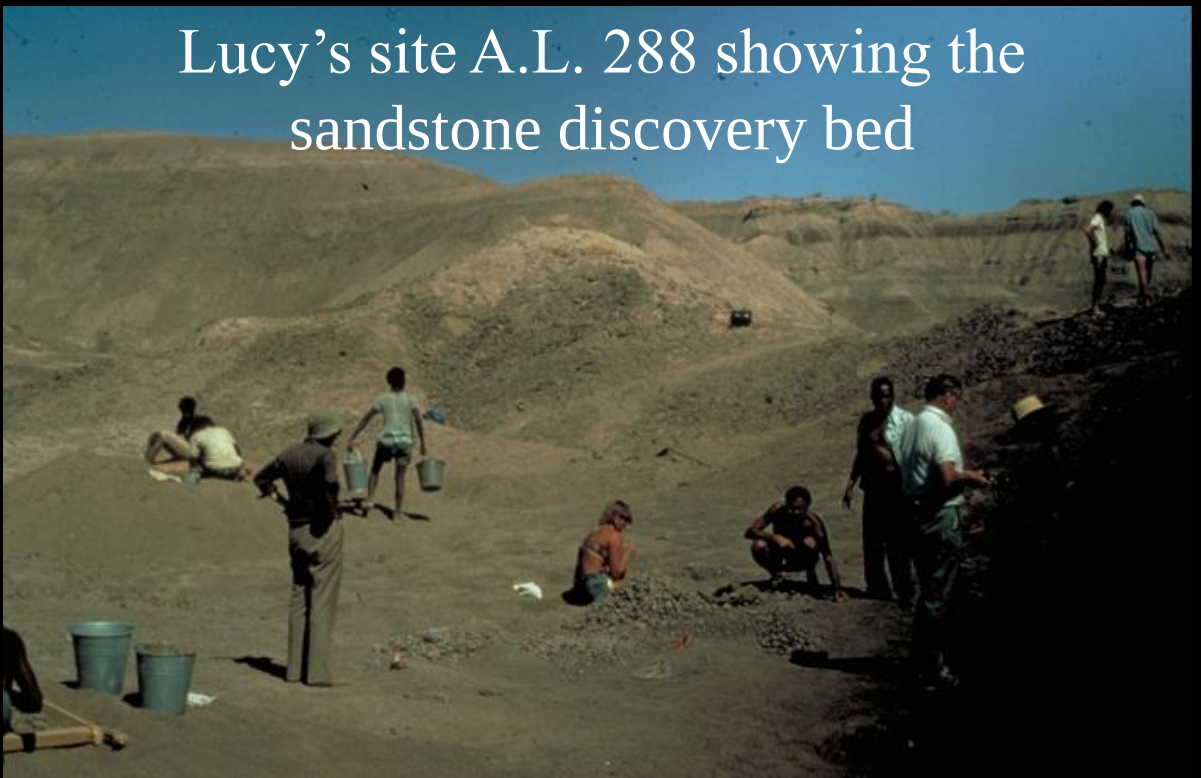

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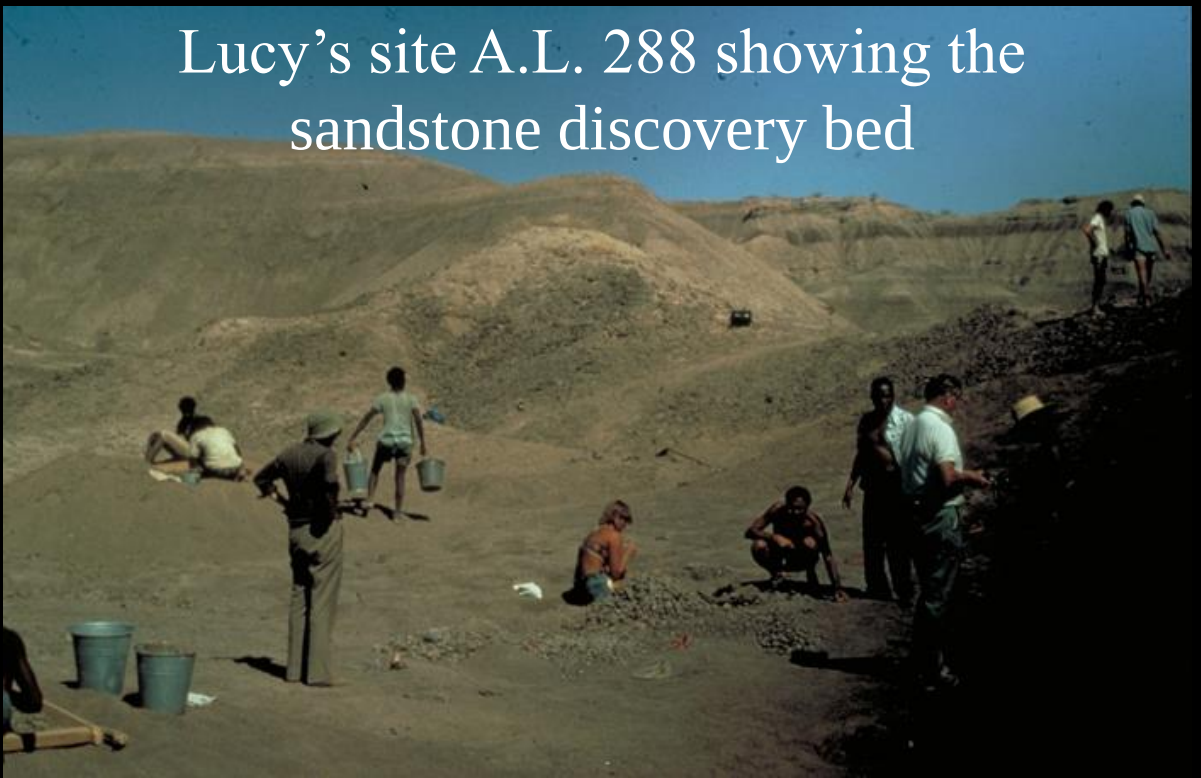

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Trees!!

Given Lucy's small size (~27 kg, ~1.1 meters in height), we propose that she nested in trees at night to avoid predators, and also climbed trees to forage.

Chimpanzee average night nest height is nearly 14 m.

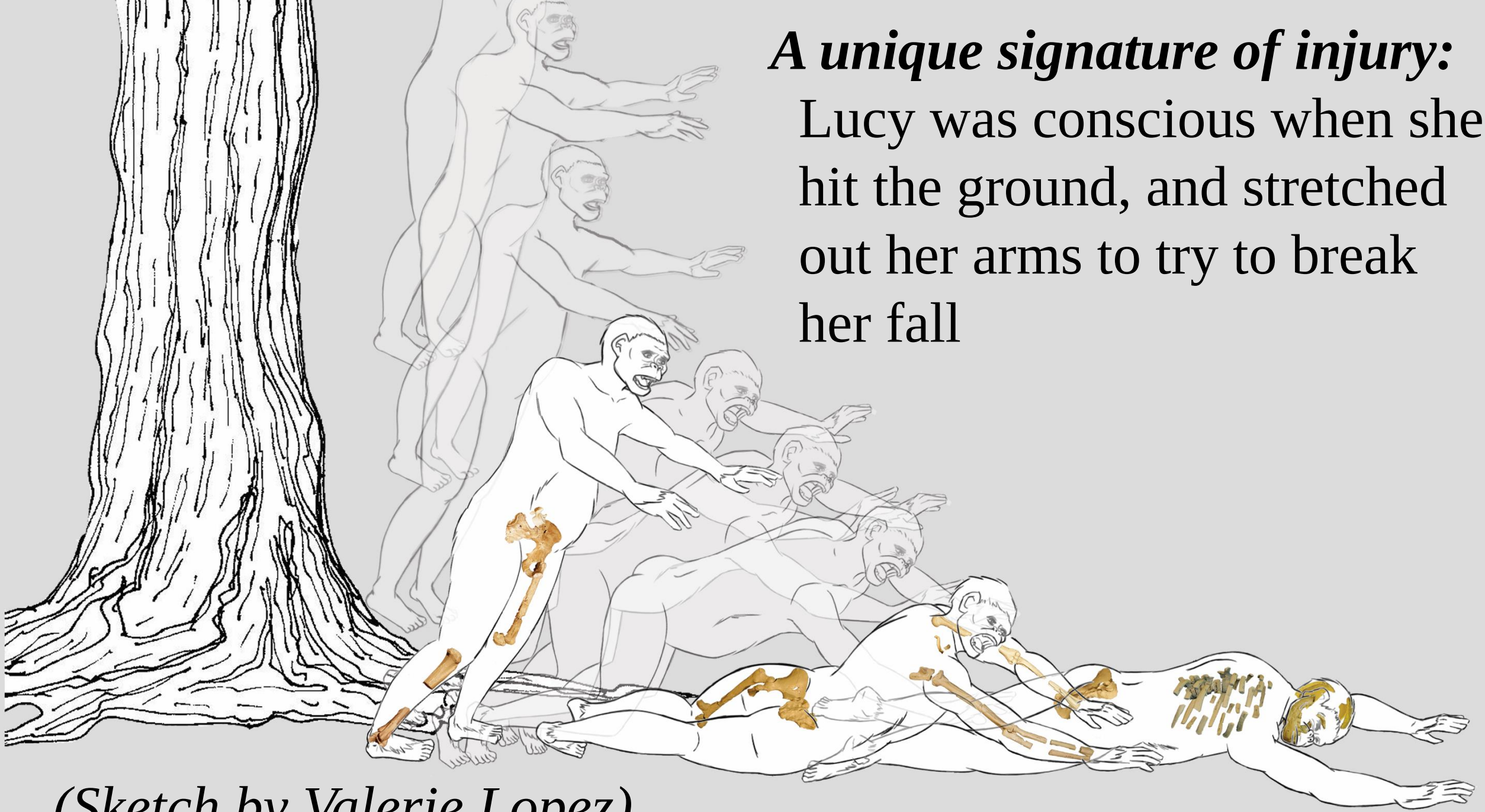
A fall from this height produces an impact velocity of ~60 km/hr, sufficient to produce the fractures seen in her skeleton.

Chimpanzee tree night nest
(Smithsonian image)

We hypothesize that Lucy suffered perimortem fractures after she fell out of a tree from considerable height.

Chimpanzee nest height:
13.7 m = 59 kph (37 mph)
48 m = 110 kph (68 mph)

In addition to the skeletal fractures, it is probable that Lucy suffered extensive damage to her internal organs, and that death followed swiftly.



A unique signature of injury:

Lucy was conscious when she hit the ground, and stretched out her arms to try to break her fall

(Sketch by Valerie Lopez)

How to evaluate our hypothesis?
3D files and printouts

Ethiopia provided release of 3D files so users can download to view or print.

Effort permits a wider and more thorough evaluation of our hypothesis because people can look at the evidence for themselves.

After more than 3 million years, Lucy is leading the charge for sharing the Ethiopian record of fossil hominins!

www.eLucy.org

3D printout of reconstructed right humerus

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Solving a 3.2 Million Year Old Mystery?

1) *Did early human ancestors divide their time between the ground and the trees?*
2) *Did Lucy die from injuries sustained from hitting the ground after a fall out a tree?*

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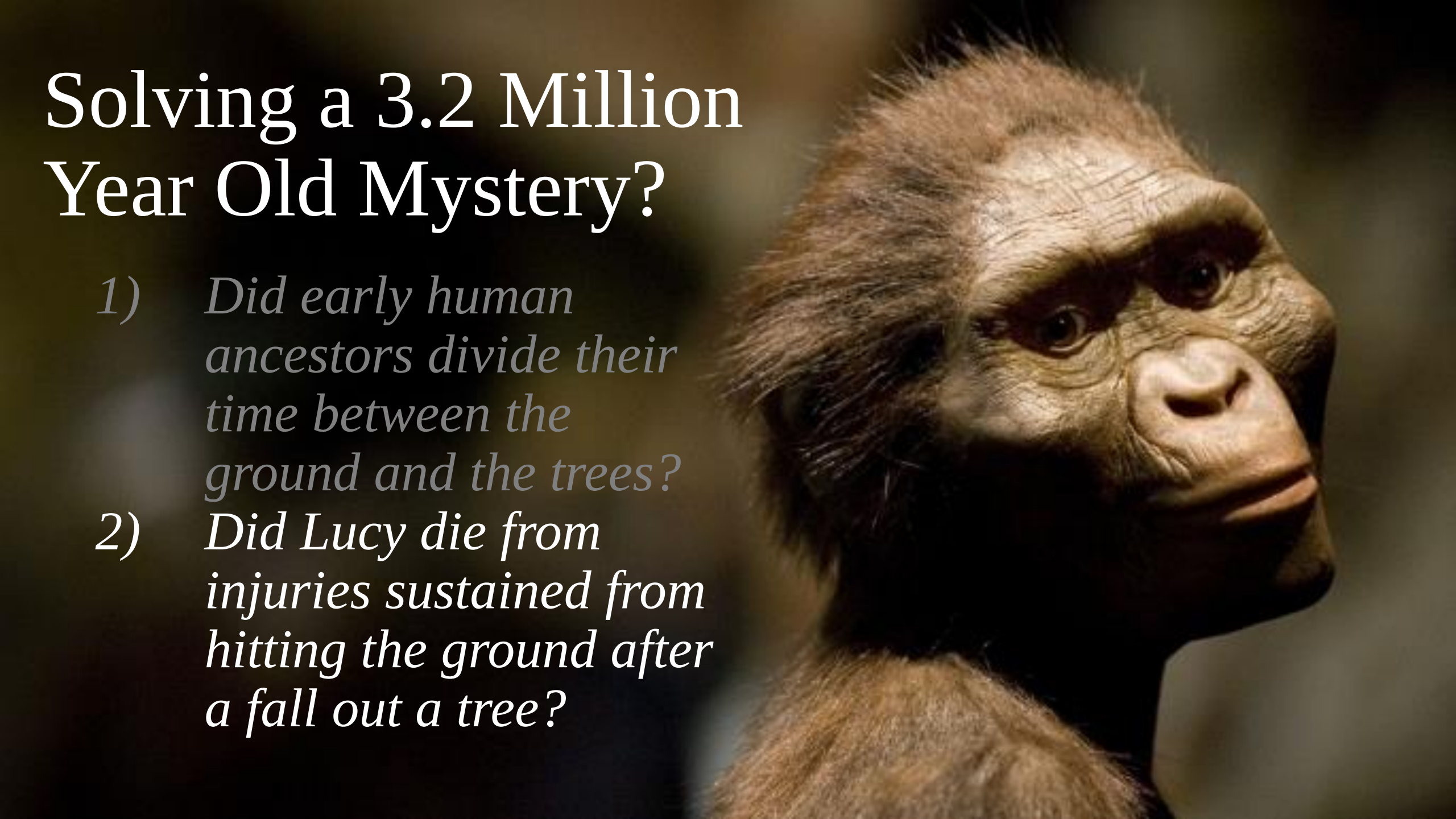

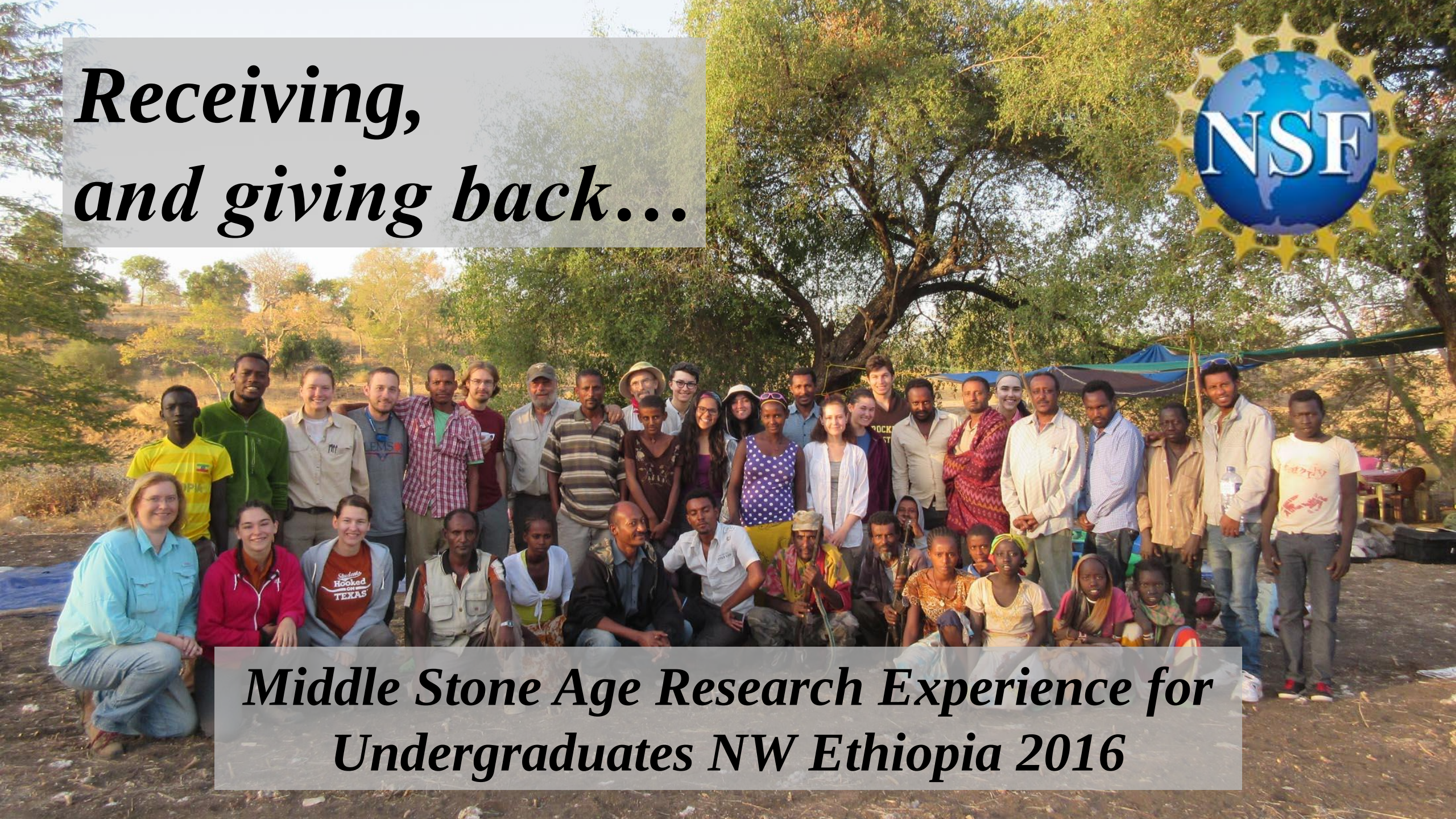
Receiving,
and giving back…
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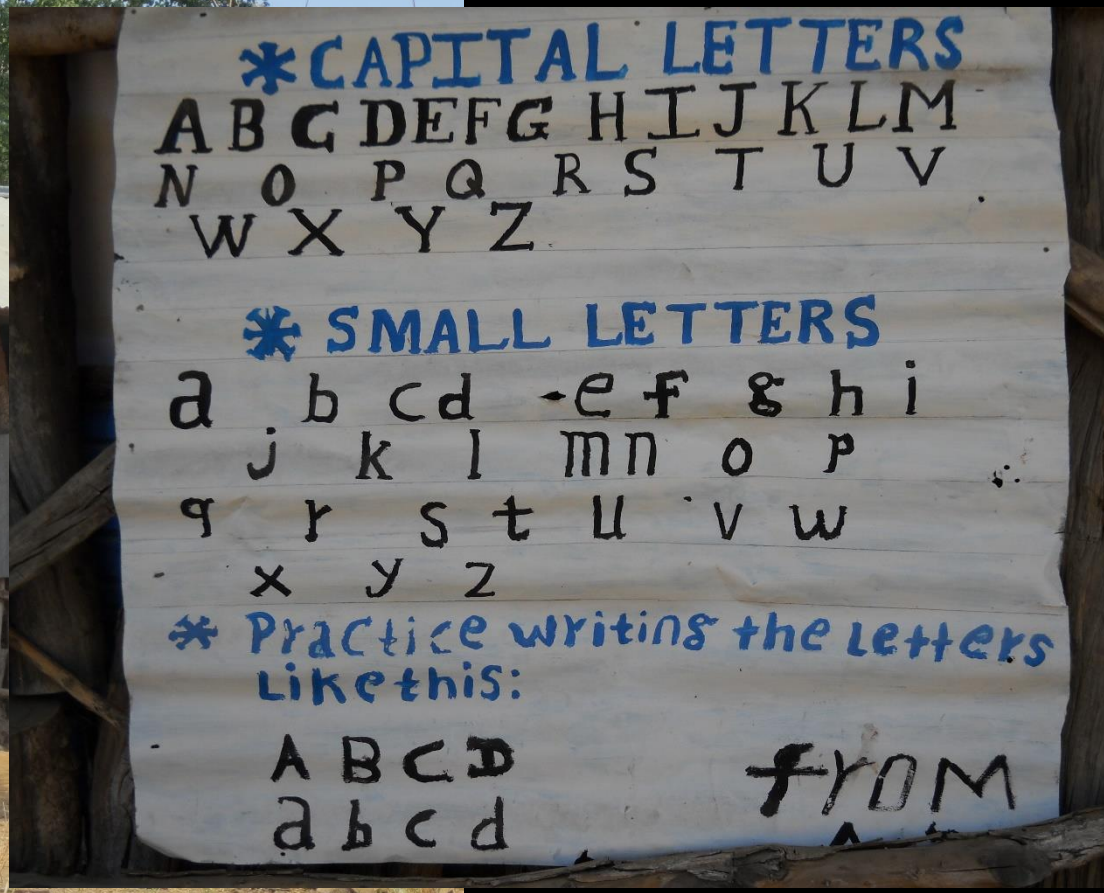
Undergraduates NW Ethiopia 2016


adidas


AFRICA


*CAPITAL LETTERS
A B C D E F G H I J K L M
N O P Q R S T U V
W X Y Z
*SMALL LETTERS
a b c d e f g h i
j k l m n o p
q r s t u v w
x y z
* Practice writing the letters
like this:
A B C D
a b c d
from

HOME ABOUT OUTLINE AND GOALS NEWSLETTER **ONE MIND AT A TIME** OUR START WHO WE ARE ONE MIND AT A TIME BLOG

ONE MIND AT A TIME

Student to Student Learning Through Giving

School children in Shinfa village, Ethiopia

ABOUT

One Mind at a Time is a group of high school students dedicated to improving the lives of Ethiopian children by giving them access to the best possible education. The group believes that by working in coordination with a select school, we can work on promoting education in Ethiopia and unlocking every student's full potential, one mind at a time.

http://www.onemindethiopia.org/

ONE MIND AT A TIME

[“āmeseginalehu”]

[Thank you!]