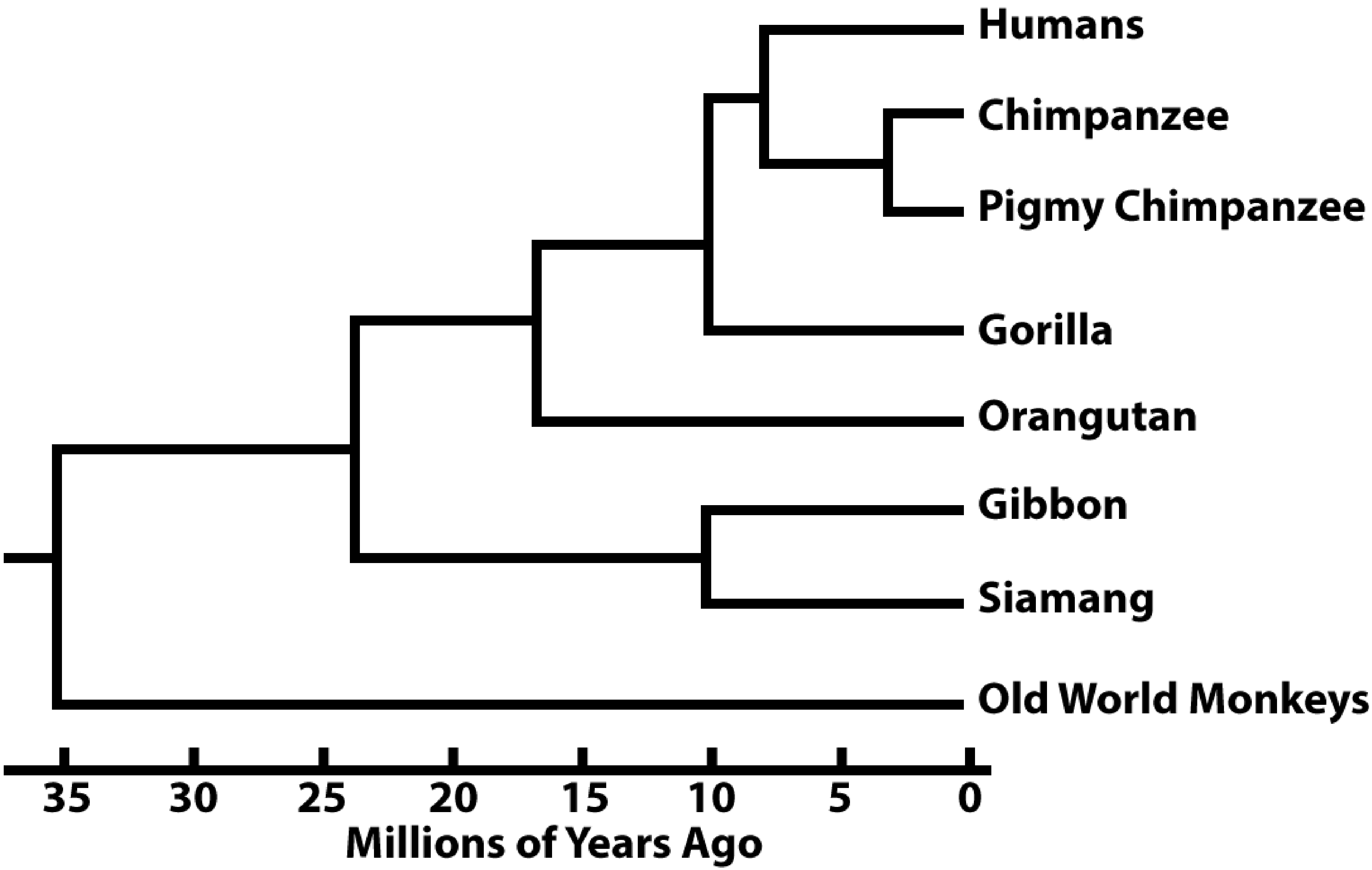
Two Sets of Intertwined Stories

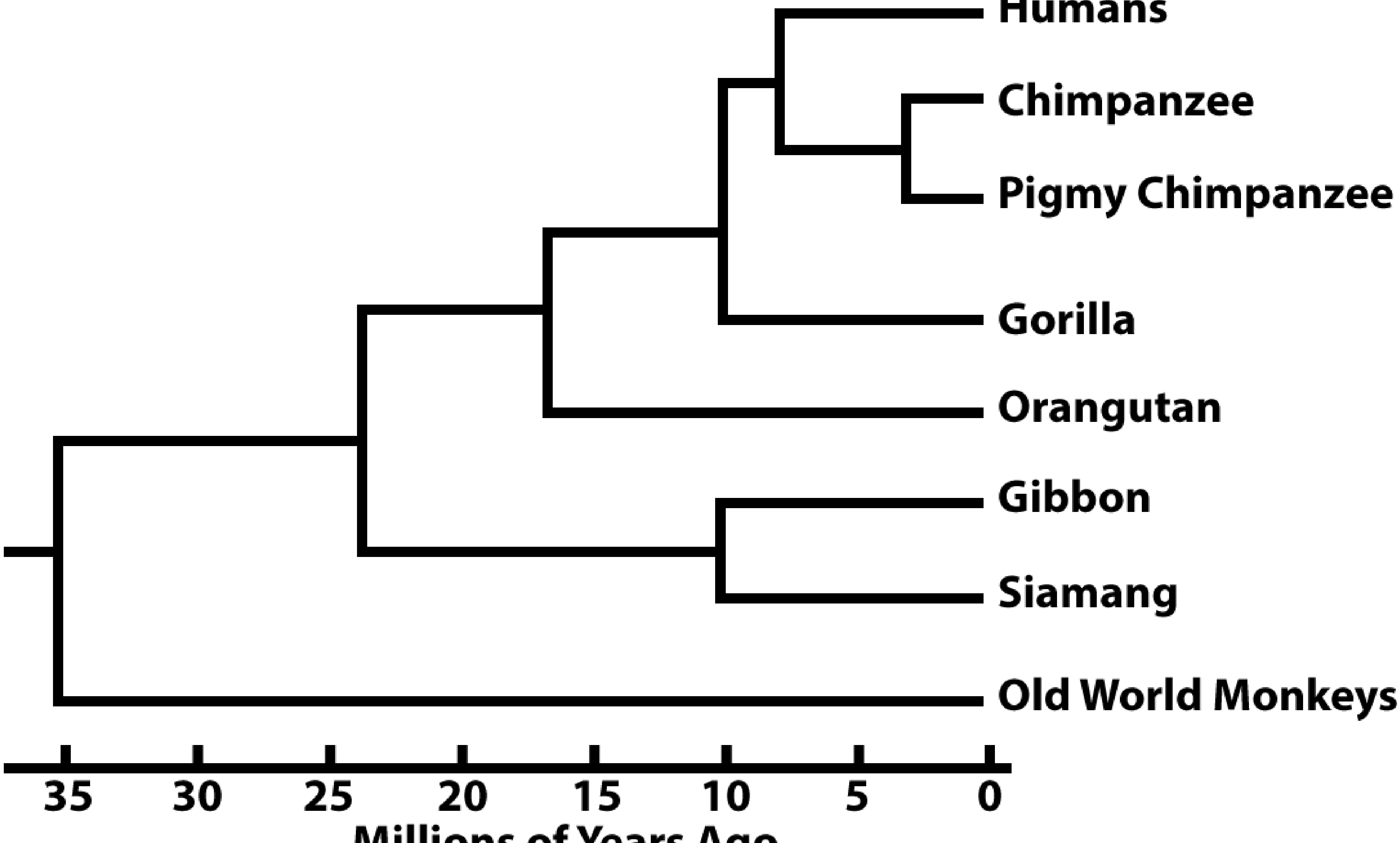
1. EVOLUTIONARY HISTORY



2. BROADER BIODIVERSITY

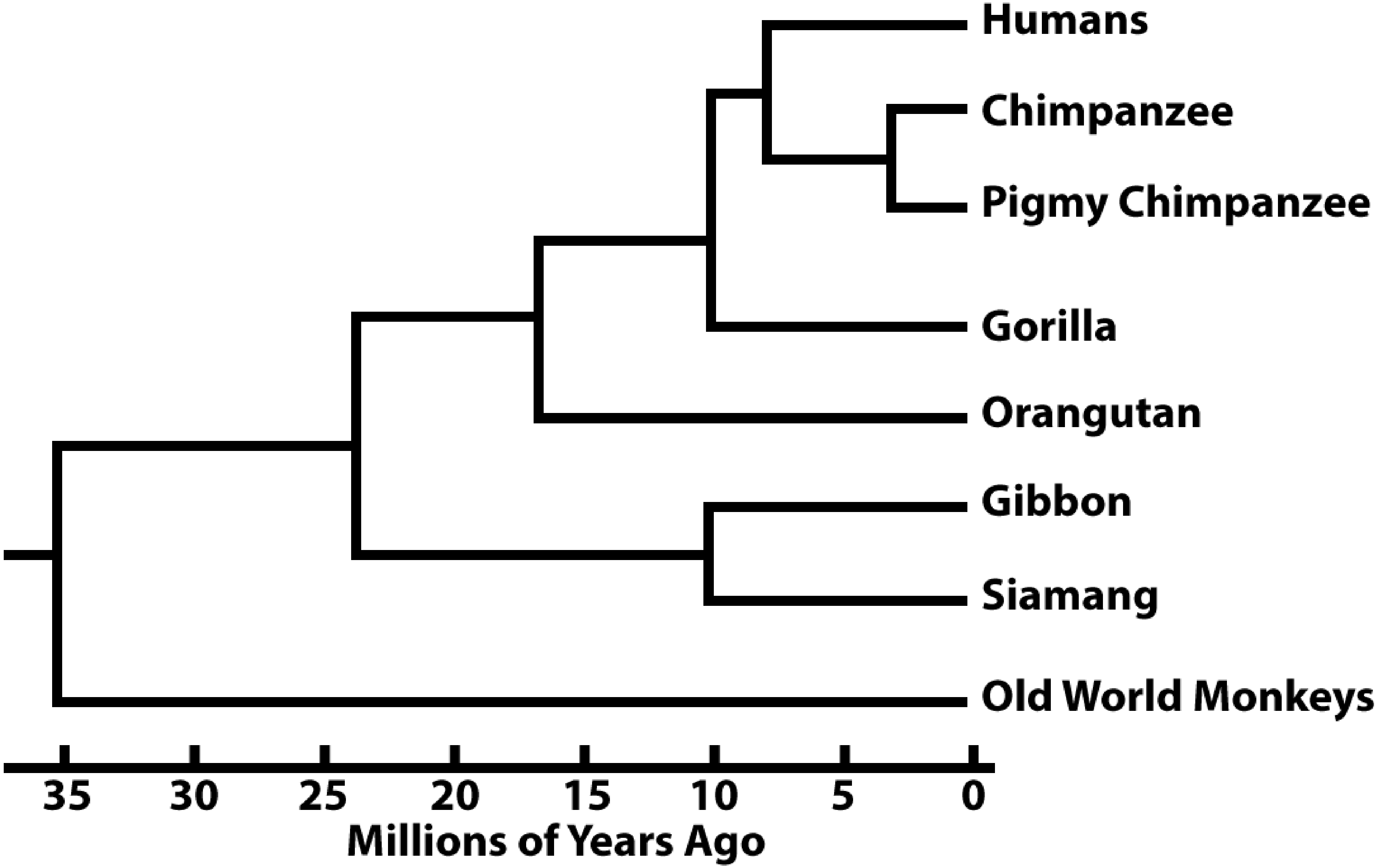
ALEXIS ROCKMAN, THE ECOTOURIST

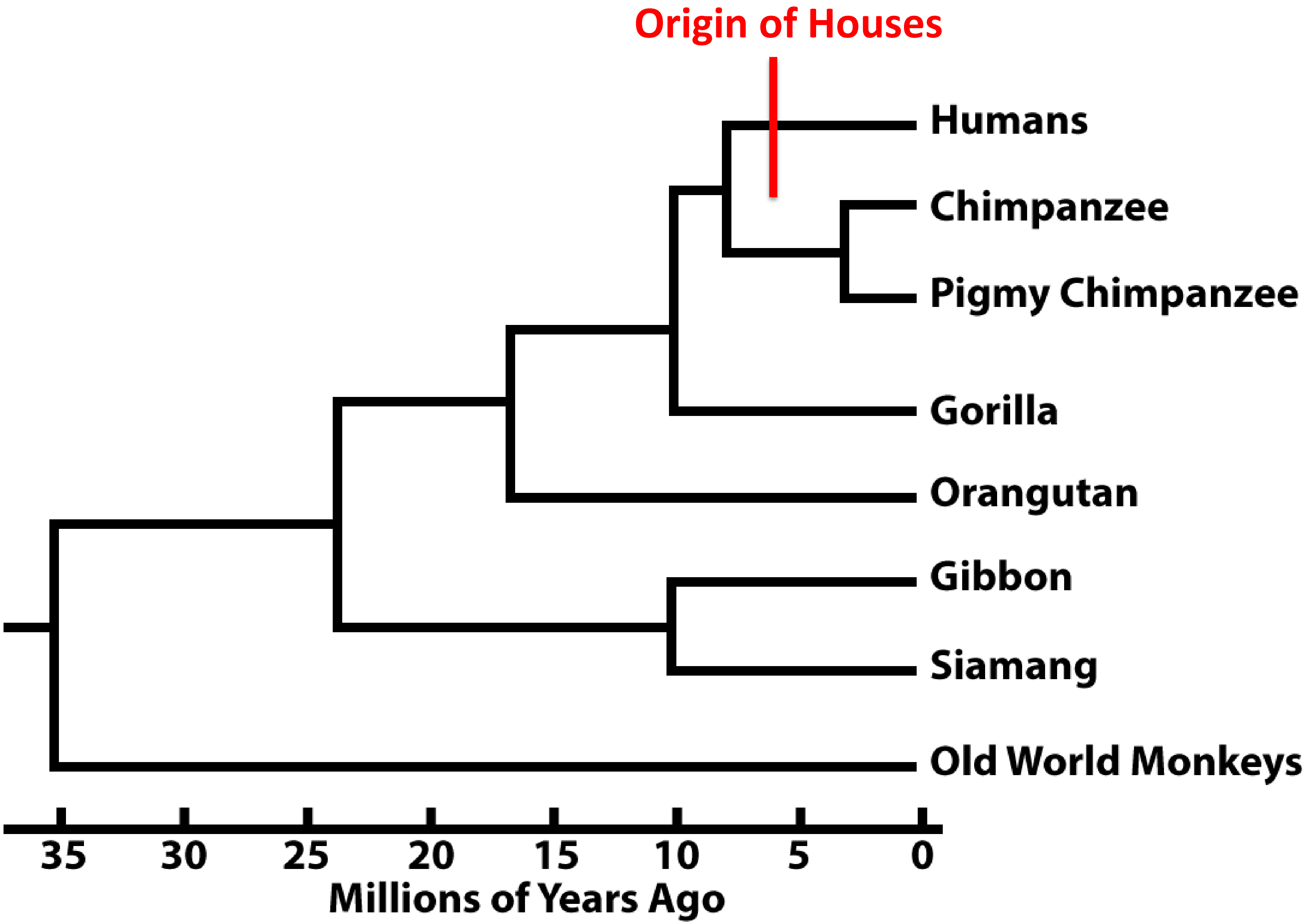
1. EVOLUTIONARY HISTORY



1. EVOLUTIONARY HISTORY (HOUSE)

1. EVOLUTIONARY HISTORY (HOUSE MICROBIOME)


Humans
Chimpanzee
Pigmy Chimpanzee
Gorilla
Orangutan
Gibbon
Siamang
Old World Monkeys
35
30
25
20
15
10
5
0
Millions of Years Ago


Origin of Houses
Humans
Chimpanzee
Pigmy Chimpanzee
Gorilla
Orangutan
Gibbon
Siamang
Old World Monkeys
35
30
25
20
15
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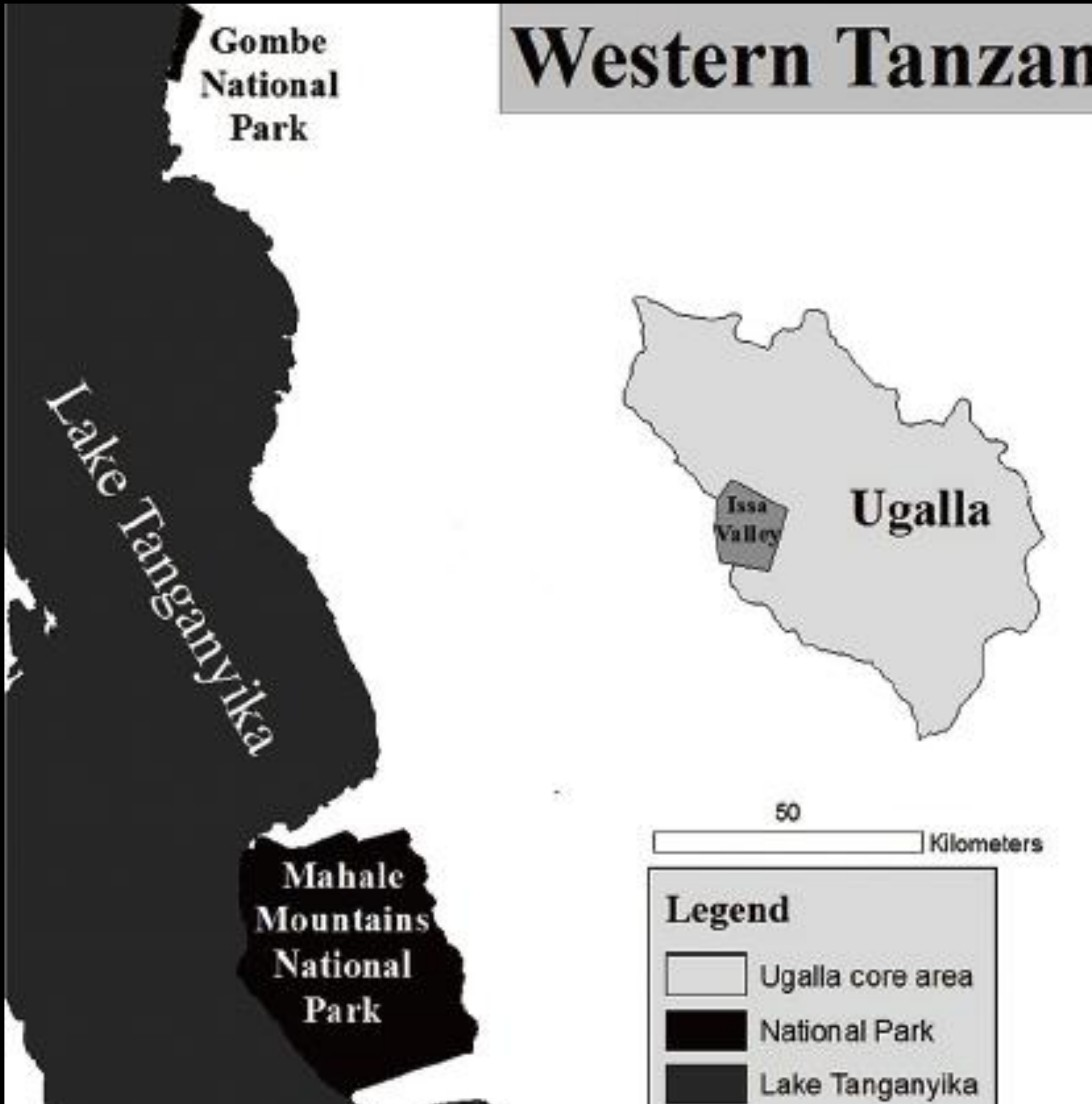
0
Millions of Years Ago


Western Tanzania
N
Gombe
National
Park
Lake Tanganyika
Issa
Valley
Ugalla
Mahale
Mountains
National
Park
50
Kilometers
Legend
Ugalla core area
National Park
Lake Tanganyika


TANZANIA

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Research

Cite this article: Thoemmes MS *et al*. 2018 Ecology of sleeping: the microbial and arthropod associates of chimpanzee beds. *R. Soc. open sci.* **5**: 180382. http://dx.doi.org/10.1098/rsos.180382

Received: 9 March 2018
Accepted: 13 April 2018

Subject Category:
Biology (whole organism)

Subject Areas:
ecology/evolution

Ecology of sleeping: the microbial and arthropod associates of chimpanzee beds

Megan S. Thoemmes[1], Fiona A. Stewart[5,6,7], R. Adriana Hernandez-Aguilar[5,8], Matthew A. Bertone[2], David A. Baltzegar[3,4], Russell J. Borski[3], Naomi Cohen[5], Kaitlin P. Coyle[3], Alexander K. Piel[5,6] and Robert R. Dunn[1,9]

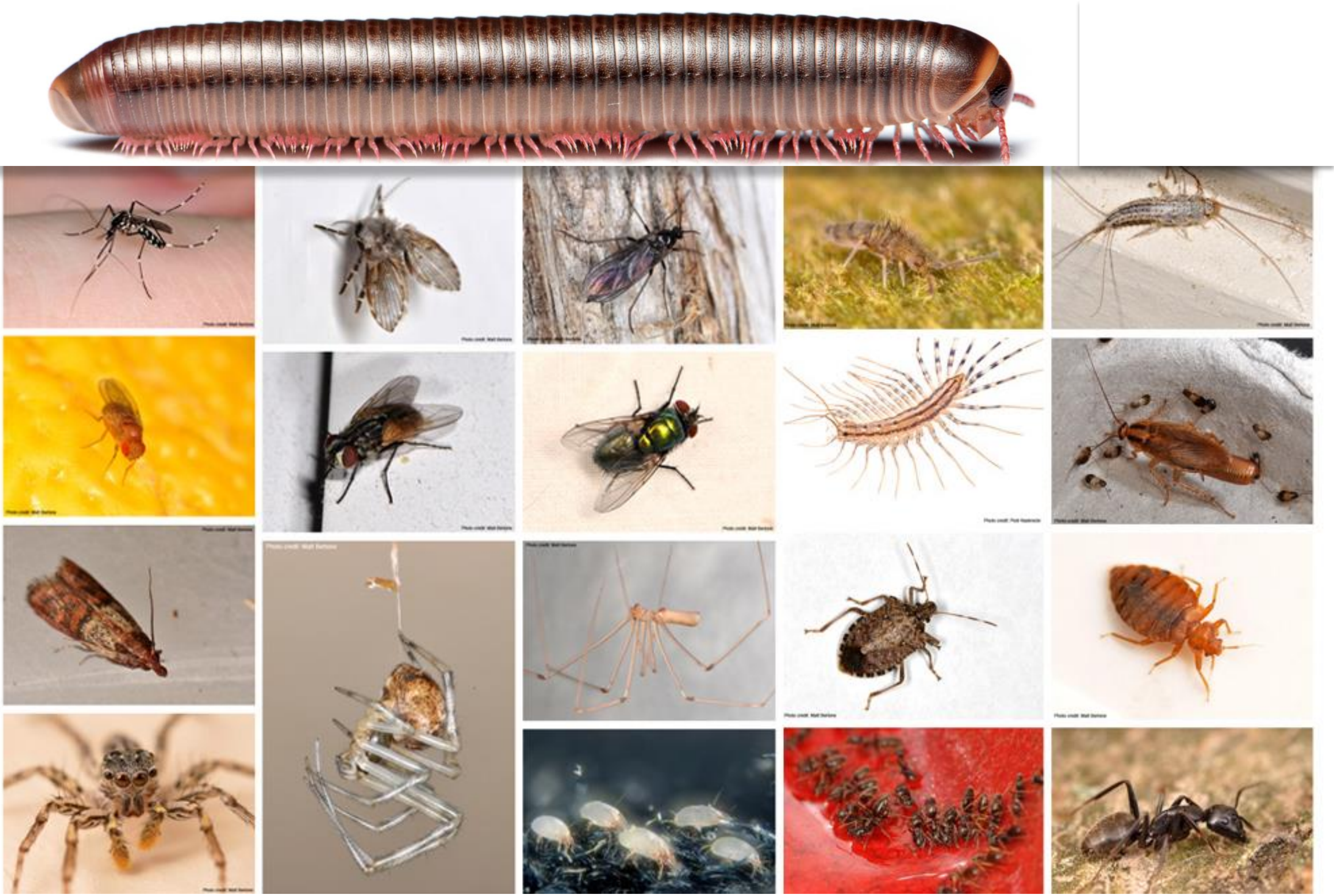
[1]Department of Applied Ecology and Keck Center for Behavioral Biology, [2]Department of Entomology and Plant Pathology, [3]Department of Biological Sciences, and [4]Genomic Sciences Laboratory, Office of Research, Innovation and Economic Development, North Carolina State University, Raleigh, NC, USA
[5]Ugalla Primate Project, Katavi Region, Tanzania
[6]School of Natural Sciences and Psychology, Liverpool John Moores University, Liverpool, UK
[7]Department of Archaeology and Anthropology, University of Cambridge, Cambridge, UK
[8]Centre for Ecological and Evolutionary Synthesis, Department of Biosciences,

DR. MATT BERTONE, ENTOMOLOGIST AND PHOTOGRAPHER (SELFIE)

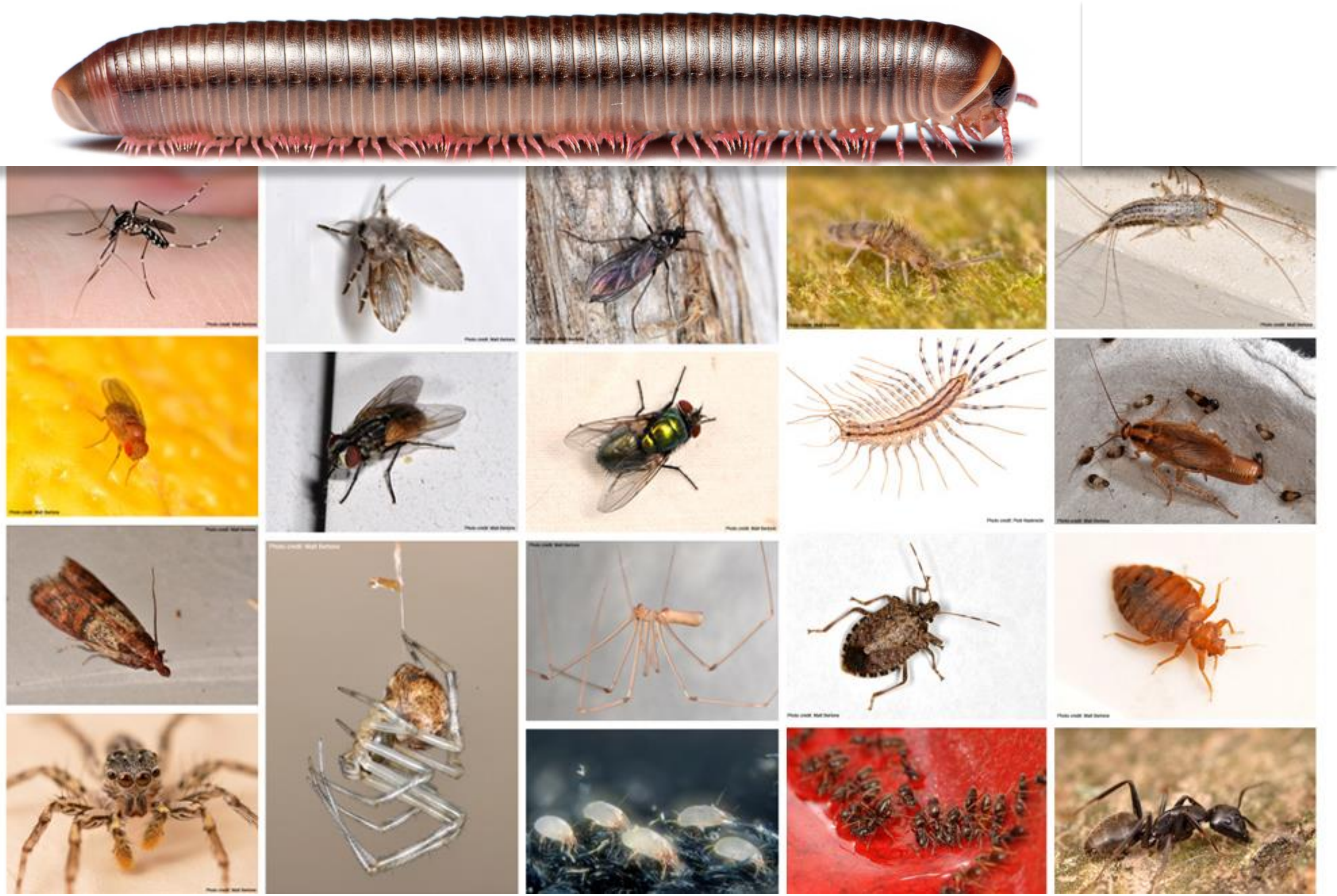
THESE AND OTHER ARTHROPOD IMAGES BY DR. MATT BERTONE.

PAINTING BY ELEANOR Q. C. OLSON

PAINTING BY ELEANOR Q. C. OLSON



More than 1000 *species*



A large proportion of which are house dependent

Photos by Matt Bertone

Photos by Matt Bertone

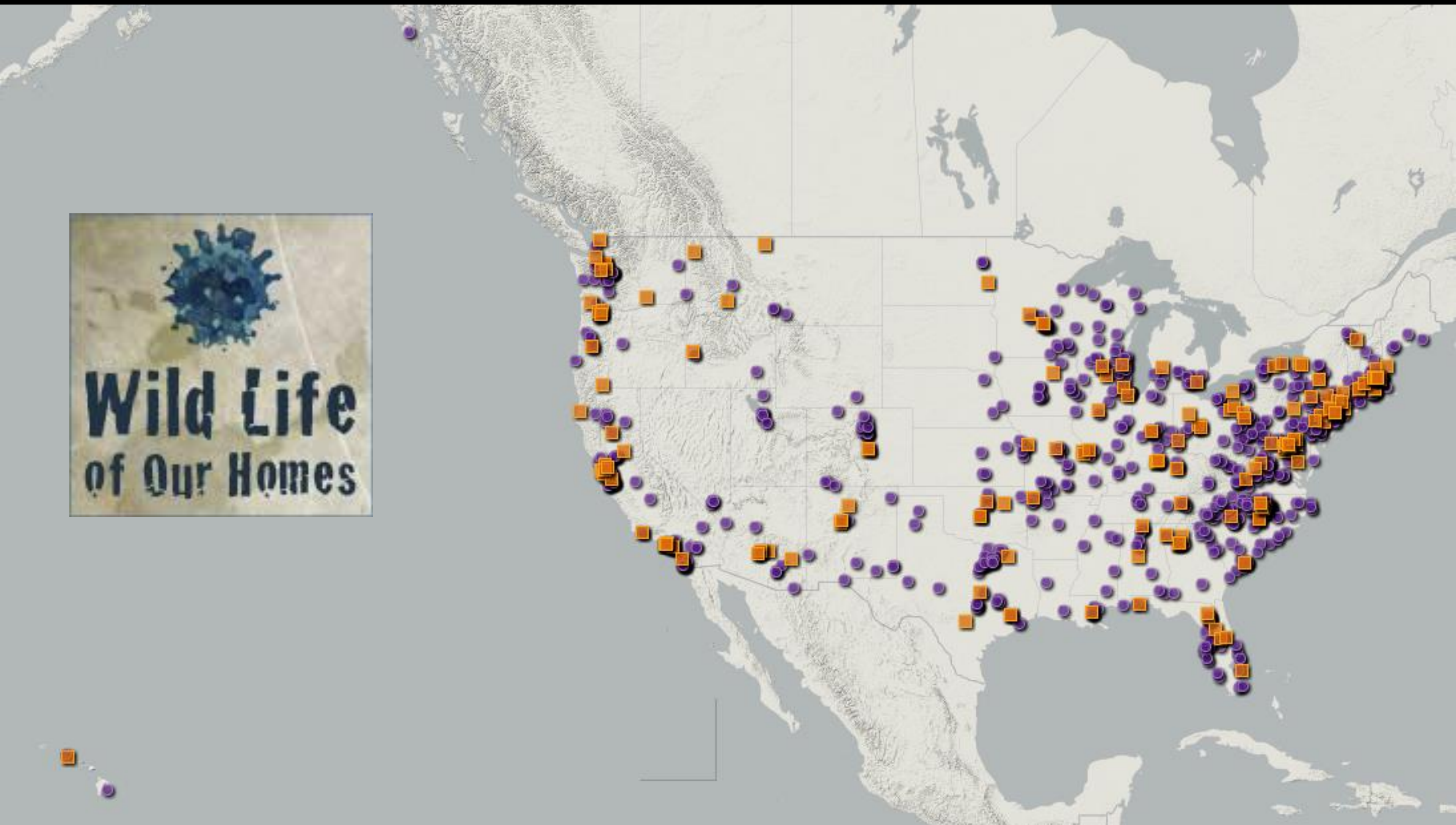






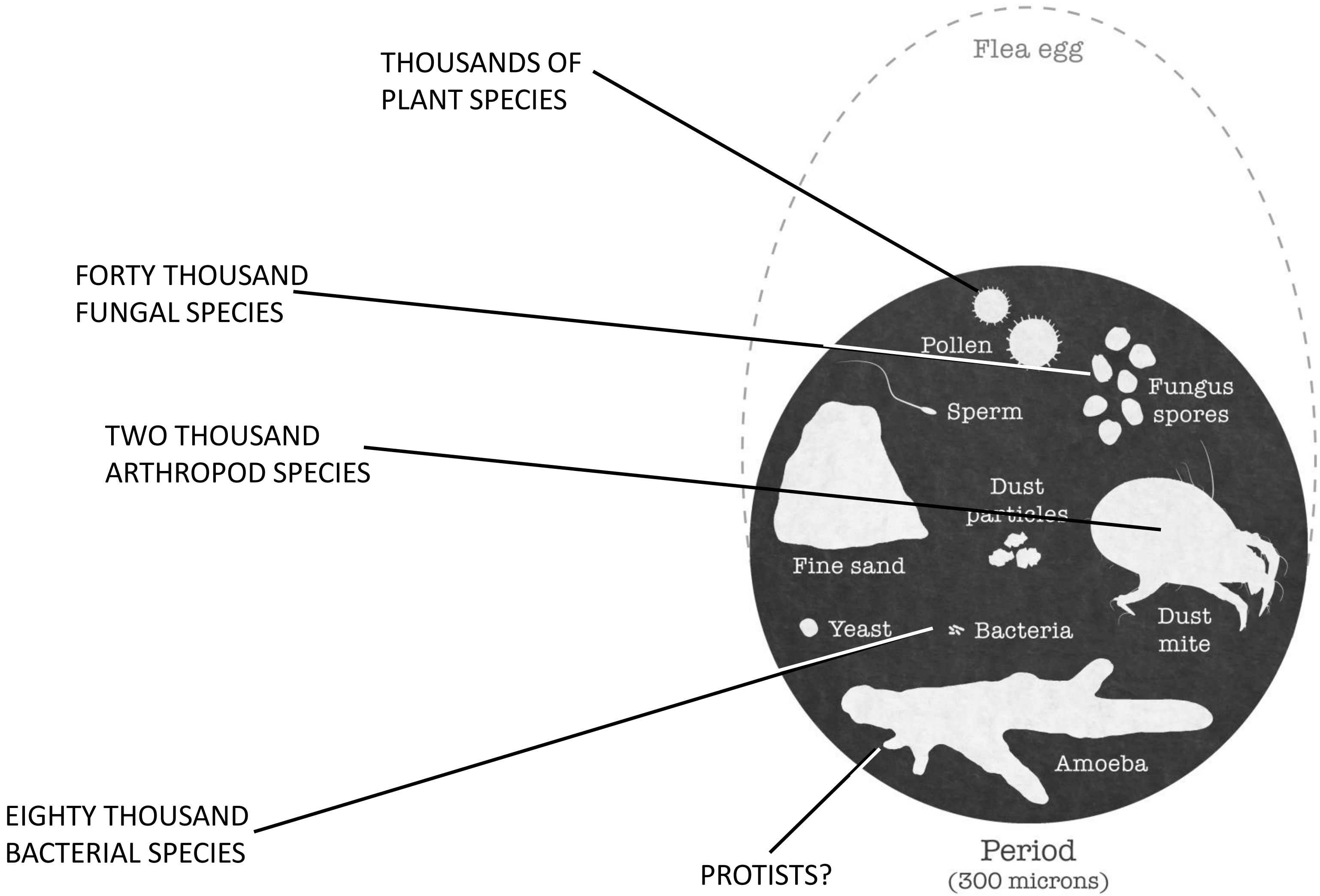





Wild Life
of Our Homes


WE RECYCLE

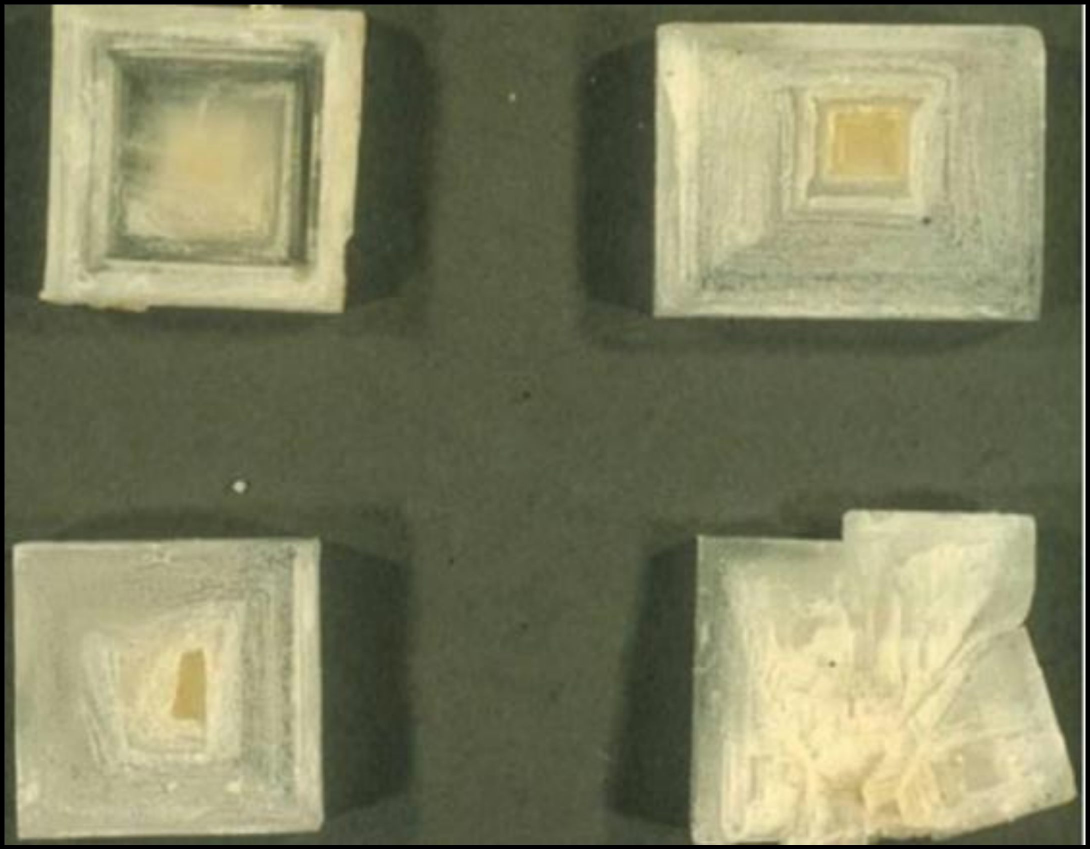
?


THOUSANDS OF PLANT SPECIES
FORTY THOUSAND FUNGAL SPECIES
TWO THOUSAND ARTHROPOD SPECIES
EIGHTY THOUSAND BACTERIAL SPECIES
PROTISTS?
Flea egg
Pollen
Fungus spores
Sperm
Dust particles
Fine sand
Dust mite
Yeast
Bacteria
Amoeba
Period
(300 microns)

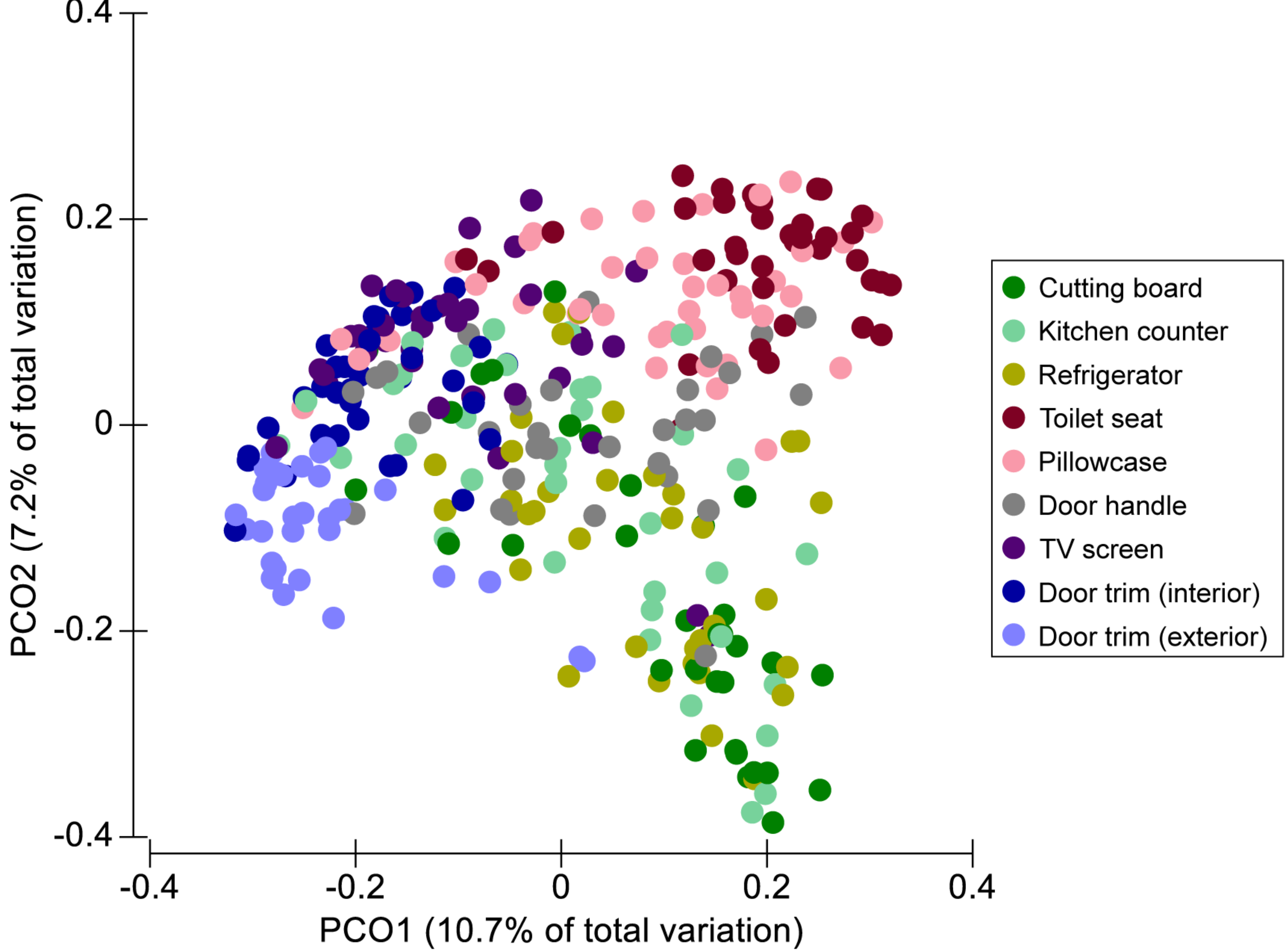

AOSmith
LG
ENERGYGUIDE
DANGER


Nutrition Facts


A.1
B.1
C.1
D.1
F
A
H
D
G
B
C
E
E.1
F.1
G.1
H.1



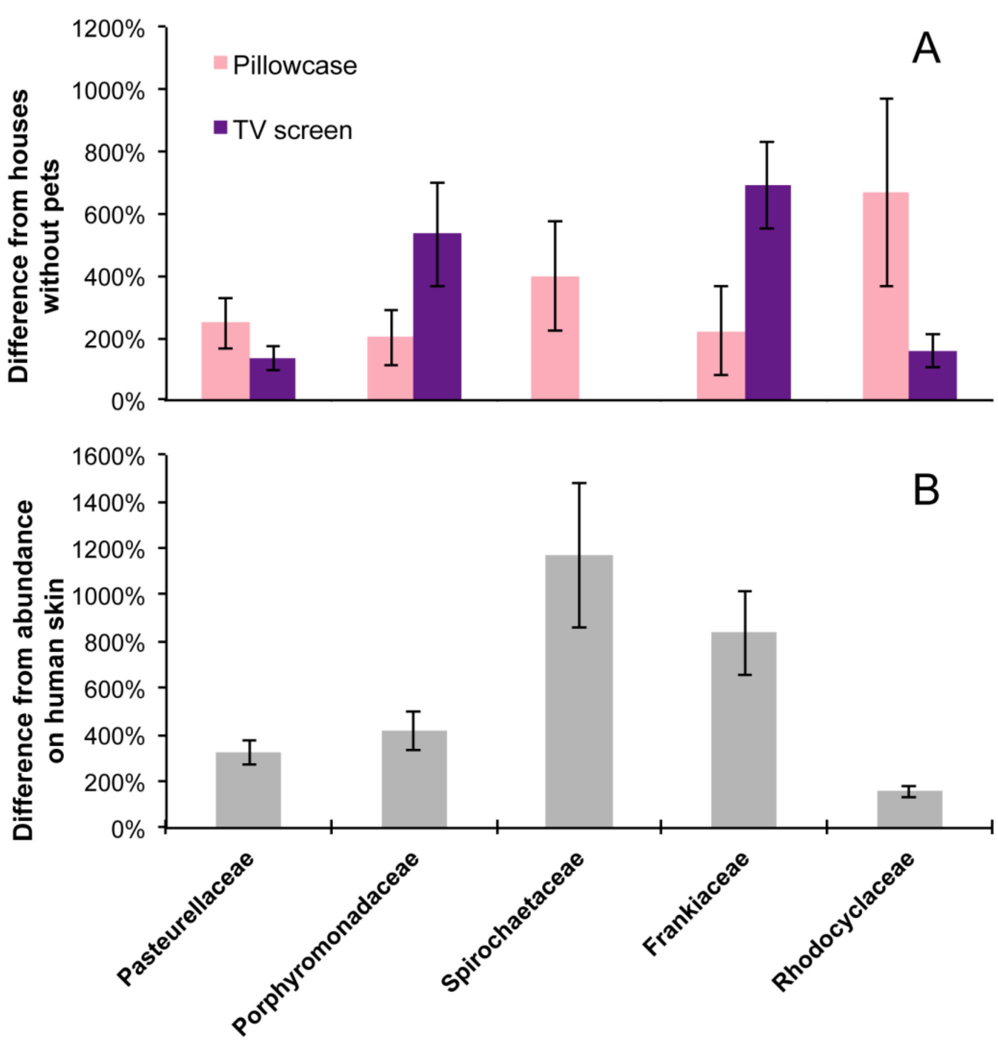
Most “Control” Favors Body Microbes



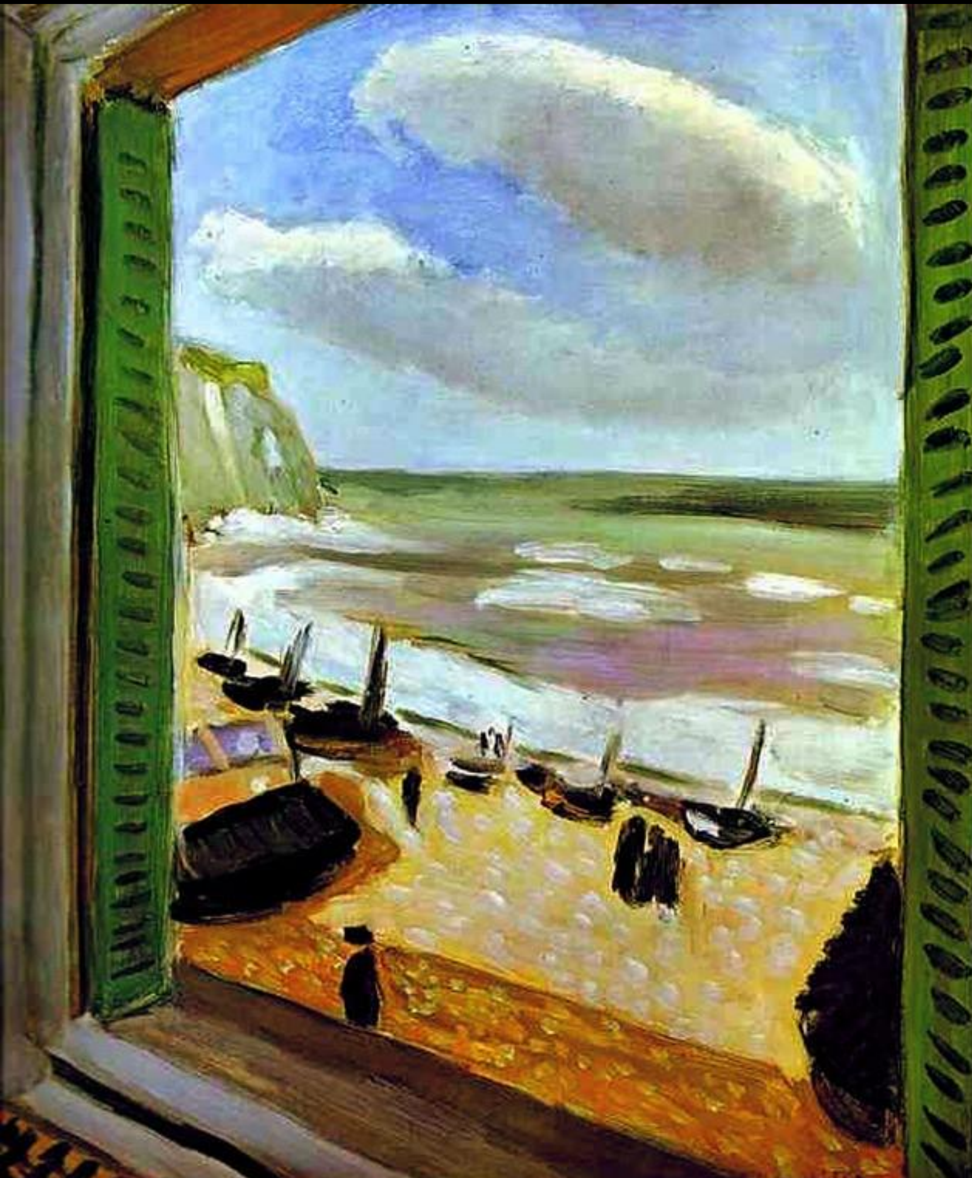
CONTROL OF OCCUPANTS

CONTROL VIA NON-HUMAN ANIMALS

Pet Dogs Favor Dog Body Microbes



Closing Windows Favors Body Microbes

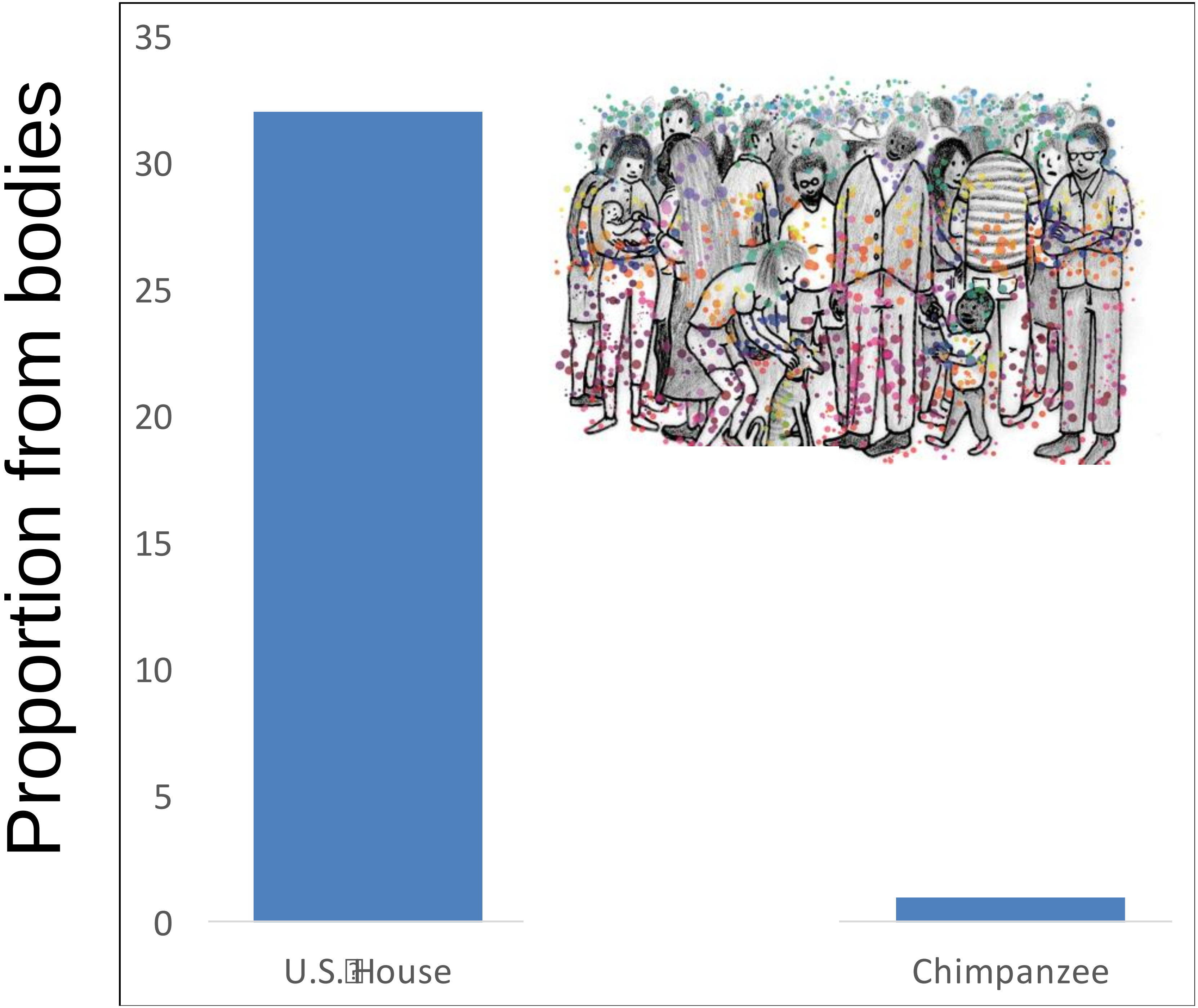


Chlorinating Water Favors Chlorine-tolerant Mycobacteria

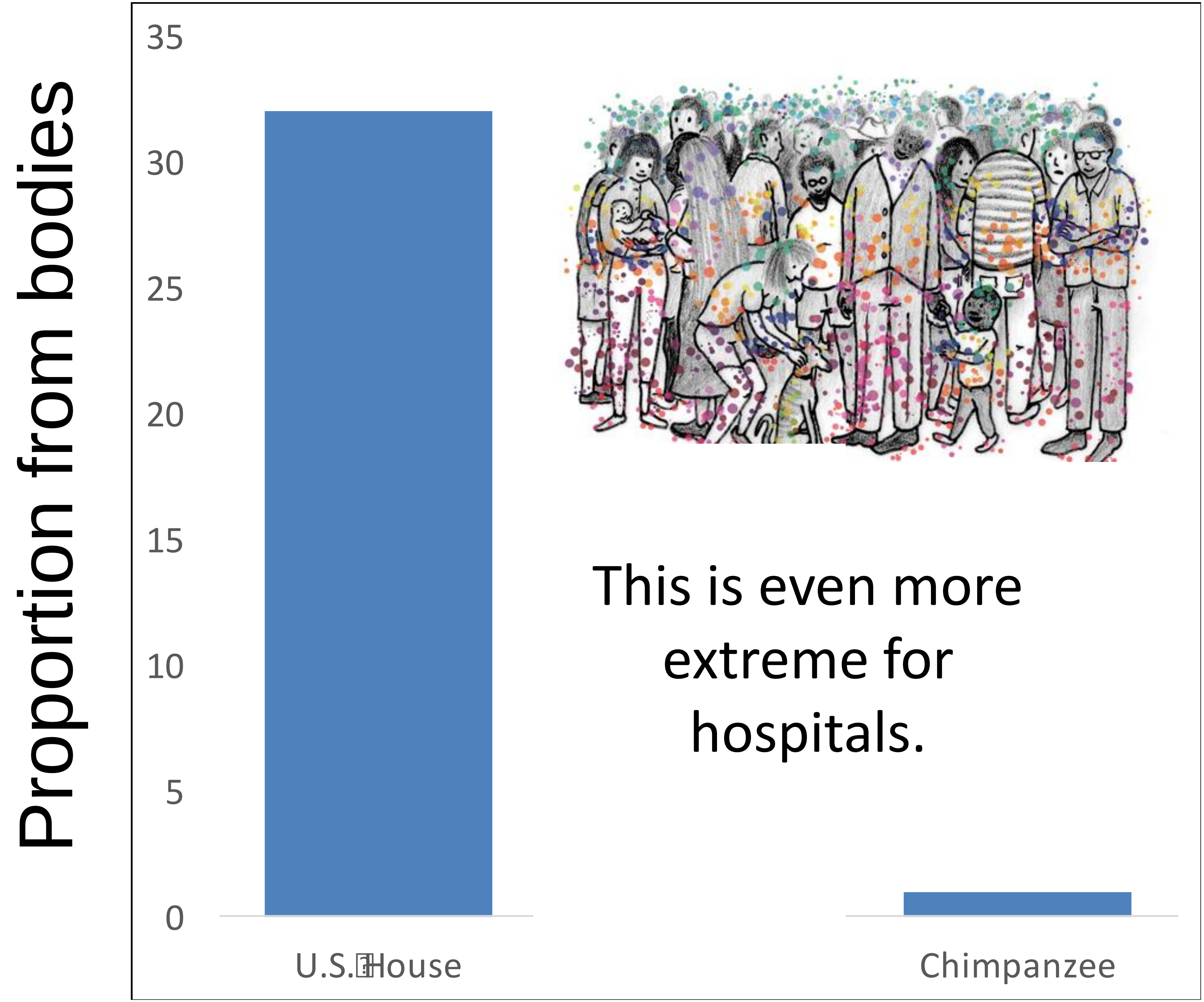
Ecological Analyses of Mycobacteria in Showerhead Biofilms and Their Relevance to Human Health

Matthew J. Gebert[a], Manuel Delgado-Baquerizo[a,b], Angela M. Oliverio[a,c], Tara M. Webster[a], Lauren M. Nichols[d], Jennifer R. Honda[e], Edward D. Chan[f,g,h], Jennifer Adjemian[i,j], Robert R. Dunn[d,k], Noah Fierer[a,c]

[a]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado, USA
[b]Departamento de Biología y Geología, Física y Química Inorgánica, Escuela Superior de Ciencias Experimentales y Tecnología, Universidad Rey Juan Carlos, Móstoles, Spain
[c]Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, Colorado, USA
[d]Department of Applied Ecology, North Carolina State University, Raleigh, North Carolina, USA
[e]Department of Biomedical Research, Center for Genes, Environment, and Health, National Jewish Health, Denver, Colorado, USA
[f]Department of Medicine, National Jewish Health, Denver, Colorado, USA
[g]Division of Pulmonary Sciences and Critical Care Medicine, University of Colorado Denver, Aurora, Colorado, USA
[h]Denver Veterans Affairs Medical Center, Denver, Colorado, USA
[i]National Institute of Allergy and Infectious Diseases, Bethesda, Maryland, USA
[j]United States Public Health Service Commissioned Corps, Rockville, Maryland, USA
[k]Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark



Proportion from bodies
35
30
25
20
15
10
5
0
U.S. House
Chimpanzee


Proportion from bodies
35
30
25
20
15
10
5
0
U.S. House
Chimpanzee
This is even more extreme for hospitals.

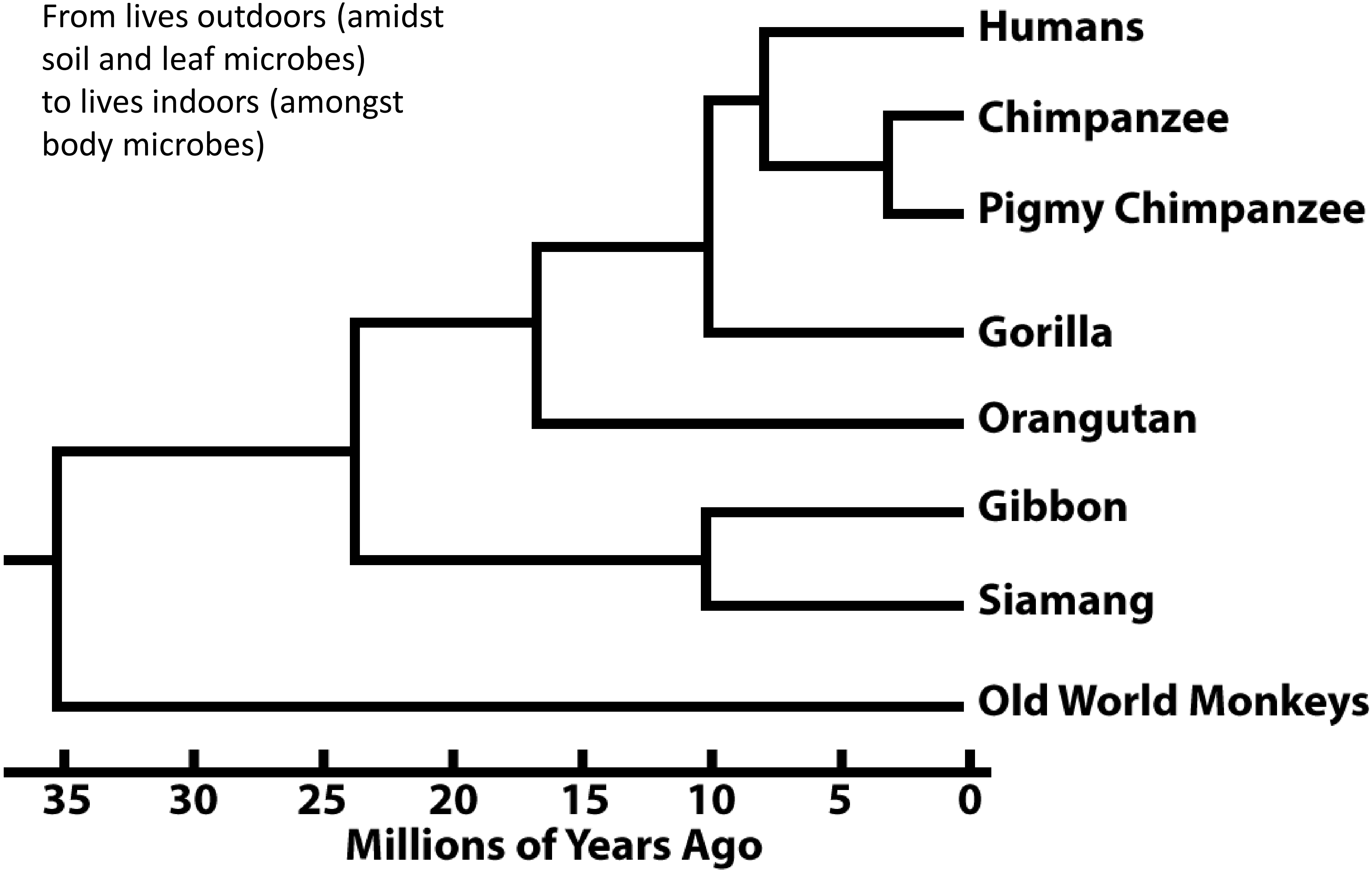
~95% of time indoors

~95% of time indoors

How much time did you spend outdoors today?

1. EVOLUTIONARY HISTORY (HOUSE)

From lives outdoors (amidst soil and leaf microbes) to lives indoors (amongst body microbes)



Net effects

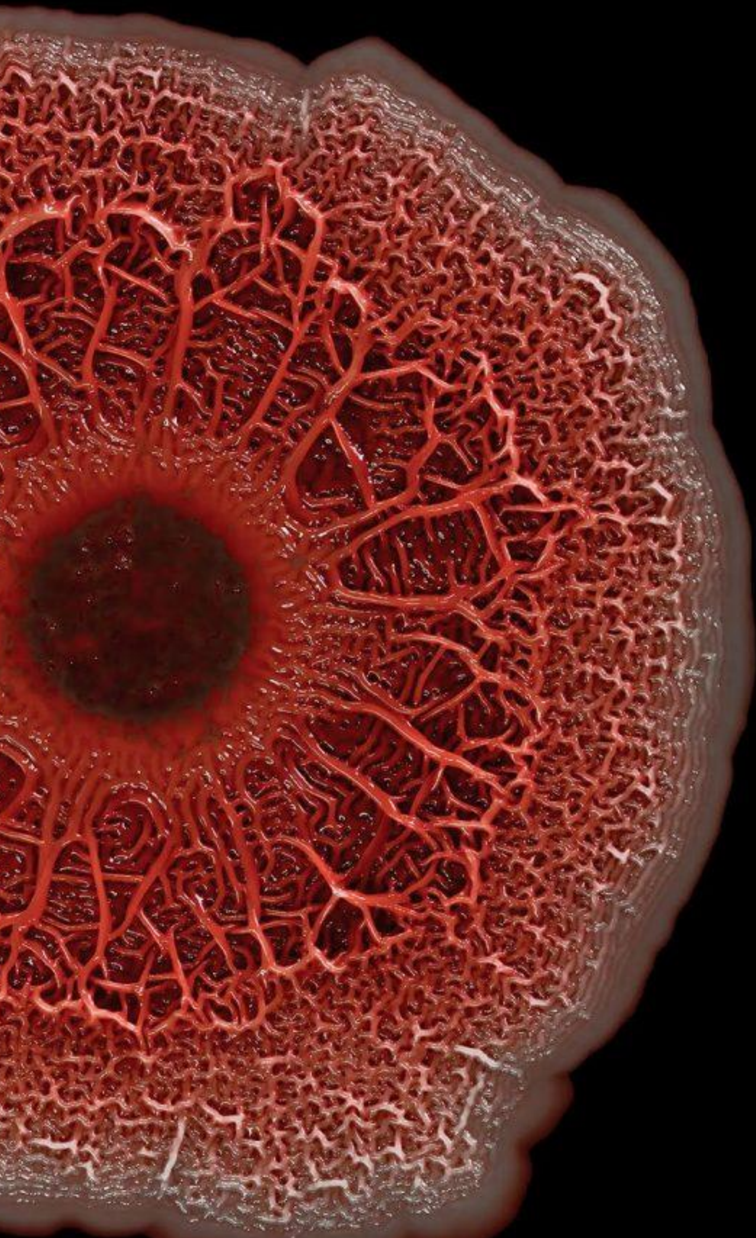
- Microbial composition that appears to predispose people to allergy, asthma, and other inflammatory diseases (as much via what is absent as what is present)

We don’t understand this effect entirely, but it is clear that it is occurring.

Net effects

- Microbial composition that appears to predispose people to allergy, asthma, and other inflammatory diseases (as much via what is absent as what is present)
- **An environment that promotes survival of biocide resistant bacteria and opportunistic pathogens (which are often poor competitors)**

Antibiotic use + bleaching favors resistant organisms (poor competitors)



Pseudomonas aerigunosa
photo of colony by
Scott Chimileski

Environmental Science & Technology

pubs.acs.org/est

Article

Structure and Functional Attributes of Bacterial Communities in Premise Plumbing Across the United States

Tara M. Webster, Alexander McFarland, Matthew J. Gebert, Angela M. Oliverio, Lauren M. Nichols, Robert R. Dunn, Erica M. Hartmann, and Noah Fierer*

Cite This: *Environ. Sci. Technol.* 2021, 55, 14105−14114

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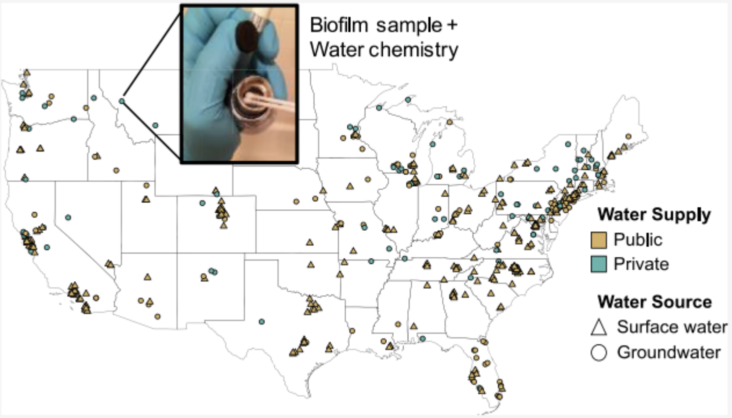
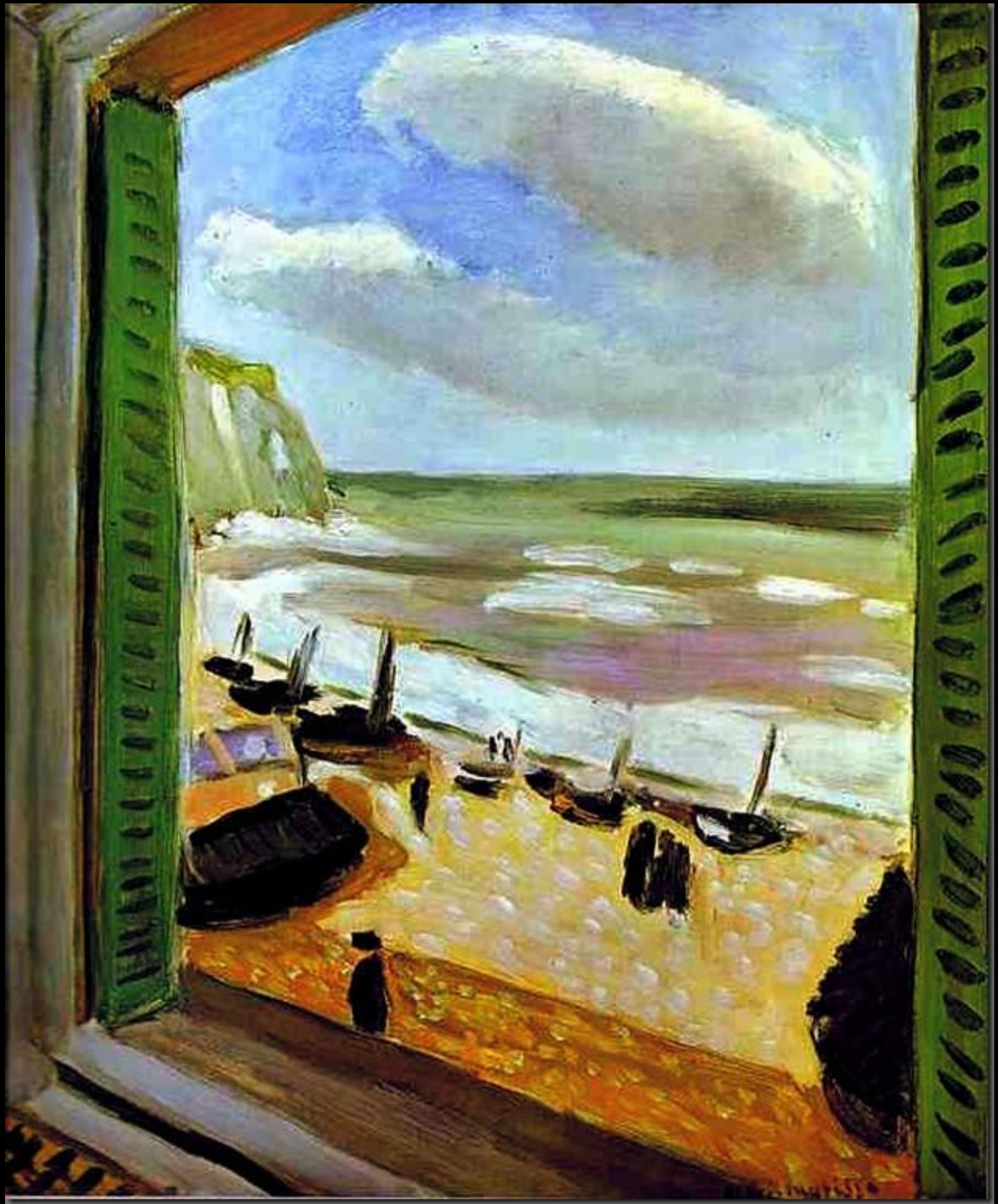
ABSTRACT: Microbes that thrive in premise plumbing can have potentially important effects on human health. Yet, how and why plumbing-associated microbial communities vary across broad spatial scales remain undetermined. We characterized the bacterial communities in 496 showerheads collected from across the continental United States. The overall community structure, determined by 16S rRNA gene amplicon sequencing, revealed high levels of bacterial diversity. Although a large fraction of the observed variation in community composition could not be explained, differences in bacterial community composition were associated with water supply (private well water vs public municipal water), water source (groundwater vs surface water), and associated differences in water chemistry (pH and chlorine). Most notably, showerheads in homes supplied with public water had higher abundances of *Blastomonas*, *Mycobacterium*, and *Porphyrobacter*, while *Pseudorhodoplanes*, *Novosphingobium*, and *Nitrospira* were more abundant in those receiving private well water. We conducted





Net effects

- Microbial composition that appears to predispose people to allergy, asthma, and other inflammatory diseases (as much via what is absent as what is present)
- An environment that promotes survival of antibiotic resistant bacteria and opportunistic pathogens (which are often poor competitors)
- **An environment where beneficial microbes not acquired during birth are very unlikely to be acquired later on.**

Cell Reports Medicine

Volume 1, Issue 9, 22 December 2020, 100156

Article

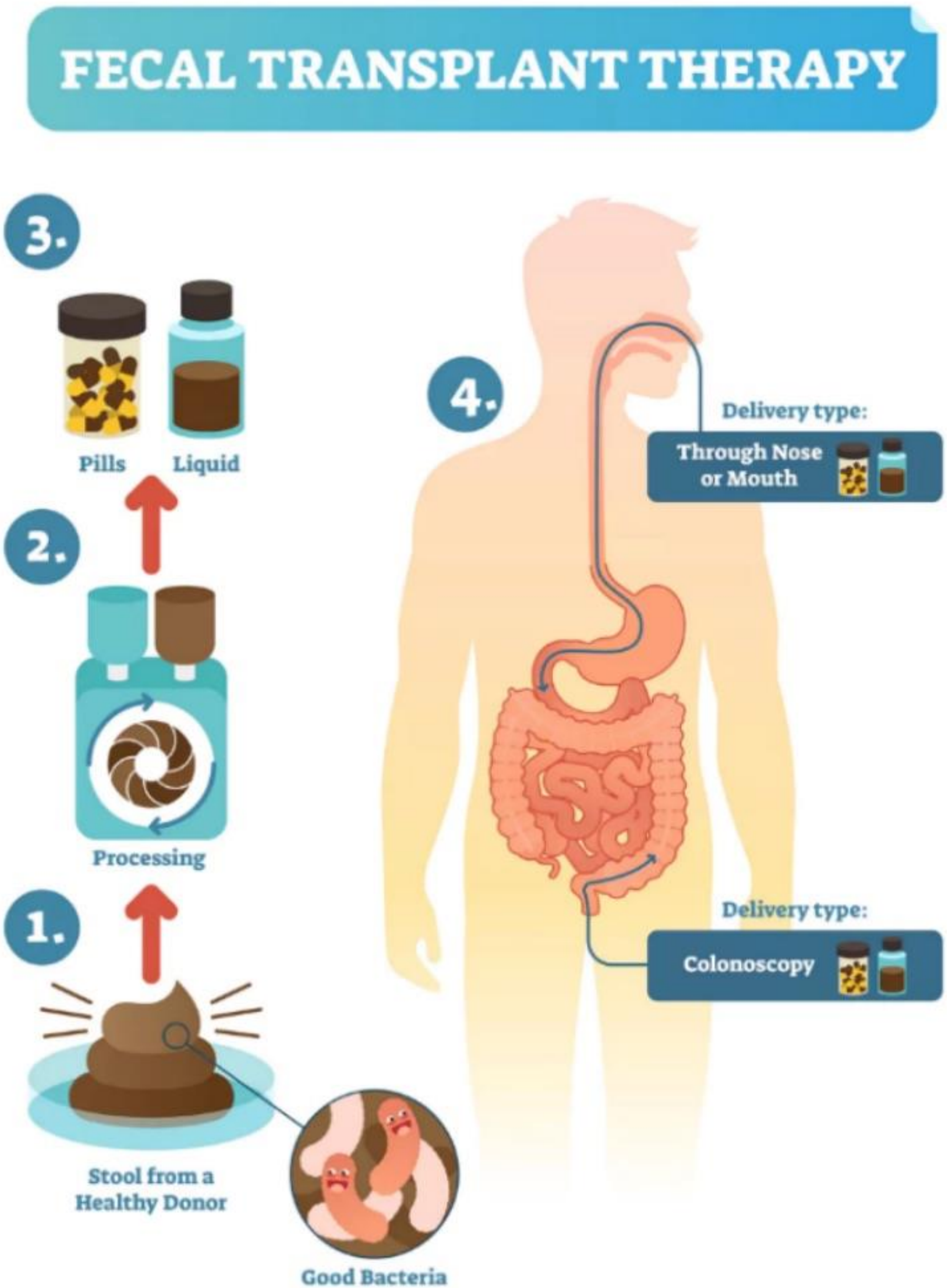
Delivery Mode Affects Stability of Early Infant Gut Microbiota

Caroline M. Mitchell [1], Chiara Mazzoni [2], Larson Hogstrom [3], Allison Bryant [1], Agnes Bergerat [1], Avital Cher [2], Shawna Pochan [1], Penelope Herman [1], Maureen Carrigan [1], Karen Sharp [1], Curtis Huttenhower [3, 4], Eric S. Lander [3, 5, 6]

In Trying to Keep Life Out

- We have favored a set of species that have adapted to the indoors (and are not necessarily good for us)
- We have excluded beneficial species (to our own detriment in the context of allergy/asthma/autoimmune disorders)
- We have created homes that are less healthy than those built by our ancestors eight million years ago.

If not this future then what?

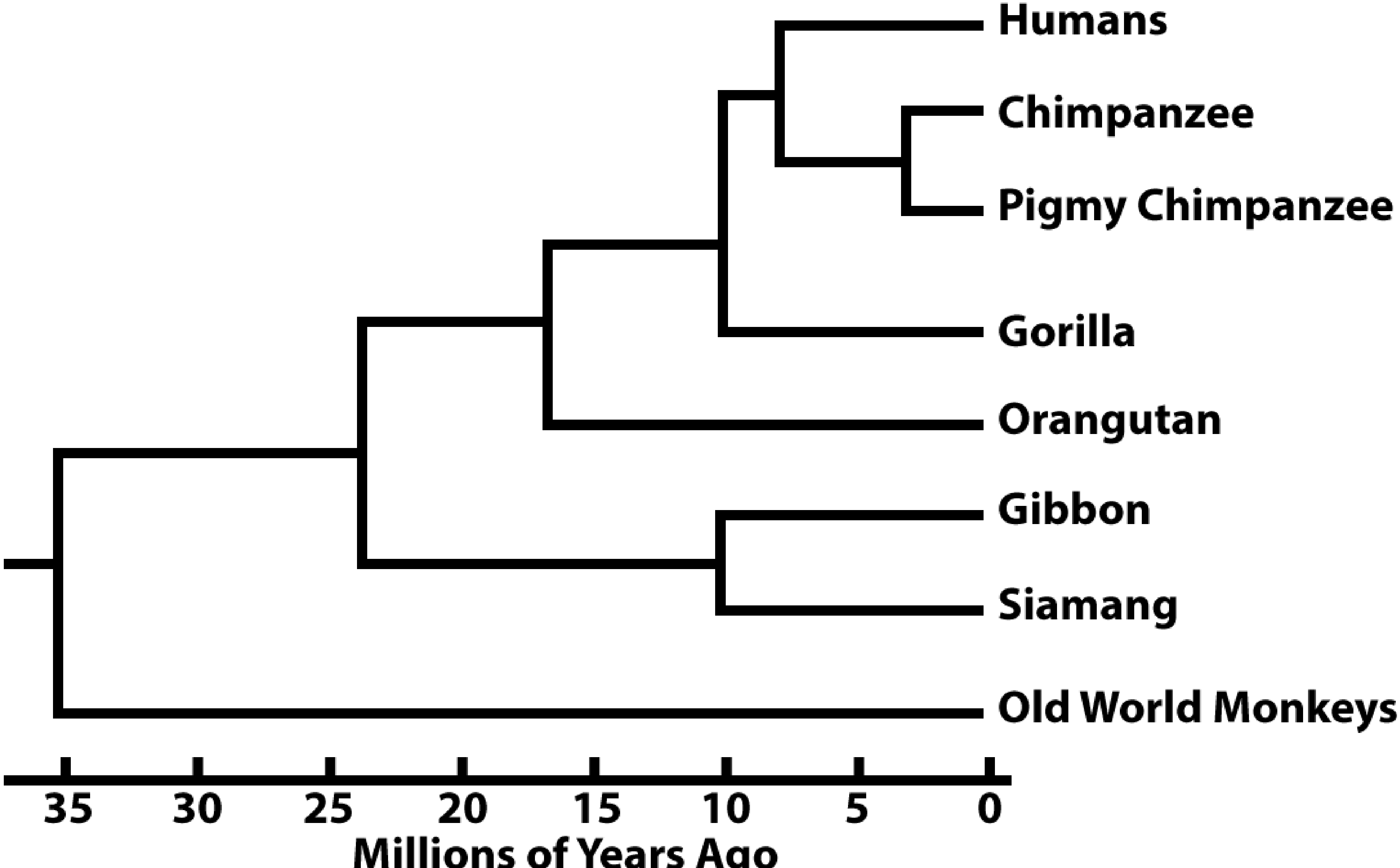


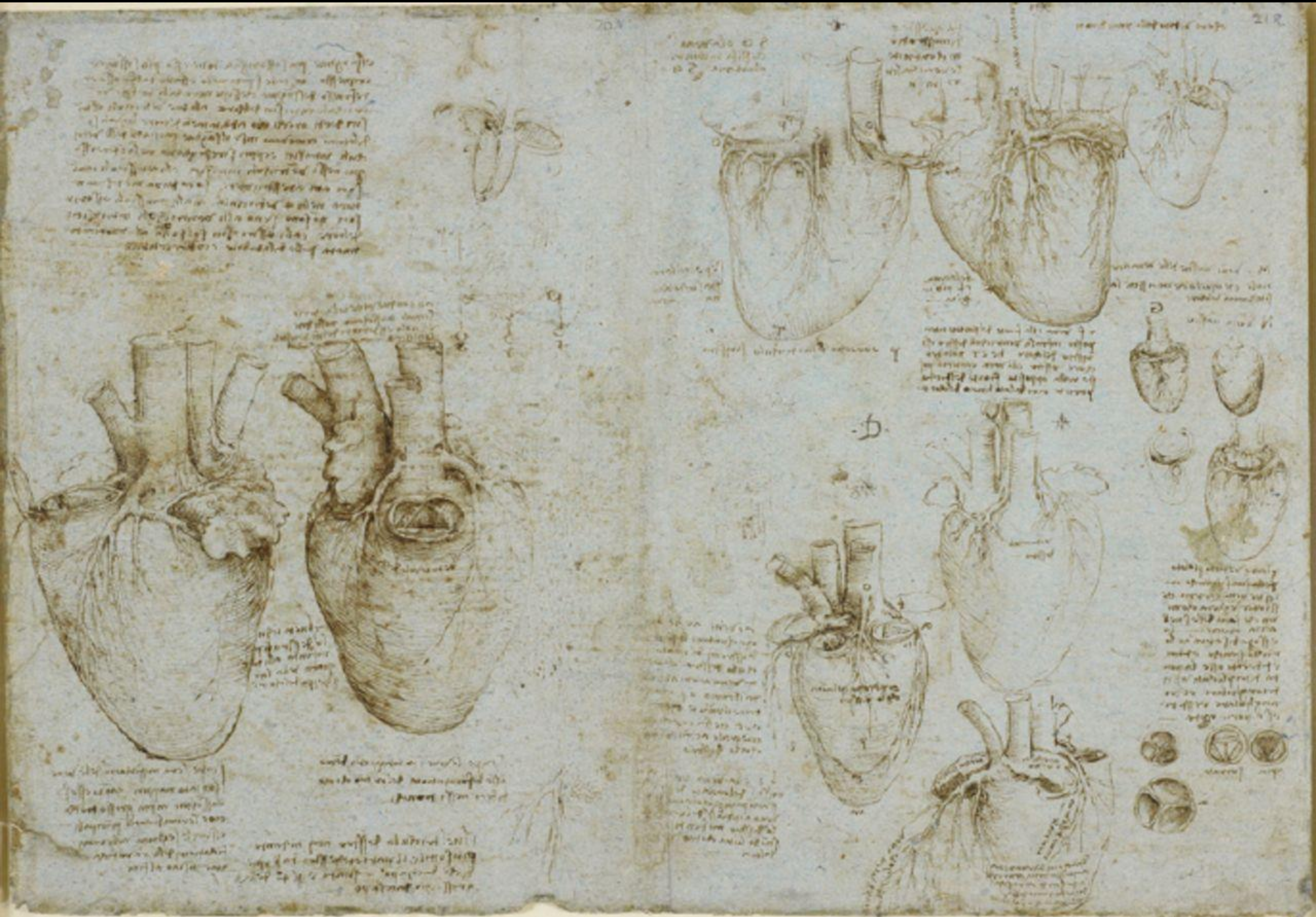
Predictions for the next 5-10 years of medicine (in 2017)

Predictions for the next 5-10 years of medicine (2022)

- An initial focus on re-introduction of outdoor microbes into homes (plants, fermented foods, open windows)
  - This is akin to the earliest fecal transplants
- Initial haphazard results (Which soil? Which plants? Which fermented foods?)
- One thread of future interventions will focus on bringing microbial processes into the home (e.g., fermenters/digesters)
- Another thread will focus on specific microbes used as therapeutics (on surfaces, in the home)
- All of this is already happening, just in remote corners

1. EVOLUTIONARY HISTORY (HEART)

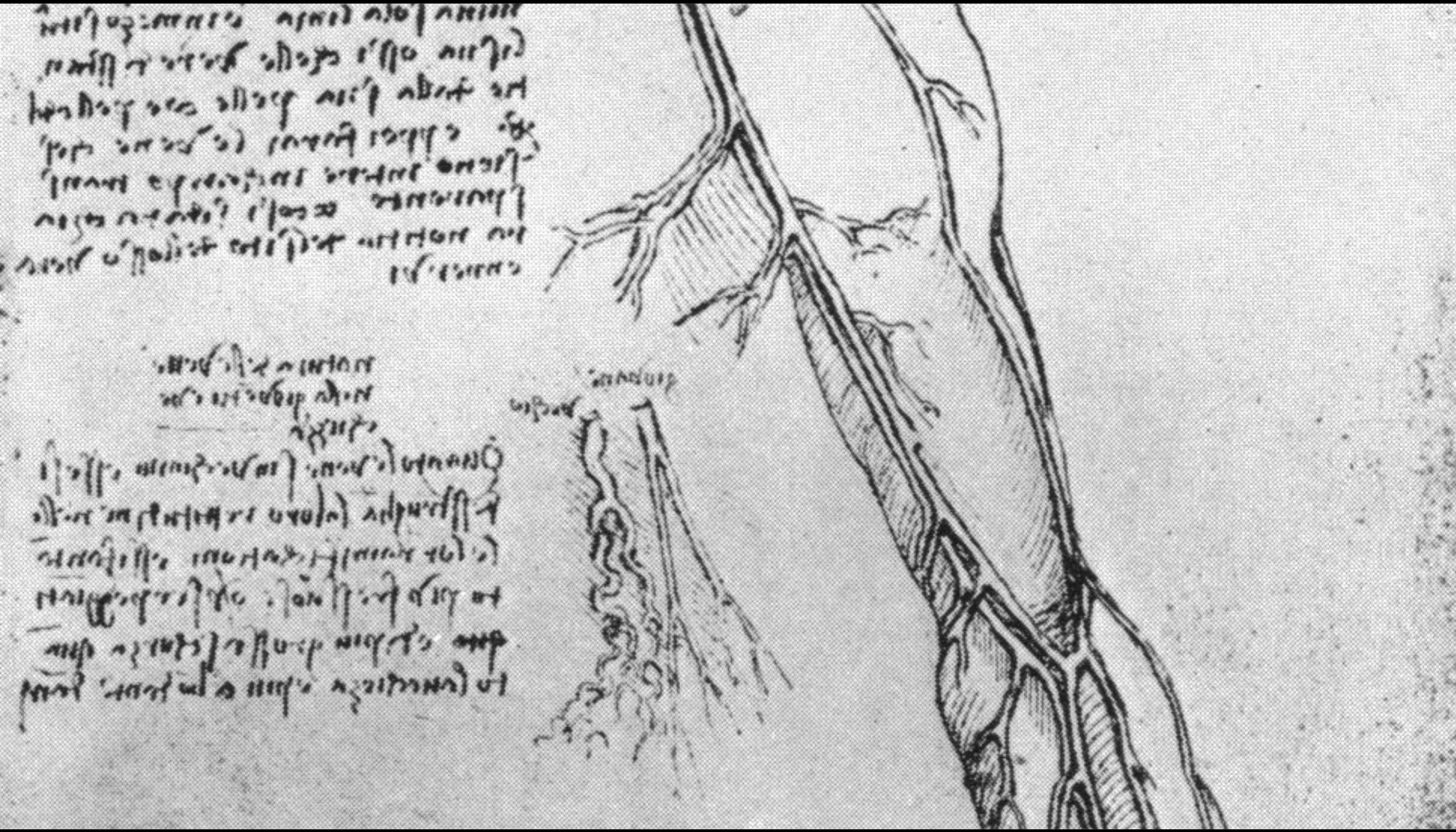




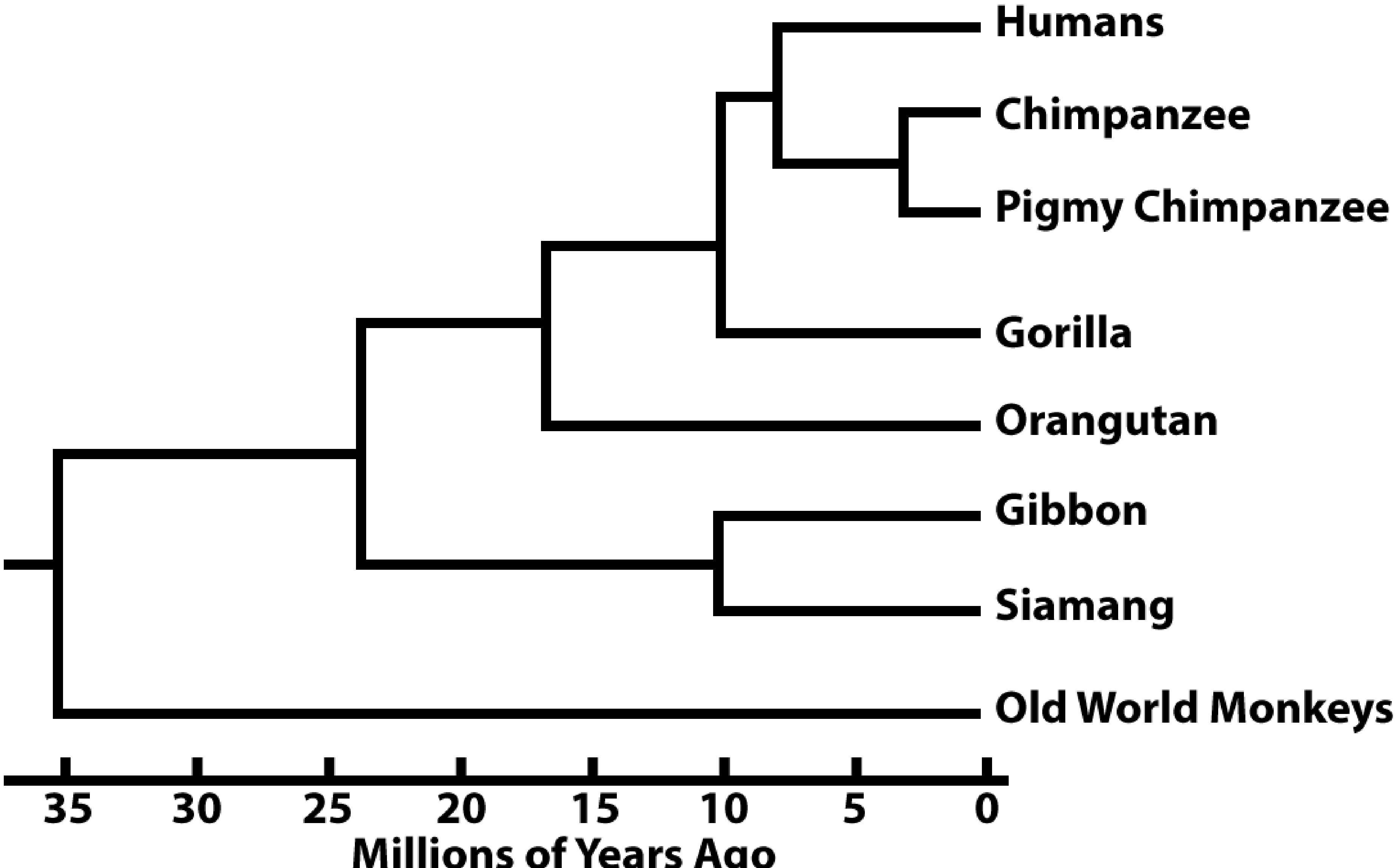
The Anatomy of an Old Man (*Il Vecchio*)

“As a well-spent day brings happy sleep, so life well used brings happy death”

Tortuous Arteries

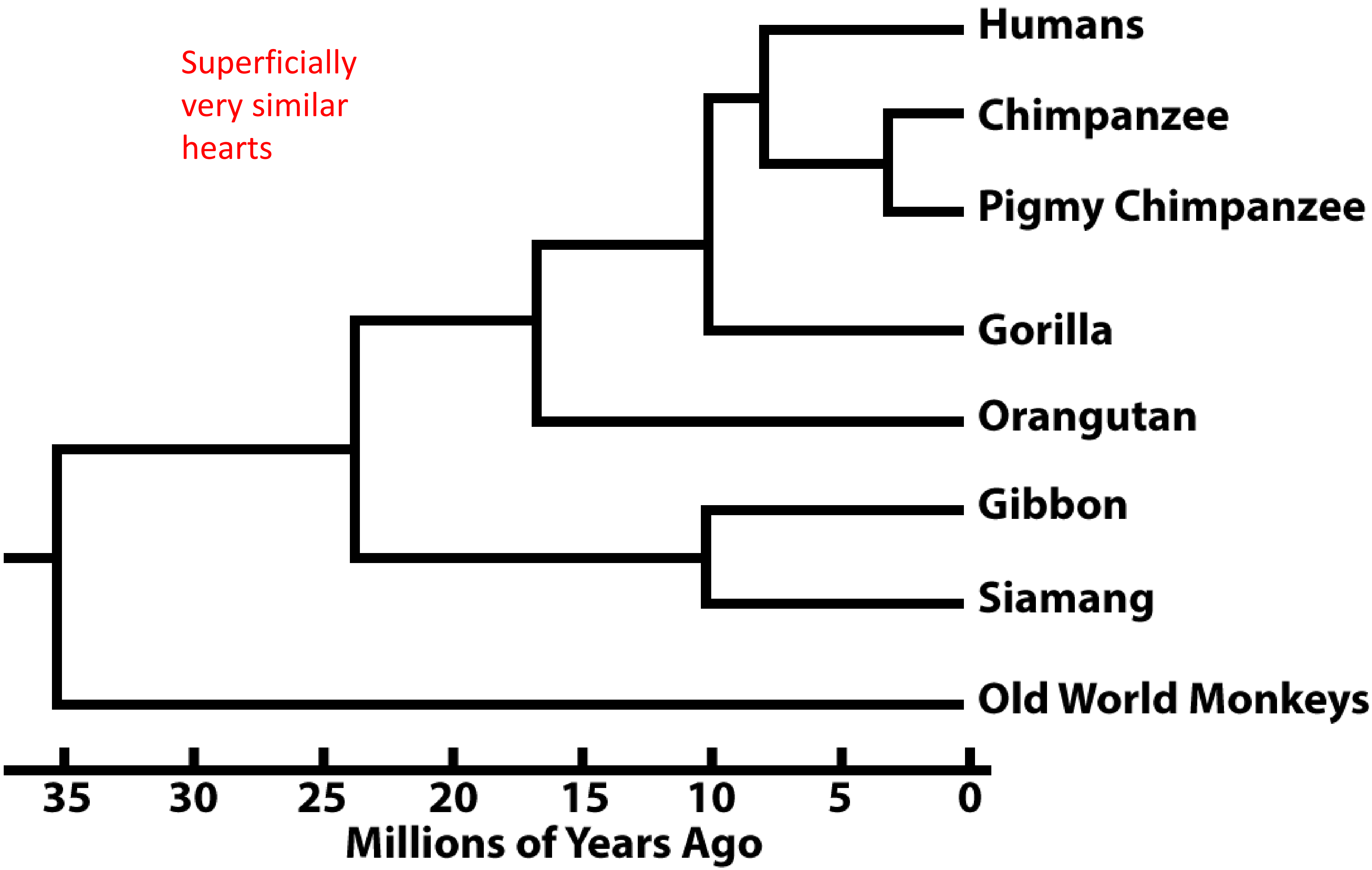


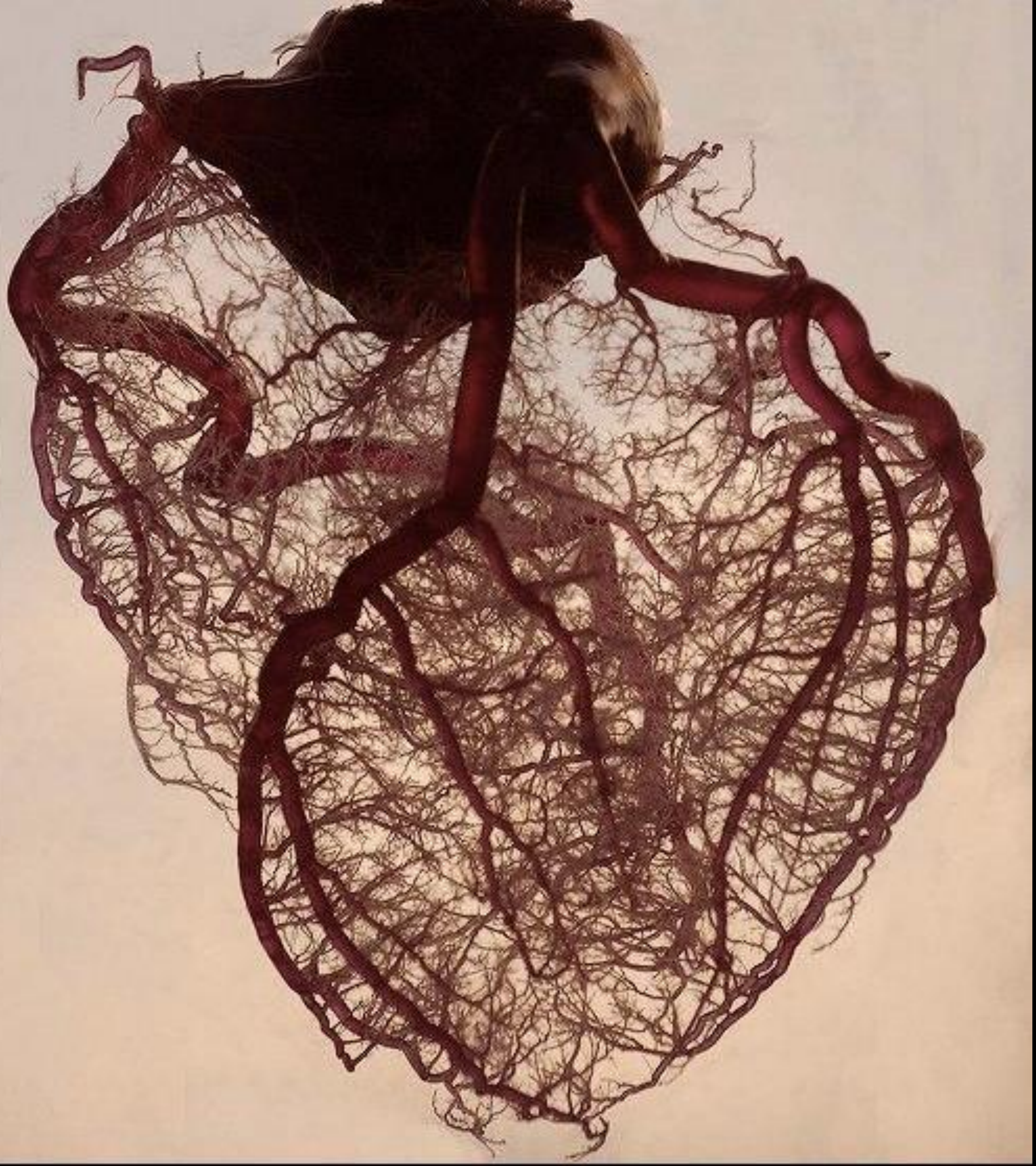
1. EVOLUTIONARY HISTORY (HEART)



1. EVOLUTIONARY HISTORY (HEART)

Superficially very similar hearts



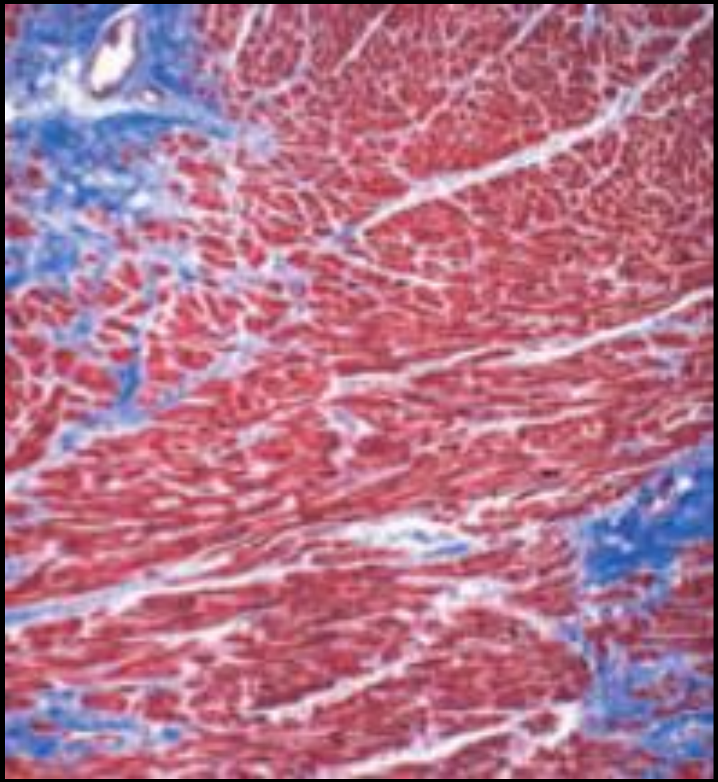


Sanaga-Yong Chimpanzee Rescue Center in Cameroon. Lucy has just died of a heart attack. The other chimpanzees mourn.

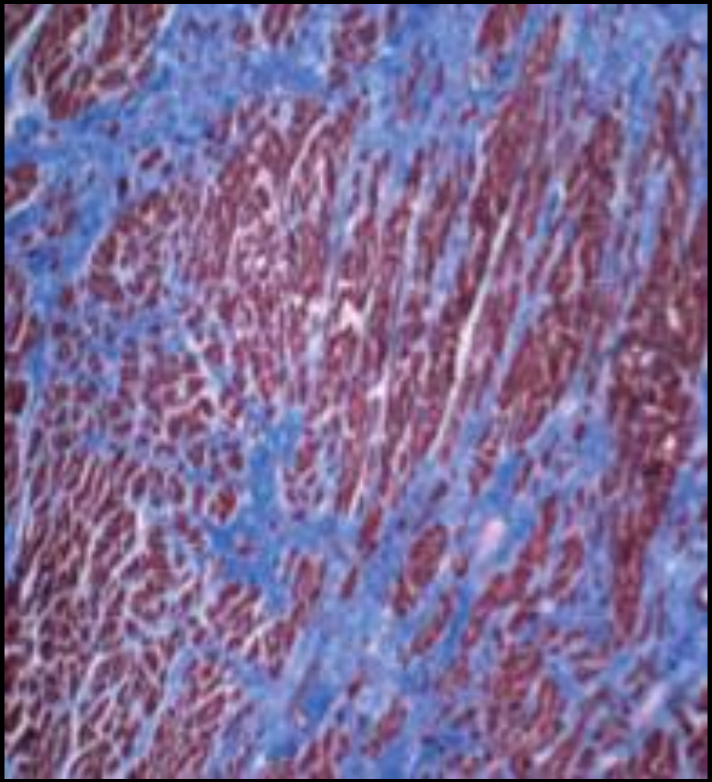
Yerkes National Primate Center, Emory

Nissi Varki, UCSD

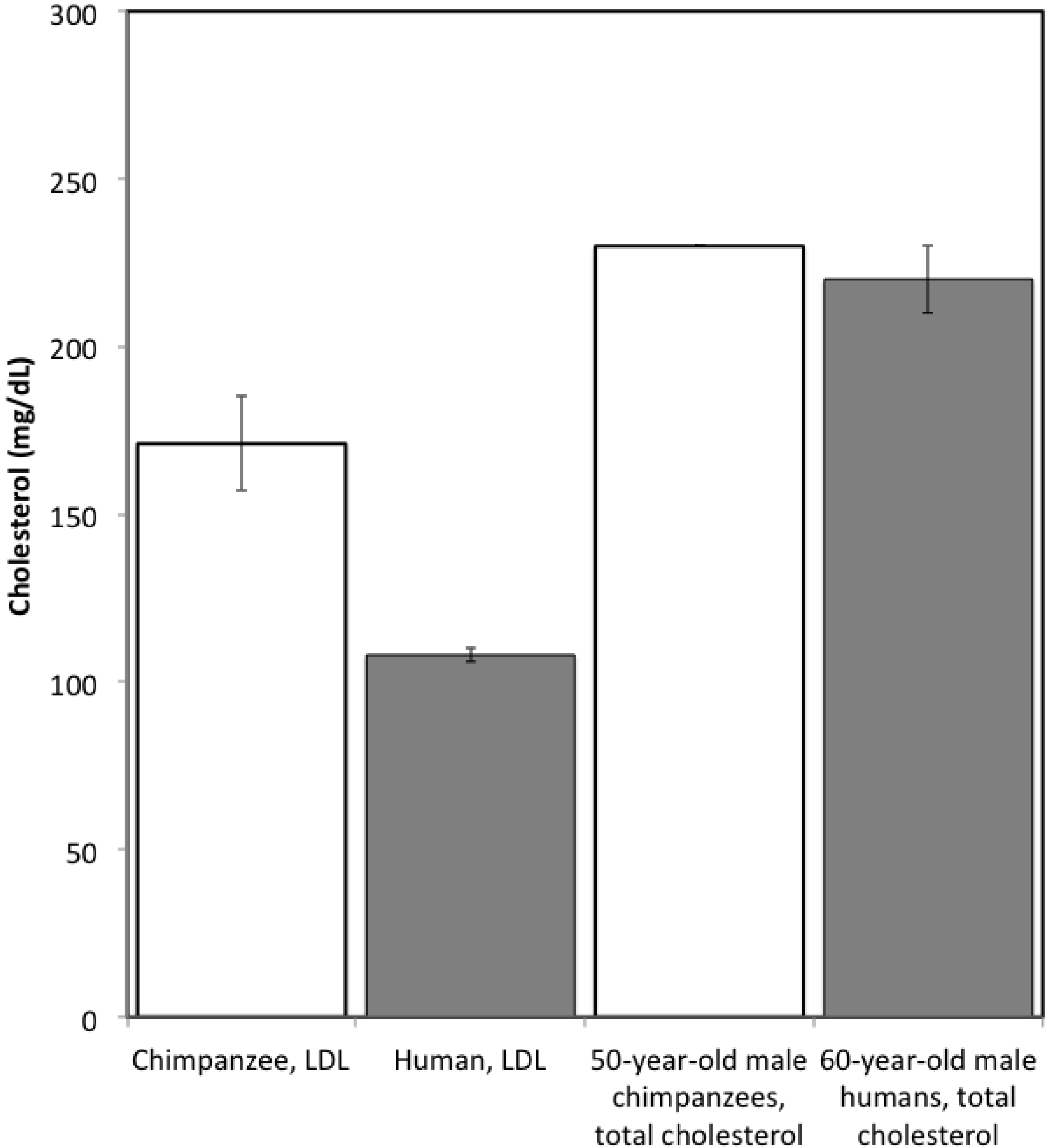
Human



Chimpanzee

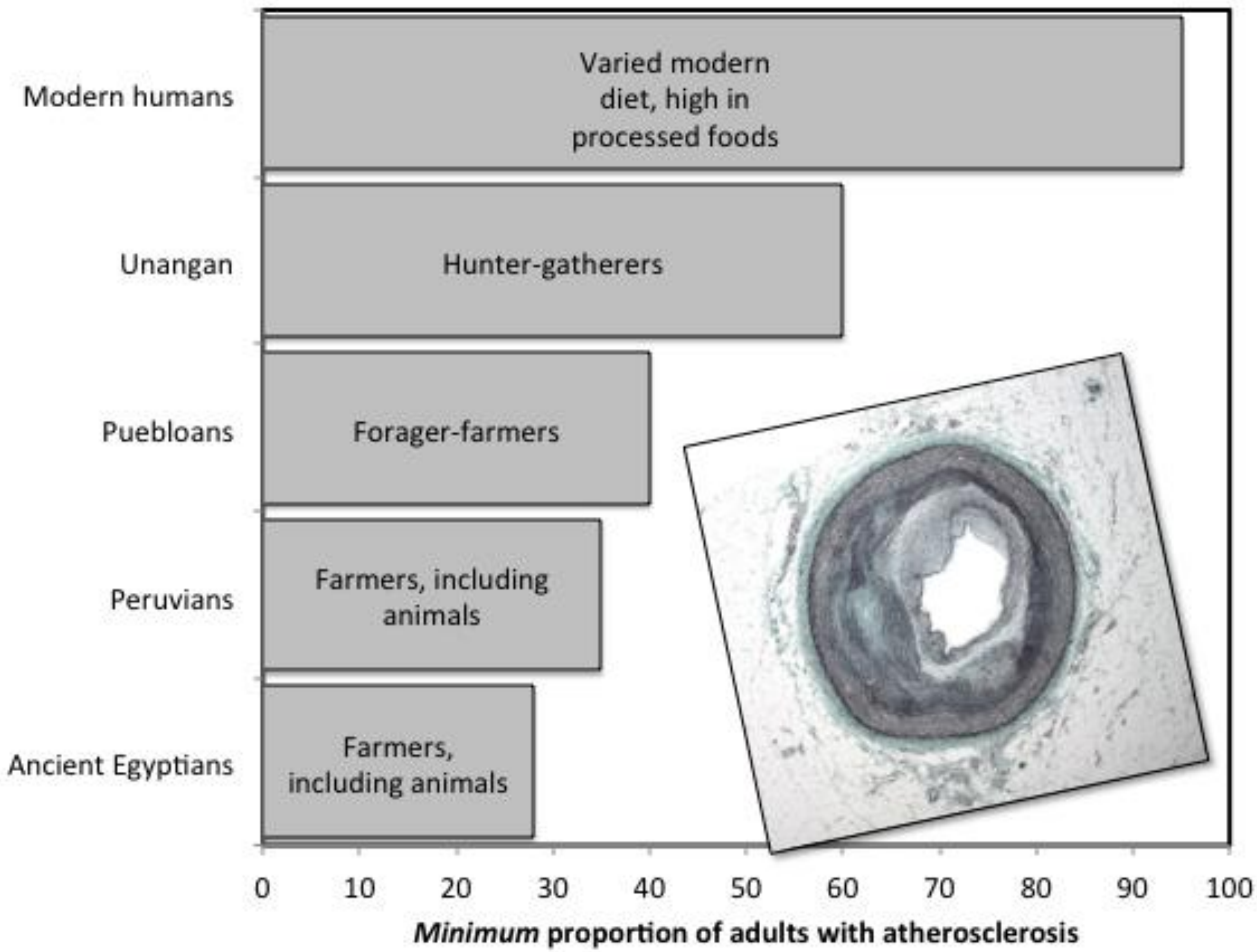


Varki, Nissi, Dan Anderson, James G. Herndon, Tho Pham, Christopher J. Gregg, Monica Cheriyan, James Murphy et al. "Heart disease is common in humans and chimpanzees, but is caused by different pathological processes." Evolutionary applications 2, no. 1 (2009): 101-112.

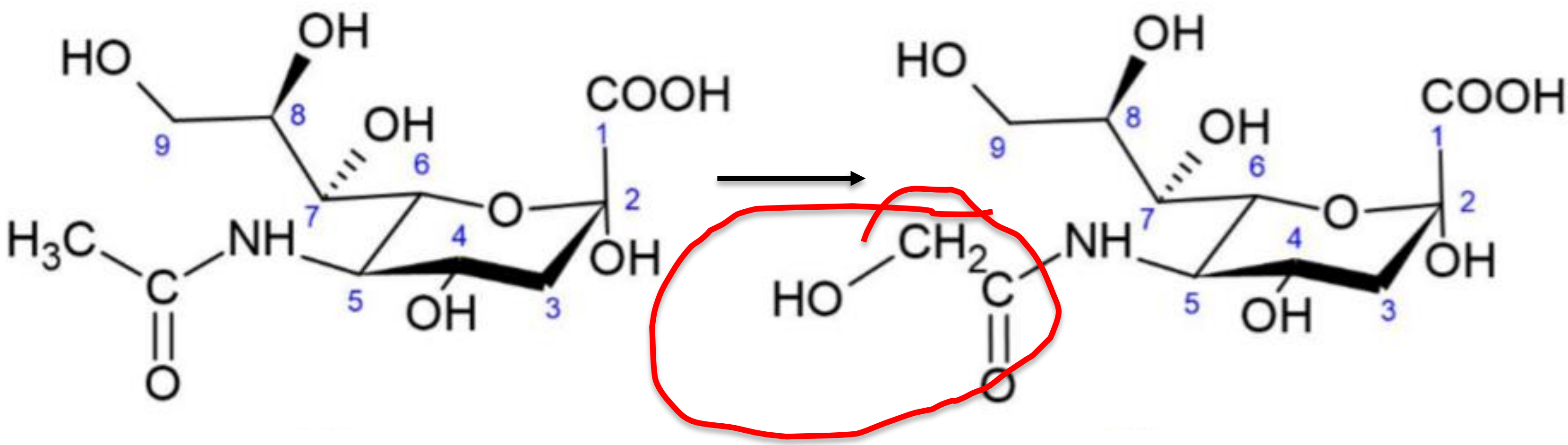


It doesn't appear to be due to differences in cholesterol

All humans seem to have the propensity for atherosclerosis

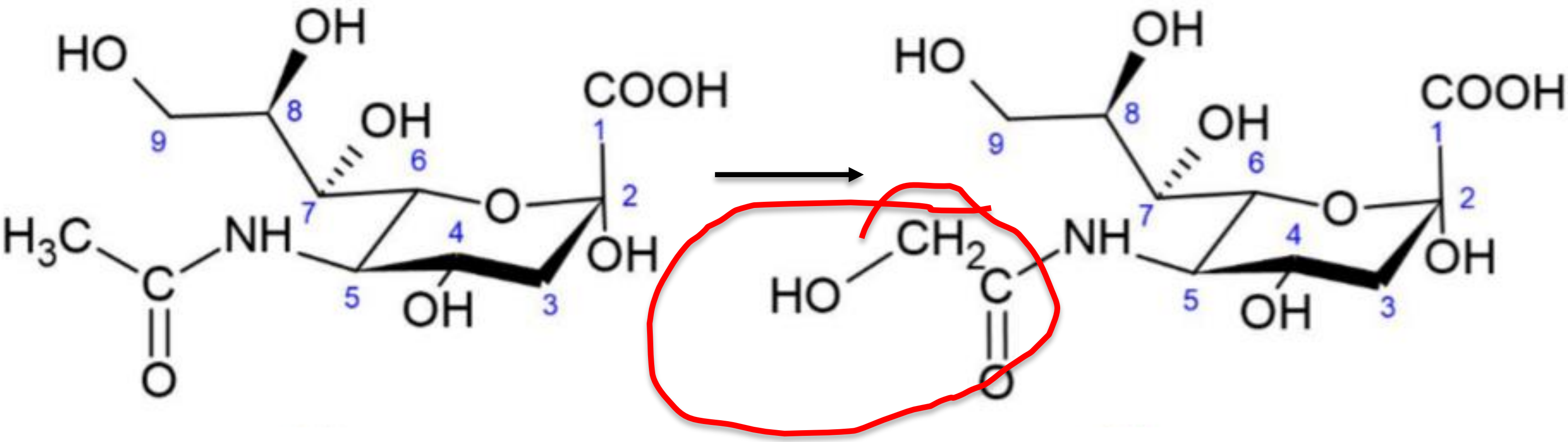


Ancient malaria



Neu5**A**c Neu5**G**c

Ancient malaria



Neu5**A**c

Neu5**G**c

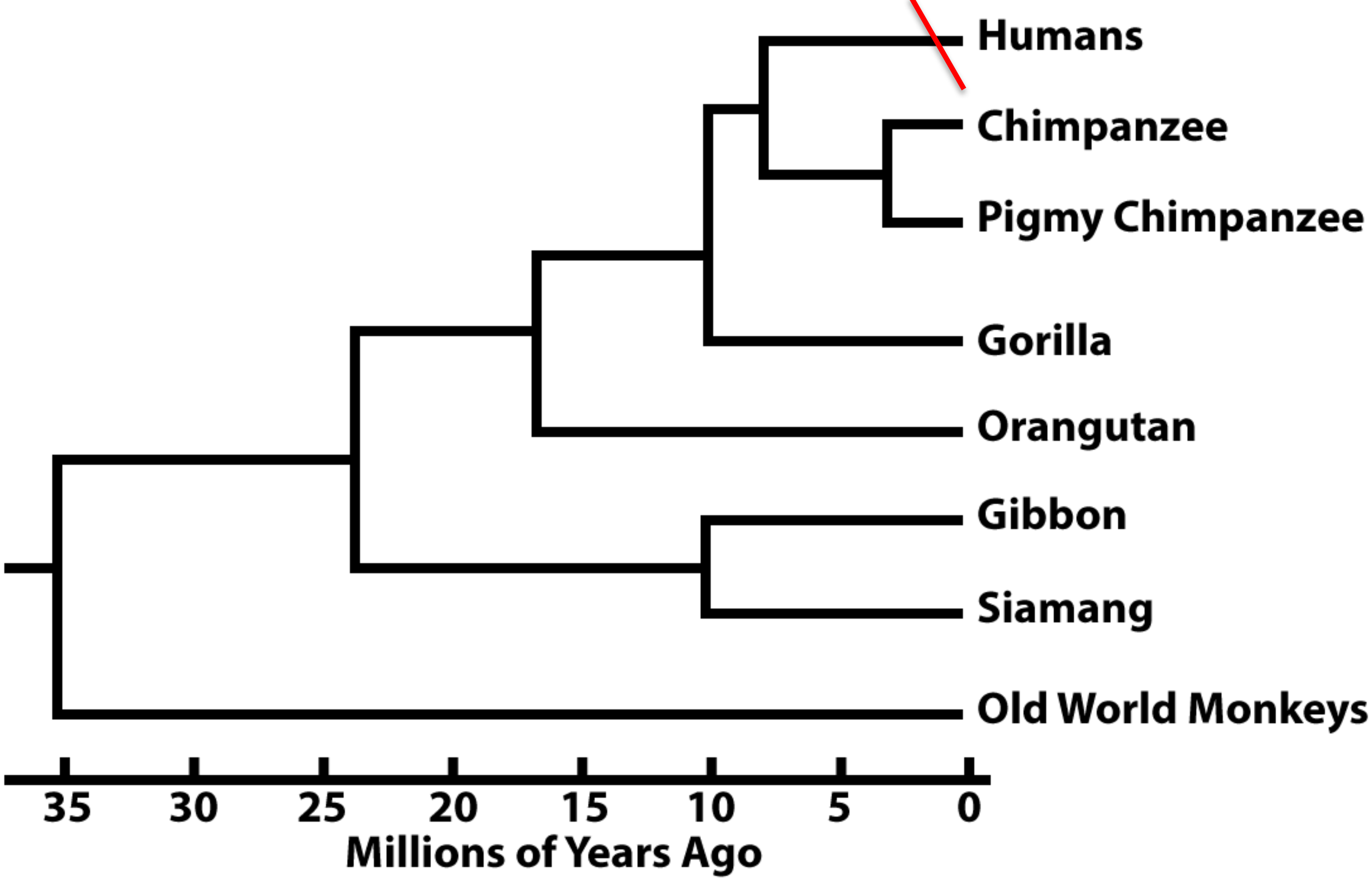
RESEARCH ARTICLE | BIOLOGICAL SCIENCES | FREE ACCESS

Uniquely human evolution of sialic acid genetics and biology

Ajit Varki Authors Info & Affiliations

May 5, 2010 | 107(supplement_2)8939-8946 | https://doi.org/10.1073/pnas.0914634107

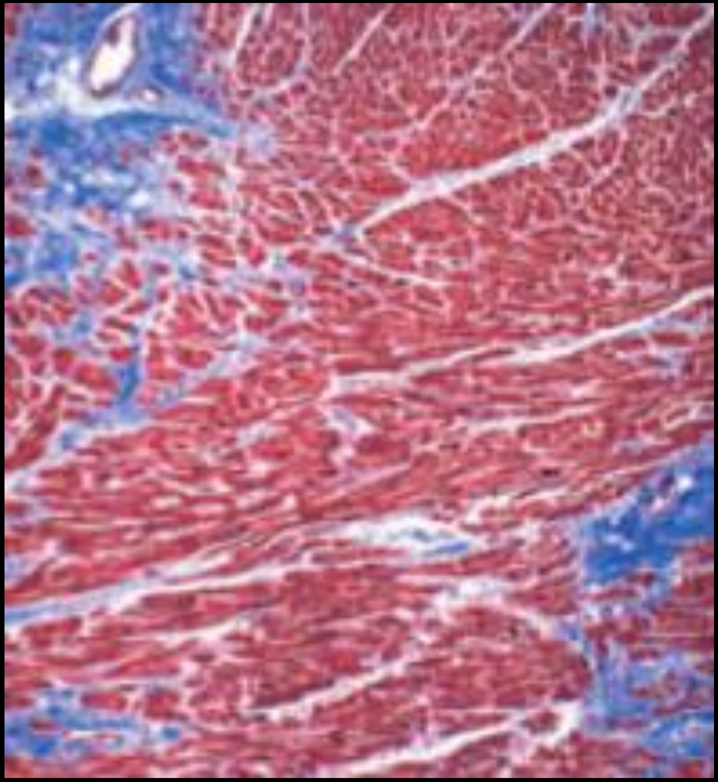
Broken gene associated with converting Neu5Ac to Neu5Gc



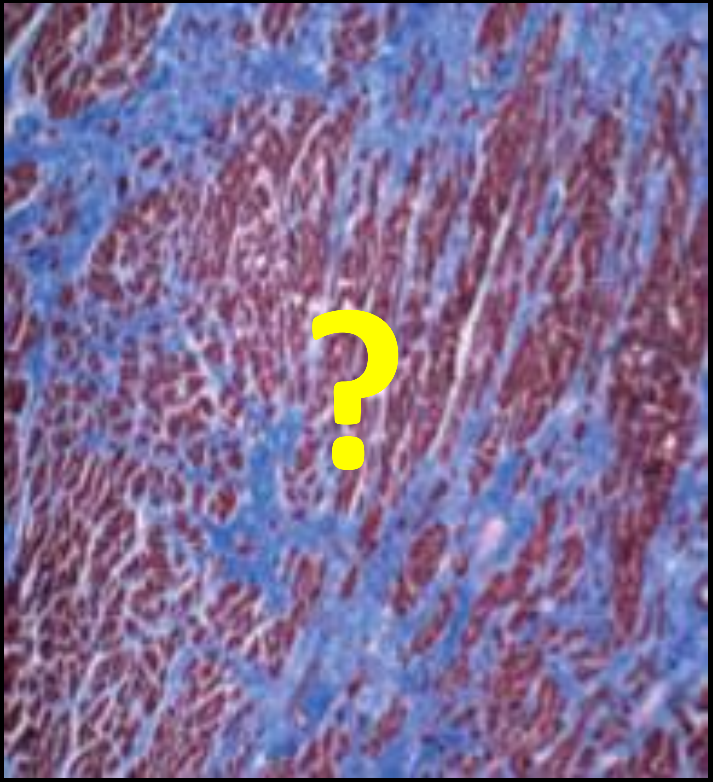
Meat-eating has been shown to accelerate atherosclerosis via sialic acids. Human-like mice develop atherosclerosis more rapidly in general and, especially when fed red meat.

Kawanishi, Kunio, Joanna K. Coker, Kaare V. Grunddal, Chirag Dhar, Jason Hsiao, Karsten Zengler, Nissi Varki, Ajit Varki, and Philip LSM Gordts. "Dietary Neu5Ac Intervention Protects Against Atherosclerosis Associated With Human-Like Neu5Gc Loss—Brief Report." *Arteriosclerosis, thrombosis, and vascular biology* 41, no. 11 (2021): 2730-2739.

Human



Chimpanzee



Varki, Nissi, Dan Anderson, James G. Herndon, Tho Pham, Christopher J. Gregg, Monica Cheriyan, James Murphy et al. "Heart disease is common in humans and chimpanzees, but is caused by different pathological processes." Evolutionary applications 2, no. 1 (2009): 101-112.

2. BROADER BIODIVERSITY

ALEXIS ROCKMAN, THE ECOTOURIST

2. BROADER BIODIVERSITY (HOUSES)

ALEXIS ROCKMAN, THE ECOTOURIST

Dr. Stephanie Mathews

Doubled… the number of bacteria species on Earth known to be able to break down lignin

The 1st Try Works



Lachancea thermotolerans (YB16), never before used in beer brewing

Led to a patent and a start up (Lachancea LLC, John Sheppard).
Dr. Anne Madden pictured (not here tonight).

Yeast

RESEARCH ARTICLE

Sugar-seeking insects as a source of diverse bread-making yeasts with enhanced attributes

Anne A. Madden, Caitlin Lahue, Claire L. Gordy, Joy L. Little, Lauren M. Nichols, Martha D. Calvert
... See all authors

First published: 23 October 2021 | https://doi.org/10.1002/yea.3676 | Citations: 1

Funding information: North Carolina State University; North Carolina State University Chancellor's Innovation Fund; North Carolina Biotechnology Center, Grant/Award Number: 2019-BIG-6513

Abstract

Insects represent a particularly interesting habitat in which to search for novel yeasts of value to industry. Insect-associated yeasts have the potential to have traits relevant to modern food and beverage production due to insect–yeast interactions, with such traits including diverse carbohydrate metabolisms, high sugar tolerance, and general stress

Otzi, the Iceman
(and his useful yeasts)

Note: Dr. Clint Penick (at far right)
has pillows available
for purchase

Omar Halawani

Almost Dr. Megan Thoemmes

ant and spider by Matt Bertone (Mill moth by anonymous Internet person)

Dr. Carlos Goller

2. BROADER BIODIVERSITY (HEARTS)

ALEXIS ROCKMAN, THE ECOTOURIST

1964, Dr. James Hardy

Heart Transplantation in Man

Developmental Studies and Report of a Case

James D. Hardy, MD, Carlos M. Chavez, MD, Fred D. Kurrus, MD, William A. Neely, MD, Sadan Eraslan, MD, M. Don Turner, PhD, Leonard W. Fabian, MD, and Thaddeus D. Labecki, MD, Jackson, Miss

HEART TRANSPLANTATION has interested many investigators.[1-5] Studies of related problems were begun in our laboratory in 1956. Webb and his associates studied such factors as practical methods for homologous cardiac transplantation,[6] cardiopulmonary transplantation,[7,8] restoration of function of the refrigerated heart,[9] and cardiac metabolism as influenced by ischemia and refrigeration.[10] The operative mortality was high, but extended survival of some dogs with orthotopic homotransplants was achieved. Collateral studies were conducted by other members of the department.[11-14] Thus, in the spring of 1963, Webb and the senior author (J.D.H.) considered that the laboratory and clinical heart work justified a planned approach directed toward eventual heart transplantation in man. This objective, a natural outgrowth of transplantation research, was cleared with the administrative officials of the University Medical Center.

It remained for us to evaluate further the methods available for preservation of the heart during its transplantation. While resuscitation of the transplanted heart preserved with cold arrest could be achieved in most animals, it was essential that restoration of a good beat be assured for the first heart transplanted in man. Coronary artery perfusion had previously proved superior to ice slush during aortic valve surgery in animals[15] and in human beings and it was now re-examined. However, the coronary arteries of the dog were often too small and too variable to be perfused consistently with the equipment available, and ventricular ischemia and infarction occurred with some frequency.

Meanwhile, two operating teams had been established, one of which would obtain the heart from the donor and the other would prepare the recipient. One team continued heart transplantation in dogs (W.R.W.), but the other (J.D.H.) turned to a study of beef hearts and eventually to the use of the hearts of infant calves. It was found that the coronary arteries of even newborn calves were almost equal in size to those of the human adult, and that perfusion of both the right and left coronary arteries with cold oxygenated blood under gravity flow could routinely be achieved within three minutes from the time of excision of the organ. These small calves tolerated the supine position poorly, and ventricular fibrillation frequently occurred even before intrapericardial dissection had been initiated. Even so, the animals proved satisfactory for our purposes, in that coronary artery perfusion was regularly achieved without undue delay, following which the continuously perfused organ was transferred to an adjacent operating table and inserted into the new host who was supported with the pump oxygenator. The two operating teams were combined to complete this final insertion of the transplant. The extracorporeal circuit was primed with "sterile" but unmatched blood obtained from a slaughterhouse two hours previously, and the suture technique described by Lower and associates[2] was employed. In contrast to experience with heart transplantation in dogs, anastomotic bleeding rarely constituted a problem in calves, whose tissues were tough and held sutures without tearing. Digitalization was found helpful when used cautiously,[4] but on some occasions the digitalis produced heart block which often responded dramatically to the intravenous infusion of isoproterenol (Isuprel) hydrochloride.

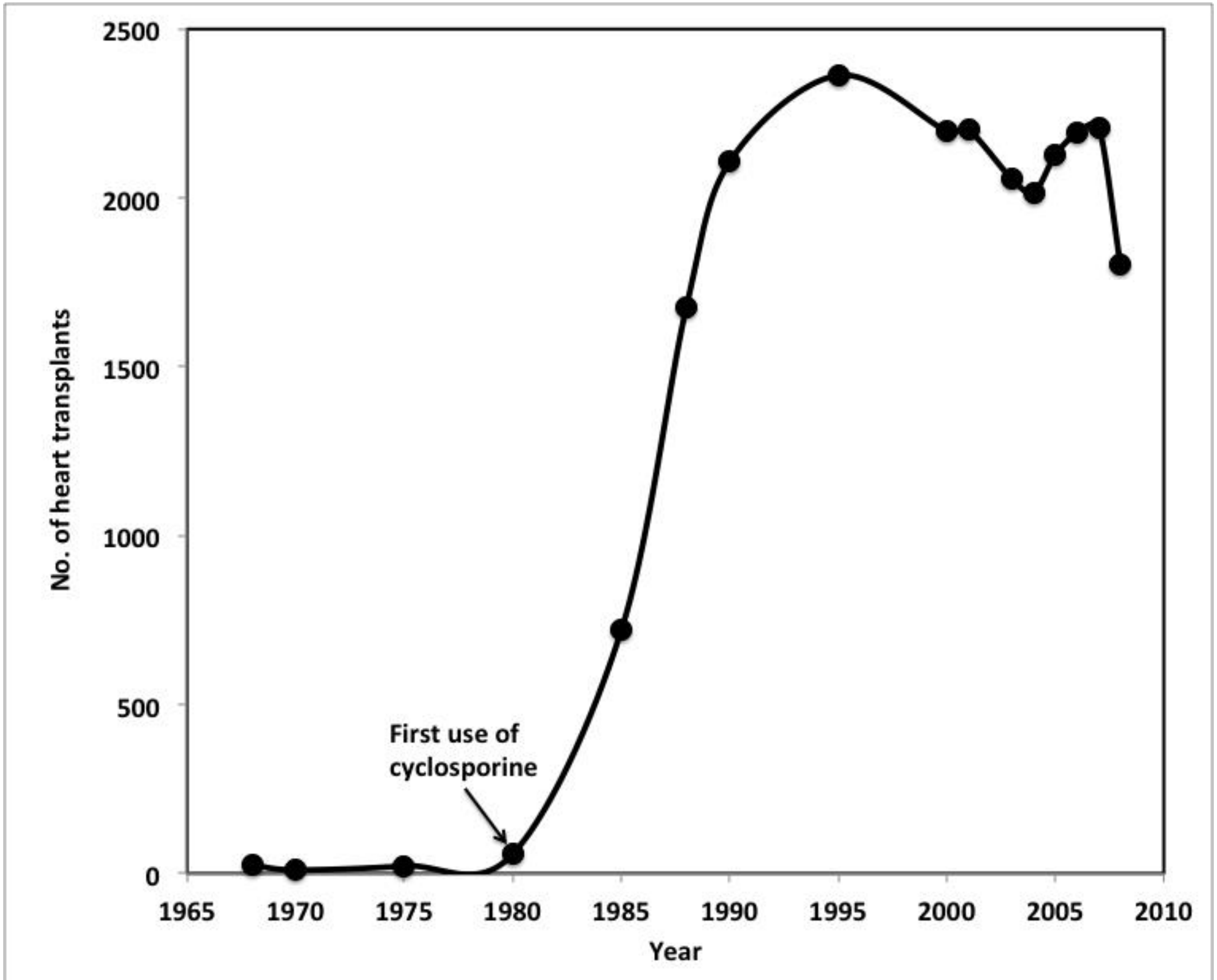
Approximately 50 calves were used in the successful completion of 20 homotransplants.[19] Coronary artery perfusion was found to be satisfactory

From the departments of surgery, anesthesiology, and medicine, and the University Hospital of the University of Mississippi Medical Center.

In the first transplant the patient lived!

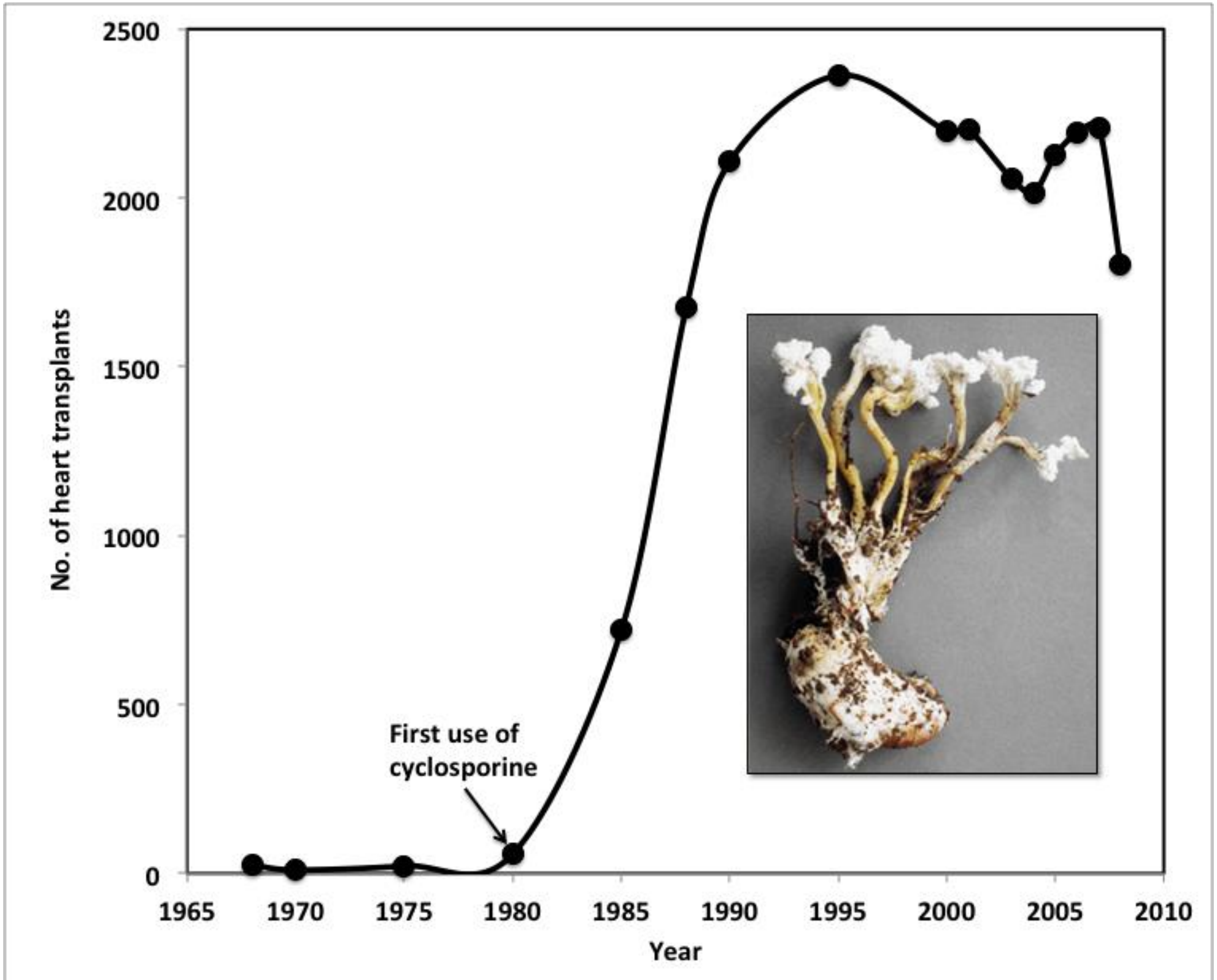

FIFTY CENTS
DECEMBER 15, 1967
THE TRANSPLANTED HEART
TIME
THE WEEKLY NEWSMAGAZINE
R. Vickrey
DR D S FREDRICKSON
6615 BRADLEY BLVD
BETHESDA
DR. CHRISTIAAN
BARNARD

But he lived just 18 days.



2500
2000
1500
1000
500
0
No. of heart transplants
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
First use of cyclosporine

The secret was Cyclosporine.



2500
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No. of heart transplants
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Year
First use of
cyclosporine

Kathie Hodge, Cornell

Xenotransplantation. Author manuscript; available in PMC 2019 Aug 30. PMCID: PMC6717028
Published in final edited form as: NIHMSID: NIHMS1043616
Xenotransplantation. 2019 Jul; 26(4): e12511. PMID: 30932224
Published online 2019 Apr 1. doi: 10.1111/xen.12511

The 'Baby Fae' baboon heart transplant – potential cause of rejection

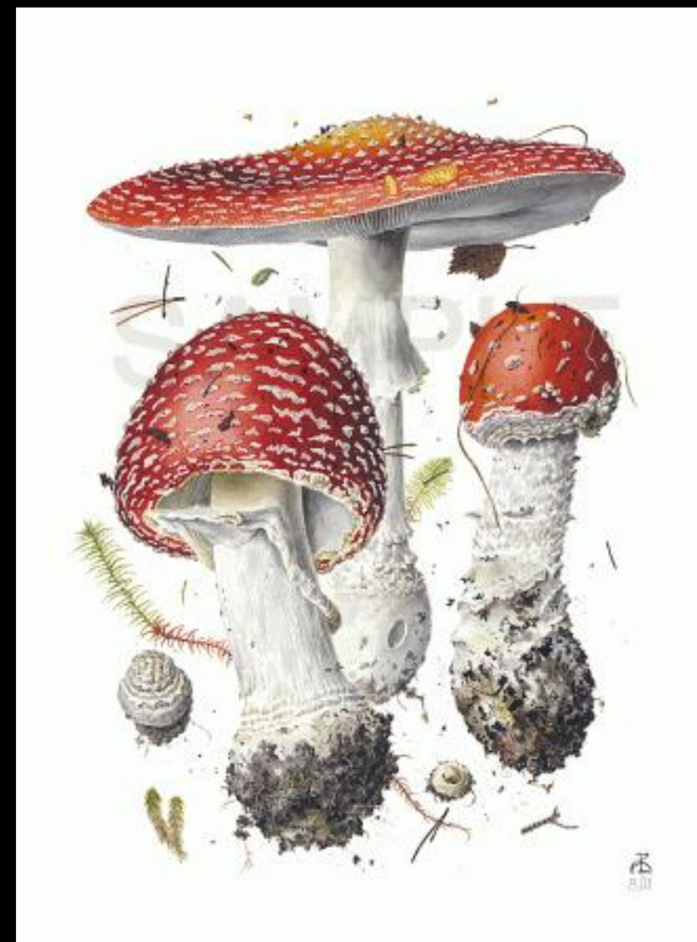
David K.C. Cooper, Hidetaka Hara, C. Adam Banks, David Cleveland, and Hayato Iwase

Baby Fae, received a baboon heart transplant. Rejected the heart after several weeks (1984).

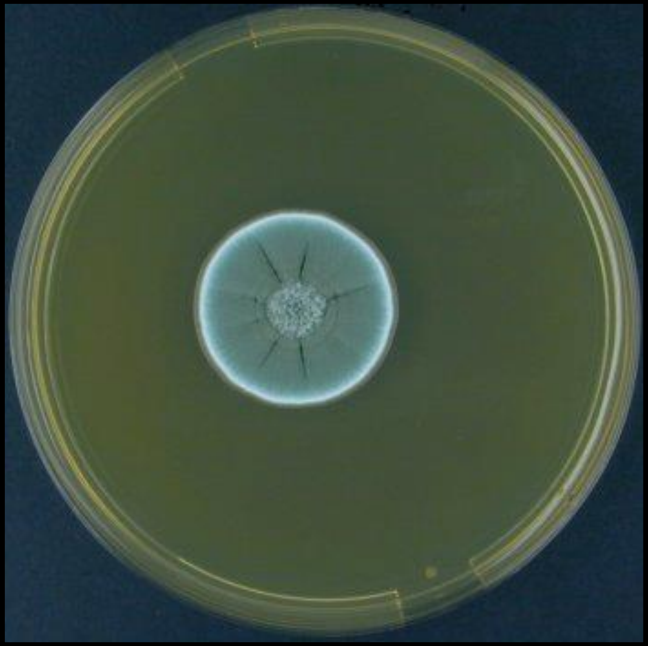
Pig heart transplant

Akira Endo

1965



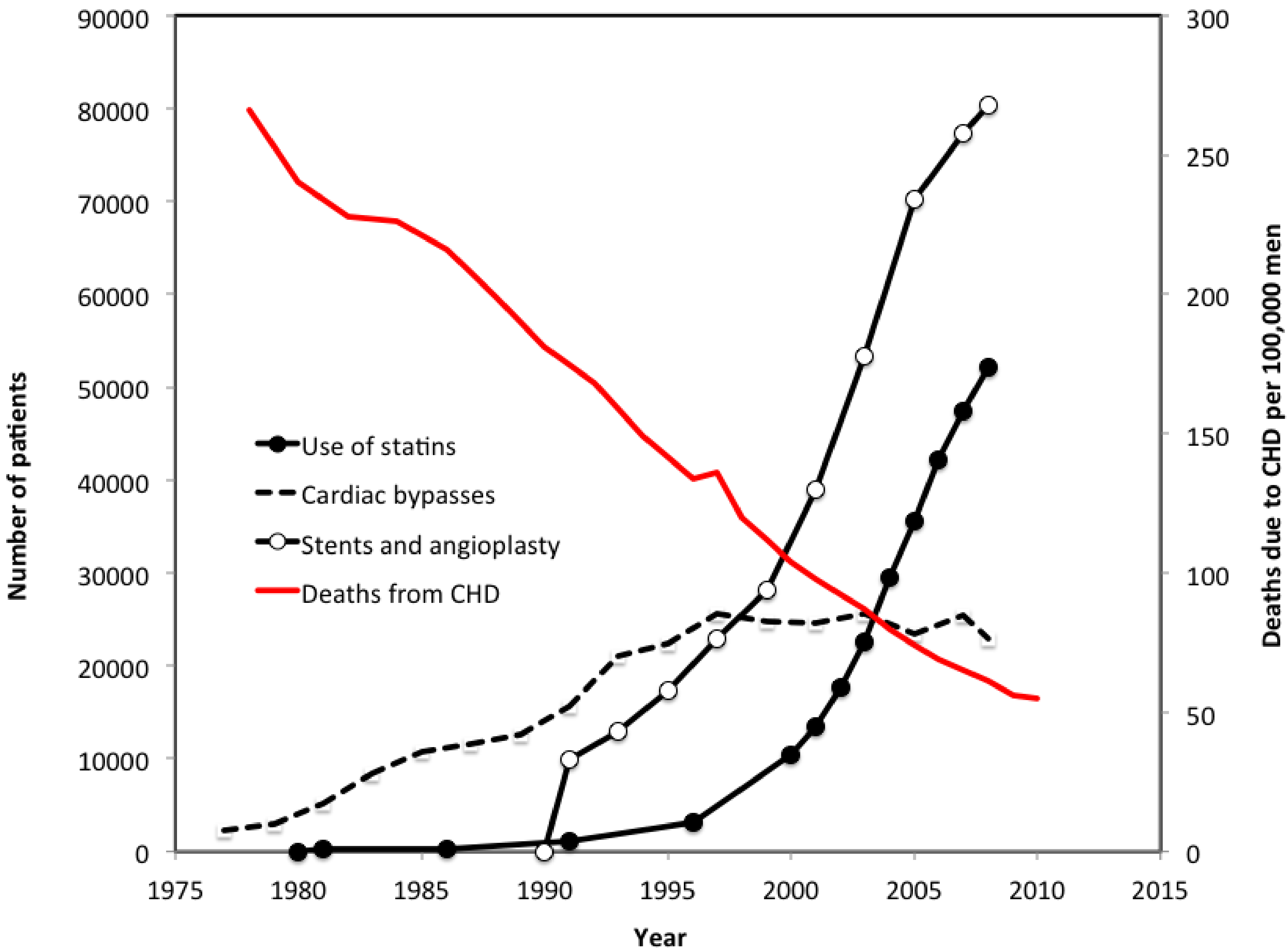
6000 fungal strains



Checked for inhibition of HMG-CoA reductase

In 1971, citrinin works but causes kidney stones.
In 1973, compactin works in petri dishes, but not in rats

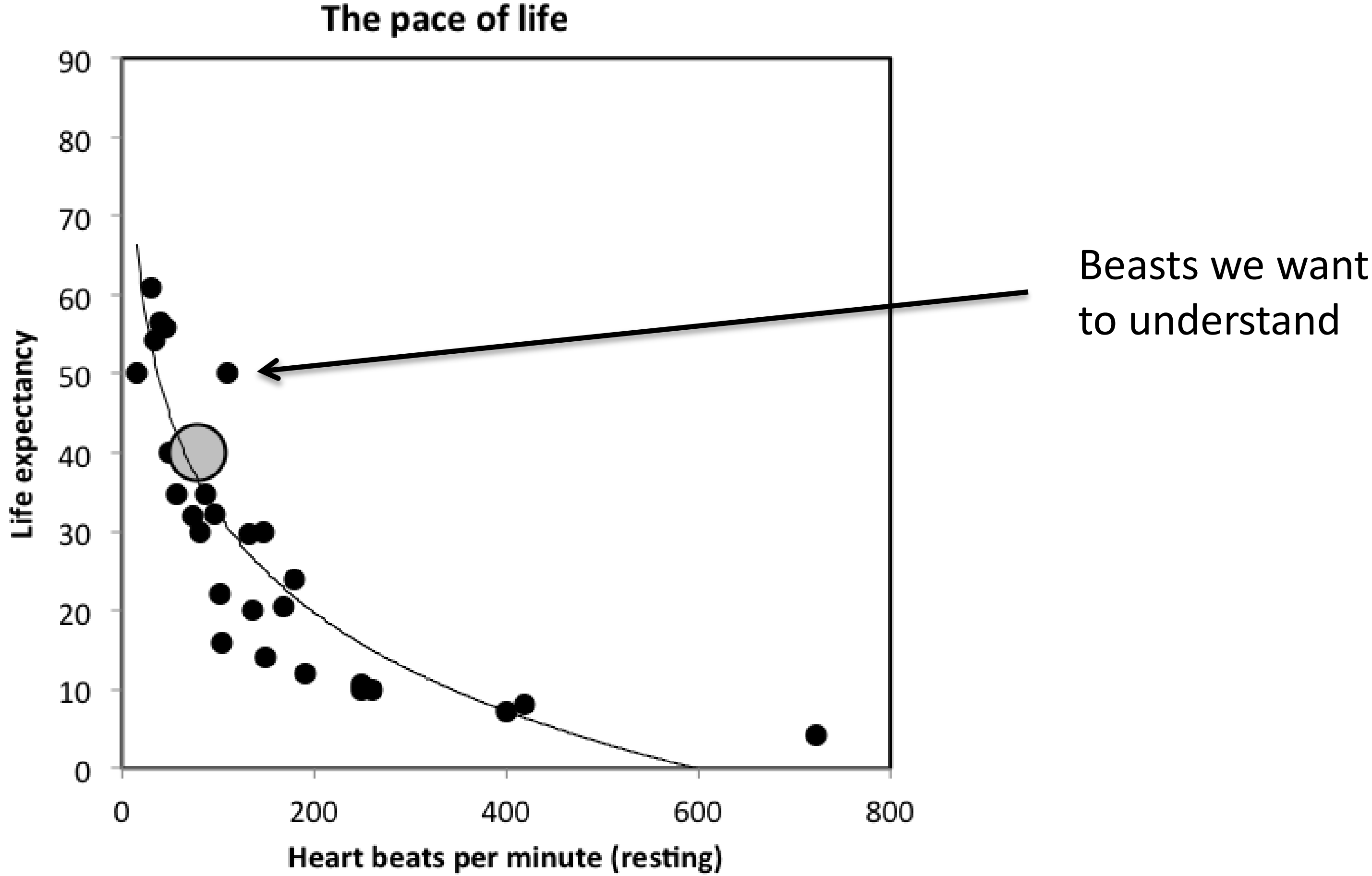
“a wonderful gift from nature”



90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Number of patients
300
250
200
150
100
50
0
Deaths due to CHD per 100,000 men
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year
Use of statins
Cardiac bypasses
Stents and angioplasty
Deaths from CHD

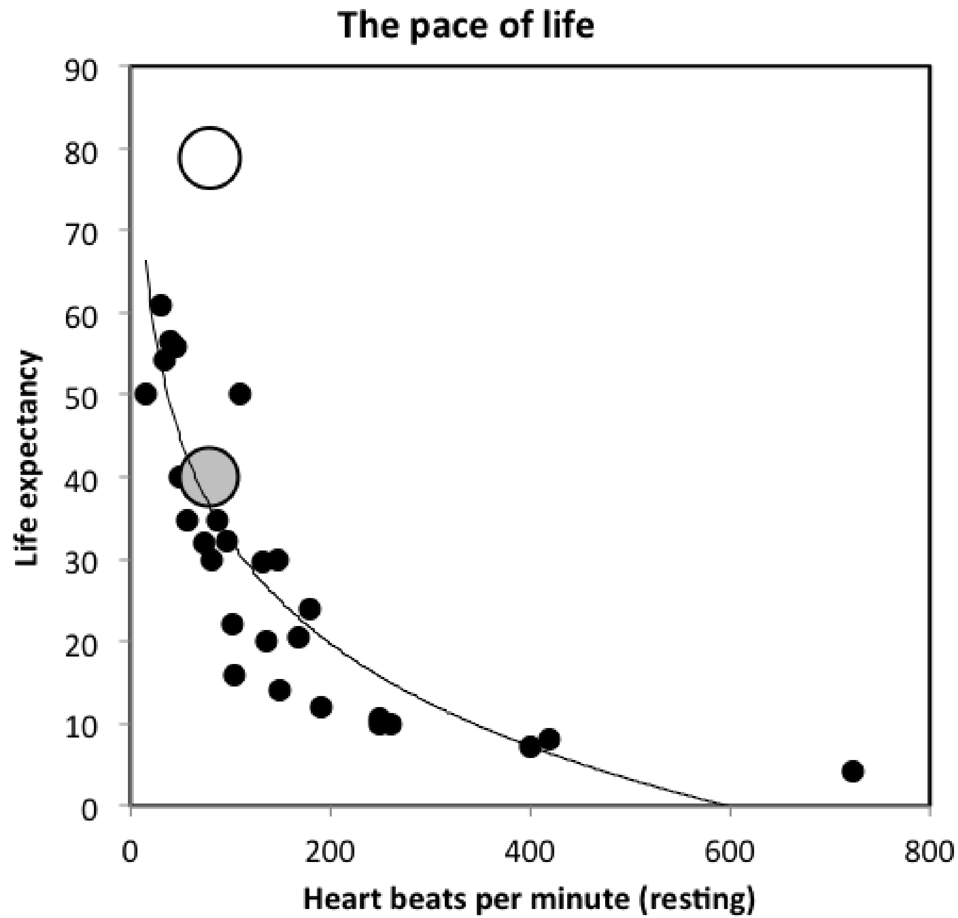
A Baby Blue Whale Heart

The organisms that get longer lives offer insights into longevity.



Adenosine

Humans get about 1.5 billion extra beats.



WE ARE JUST BEGINNING TO EXPLORE


1.5 MILLION BEETLES
5 MILLION INSECTS
7 MILLION ARTHROPODS
80% UNDISCOVERED

Pseudomonas aerigunosa
photo of colony by Scott Chimileski

Scaling laws predict global microbial diversity

Kenneth J. Locey[a,1] and Jay T. Lennon[a,1]

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Edited by David M. Karl, University of Hawaii, Honolulu, HI, and approved March 30, 2016 (received for review October 27, 2015)

Scaling laws underpin unifying theories of biodiversity and are among the most predictively powerful relationships in biology. However, scaling laws developed for plants and animals often go untested or fail to hold for microorganisms. As a result, it is unclear whether scaling laws of biodiversity will span evolutionarily distant domains of life that encompass all modes of metabolism and scales of abundance. Using a global-scale compilation of ~35,000 sites and ~$5.6 \cdot 10^6$ species, including the largest ever inventory of high-throughput molecular data and one of the largest compilations of plant and animal community data, we show similar rates of scaling in commonness and rarity across microorganisms and macroscopic plants and animals. We document a universal dominance scaling law that holds across 30 orders of magnitude, an unprecedented expanse that predicts the abundance of dominant ocean bacteria. In combining this scaling law with the lognormal model of biodiversity, we predict that Earth is home to upward of 1 trillion (10^{12}) microbial species. Microbial biodiversity seems greater than ever anticipated yet predictable from the smallest to the largest microbiome.

biodiversity | microbiology | macroecology | microbiome | rare biosphere

The understanding of microbial biodiversity has rapidly transformed over the past decade. High-throughput sequencing and bioinformatics have expanded the catalog of microbial taxa by orders of magnitude, whereas the unearthing of new phyla is reshaping the tree of life (1–3). At the same time, discoveries of novel forms of metabolism have provided insight into how microbes persist in virtually all aquatic, terrestrial, engineered, and host-associated ecosystems (4, 5). However, this period of discovery has uncovered few,

hold across genomes, cells, organisms, and communities of greatly varying size (13–15). Among the most widely known are the scaling of metabolic rate (B) with body size [M; $B = B_o M^{3/4}$ (13)] and the rate at which species richness (i.e., number of species; S) scale with area [A; $S = cA^z$ (16)]. These scaling laws are predicted by powerful ecological theories, although evidence suggests that they fail for microorganisms (17–19). Beyond area and body size, there is an equally general constraint on biodiversity, that is, the number of individuals in an assemblage (N). Often referred to as total abundance, N can range from less than 10 individuals in a given area to the nearly 10^{30} cells of bacteria and archaea on Earth (6, 7). This expanse outstrips the 22 orders of magnitude that separate the mass of a *Prochlorococcus* cell ($3 \cdot 1^{-16}$ kg) from a blue whale ($1.9 \cdot 10^5$ kg) and the 26 orders of magnitude that result from measuring Earth's surface area at a spatial grain equivalent to bacteria ($5.1 \cdot 10^{26}$ μm^2).

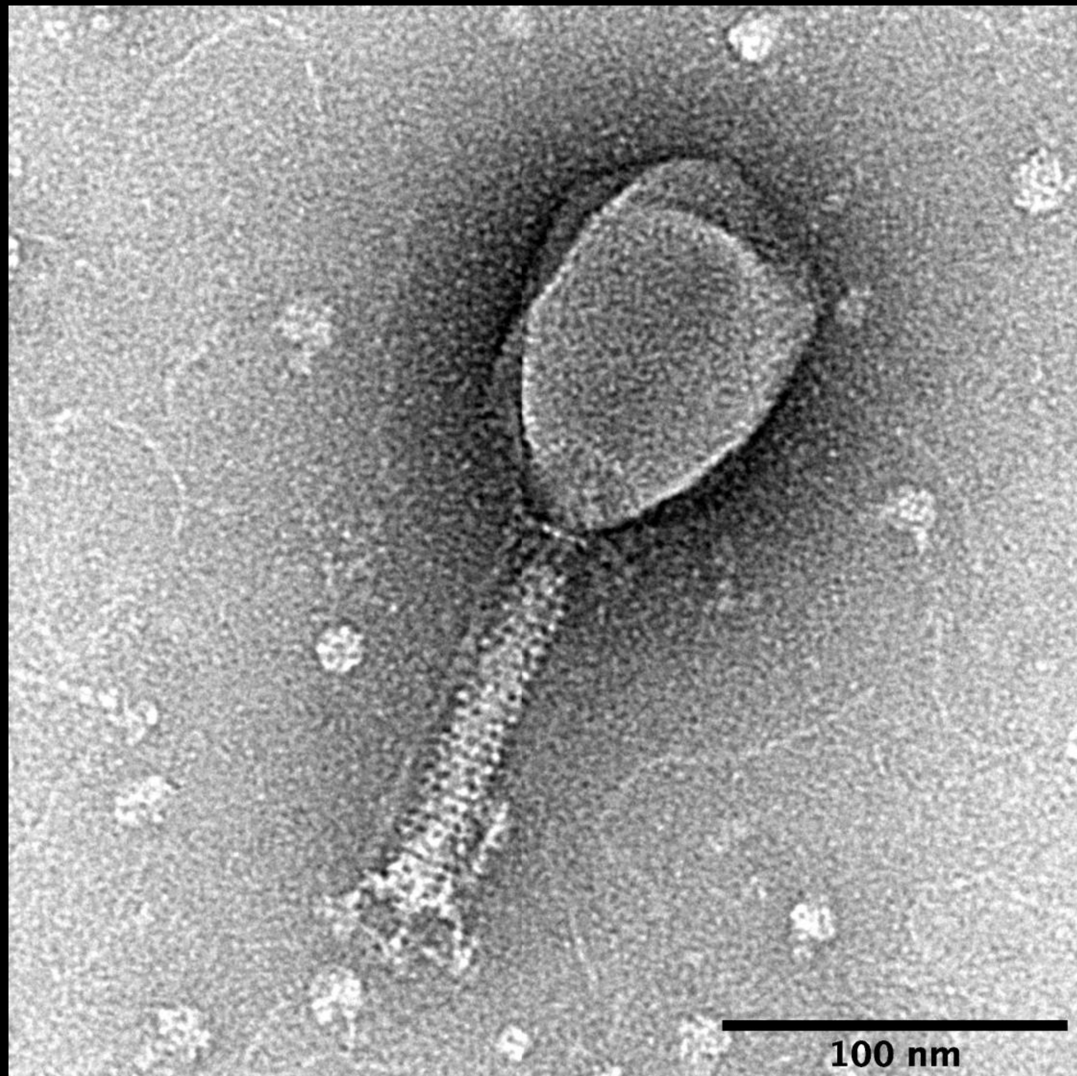
Here, we consider whether N may be one of the most powerful constraints on commonness and rarity and one of the most expansive variables across which aspects of biodiversity could scale. Although N imposes an obvious constraint on the number of species (i.e., $S \leq N$), empirical and theoretical studies suggest that S scales with N at a rate of 0.25–0.5 (i.e., $S \sim N^z$ and $0.25 \leq z \leq 0.5$) (20–22). Importantly, this relationship applies to samples from different systems and does not pertain to cumulative patterns (e.g., collector's curves), which are based on resampling (20–22). Recent studies have also shown that N constrains universal patterns of commonness and rarity by imposing a numerical constraint on how abundance varies among species, across space, and through time (23, 24). Most notably, greater N leads to increasingly uneven distributions

1,000,000,000,000 SPECIES

1,000,000,000,000 SPECIES (IF OFF BY 3 ZEROS, STILL A BILLION)

1,000,000,000,000 SPECIES
(IF OFF BY 3 ZEROS, STILL A BILLION)

JUST *30,000 ARE NAMED*



Electron micrograph of T2 bacteriophage

Two Sets of Intertwined Stories (of our relationship to the rest of life)