OF SHORES & SAVANNAS: EVOLUTIONARY ASPECTS OF ASF NUTRITION

Lora Iannotti, PhD
E3 Nutrition Lab

Aligning the Food System for Improved Nutrition: a focus on ASF
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Presentation Outline

1. Introduction
   - E3 Nutrition Lab
   - Theories & frameworks

2. Evolutionary nutrition & ASF
   - Comparative anatomy: time & space
   - Generating evidence: Ecuador & Kenya

3. Conclusions
   - Summary
   - Other dimensions

E3 Nutrition Lab

Research to identify interventions that promote healthy growth and development in the most vulnerable populations globally, with the following criteria:

Environmentally sustainable

Evolutionarily appropriate

Economically affordable

Theories & Frameworks

- Discordance theory (Eaton & Konner *NEJM* 1985)
  - Human genome evolved to adapt to conditions that no longer exist. Mismatch leading to increases in chronic diseases
- Genome-nutrition divergence (Eaton & Iannotti 2017)
  - Implications of divergence across the entire nutrition spectrum, with overlapping region of poor diet quality
- Shore-based paradigm (Cunnane & Crawford 2014)
  - Archeological evidence (e.g. shell middens) points to emergence of *Homo sapiens* and anthropometric differences in body and brain, driven by shore-based diets
- Savanna & Woodland theories
  - Hominin as hunter on savanna & woodland → grassy woodland (Washburn & Lancaster 1968; Stanford et al. 1999; White et al. 2009)

https://www.allaboutbirds.org/guide/Common_Gallinule/id

https://en.wikipedia.org/wiki/Egyptian_goose

Evidence: where are the clues?

PAST

- Archeological evidence (Kuipers et al. *Nutrition Research Reviews* 2012)
- Biogeochemistry (isotope studies)
- Comparative anatomy (hominins through time)
- Physical anthropology (Leonard *Physiology & Behavior* 2014)

PRESENT

- Hunter-gather ethnographic studies (Cordain et al. *AJCN* 2000)(Eaton *World Rev Nutr Diet* 1997)(Marlowe et al. J of Human Evolution 2014)(Strohle et al. *AJCN* 2010)
- Indigenous and pastoralist communities (Iannotti and Lesorogol *AJPA* 2010; Gallegos et al. *in process*)
- Comparative anatomy with primates (Templeton 2007)
- Observational epidemiology studies (Whalen et al. *AJE* 2014)

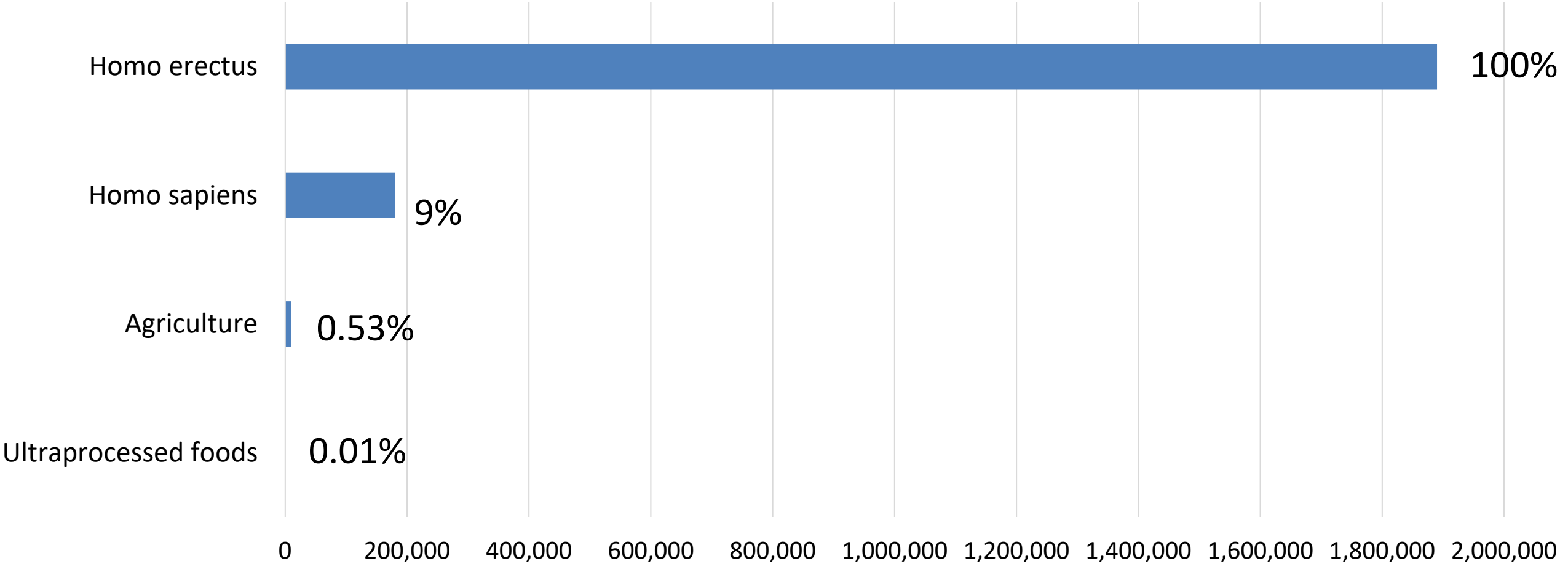
Paleolithic nutrition: nutrient & food differences from today

(Cordain et al. AJCN 2007; Eaton & Iannotti *Nutr Reviews* 2017)

- Protein ↑ [higher % of kcal, 30%] – fish, mollusks, and crustaceans, shore bird and reptile eggs, lean game meat
- Fat ↑ – [higher % of kcal, 36%, different ratios] n-6:n-3=1; DHA↑; cholesterol ↑; fish foods, game meat
- Carbohydrates ↓ [lower % of kcal, 34%] – variety; tubers, fruits & vegetables, and honey; limited grains and no refined sugar
- Micronutrients ↑ – (greater diversity) high levels of wild fruits (e.g. berries), nuts, seaweeds and grasses
- Fiber ↑ - (>100 g/d compared to 20 g/d) variety of fibers, other phytochemicals, flavonoids, plant phenols

- Ultra-processed foods - none

TIME: proportionality in *hominin* history

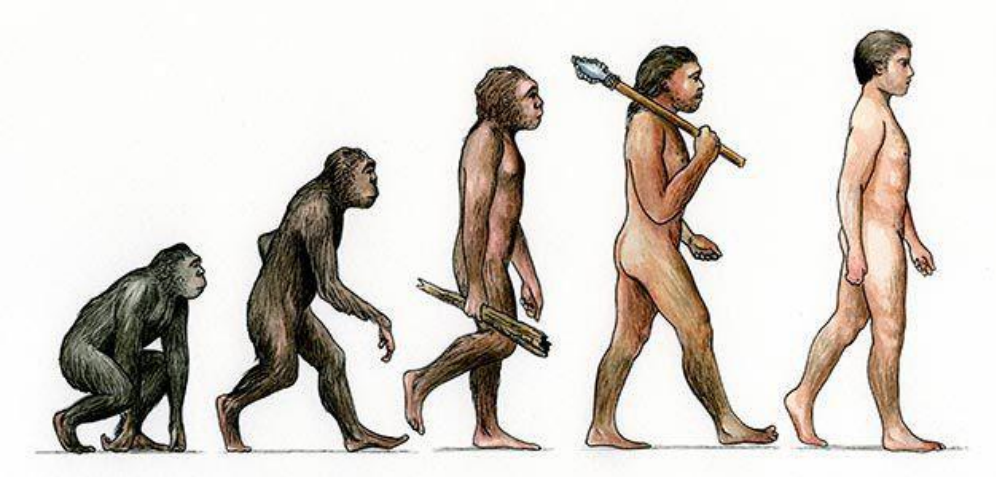


The *Homo* genus: anatomical differences

- *Homo erectus* (early hominin) ~1.8 mya
  - Anatomical differences from other *hominins* (*Australopithecus garhi* & *Homo habilis*), attributable to diet changes - animal source foods in particular.

Physical Differences

- ↑ Brain size – 3x the encephalization quotient (brain mass to body mass) (Broadhurst et al. 1998)
- ↑ Taller height - 15% taller (Walker 1993)
- ↑ Larger body mass
- ↑ Longer legs (bipedalism)
- ↓ Smaller teeth
- ↓ Colon, ↑ small intestine (>56%)



https://www.smithsonianmag.com/science-nature/the-top-ten-daily-consequences-of-having-evolved-72743121/

Brain size increase through evolution

- Encephalization quotient (EQ): brain mass to body mass

- 3.5 mya - 2.0 mya *Australopithicus* ↑20% compared to Miocene hominids
- 2 mya – 200,000 ya *Homo erectus* ↑3x compared to *Australopithicus* (Broadhurst et al.1998)

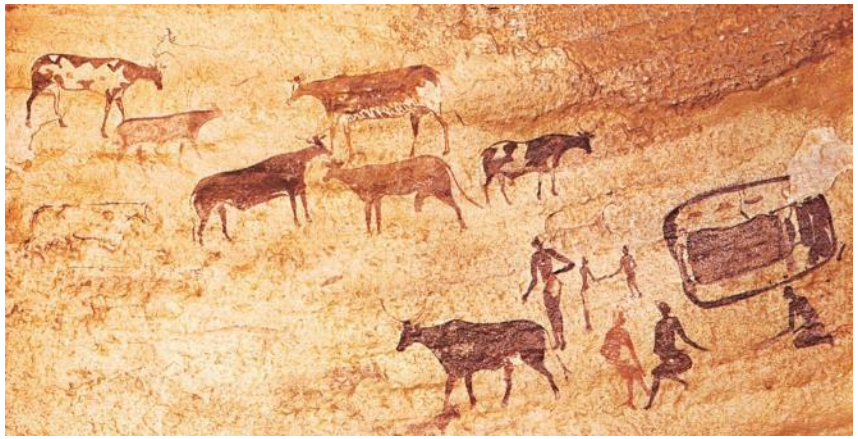
Theories

- Expensive tissue hypothesis (% RMR): gut → brain (Aiello and Wheeler 1995)
- ASF/fish diet brain-selective nutrients and cooking (Cunnane et al. 2010)(Raichle, Iannotti, and Goyal 2018)(Wrangham 2009)
- Social intelligence – shared resources (Dunbar 1998)(Isler and van Schaik 2012)

Advent of Agriculture (~10,000 ya): anthropometric reversions

Offspring numbers increase, by at what cost?

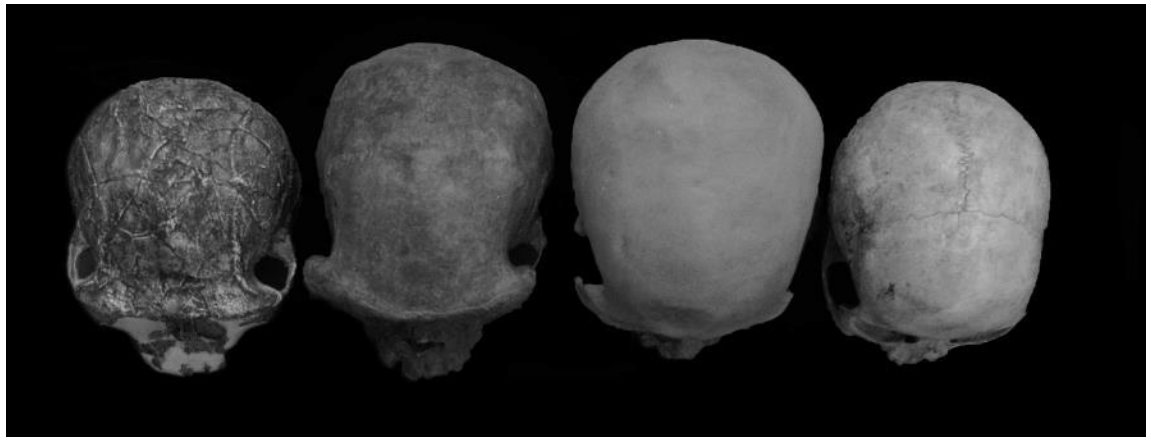
- Life expectancy ↓ from 40 to 20 yr
- Human height ↓
- Infection ↑
- Brain size ↓



http://www.britannica.com/EBchecked/media/106759/Painting-of-herdsmen-and-cattle-Tassili-n-Ajjer-Algeria

Brain size loss

- Both absolute and relative brain size decreased, 10-35 kyr (Ruff et al. 1997; Hennenberg 1988; Hawks 2014)
- Adjusted for reductions in body mass (Hawks 2014)
- Brain size reductions highly unusual in social mammals
- Theories: group cognitive abilities lower (DeSilva et al. unpublished); ASF?

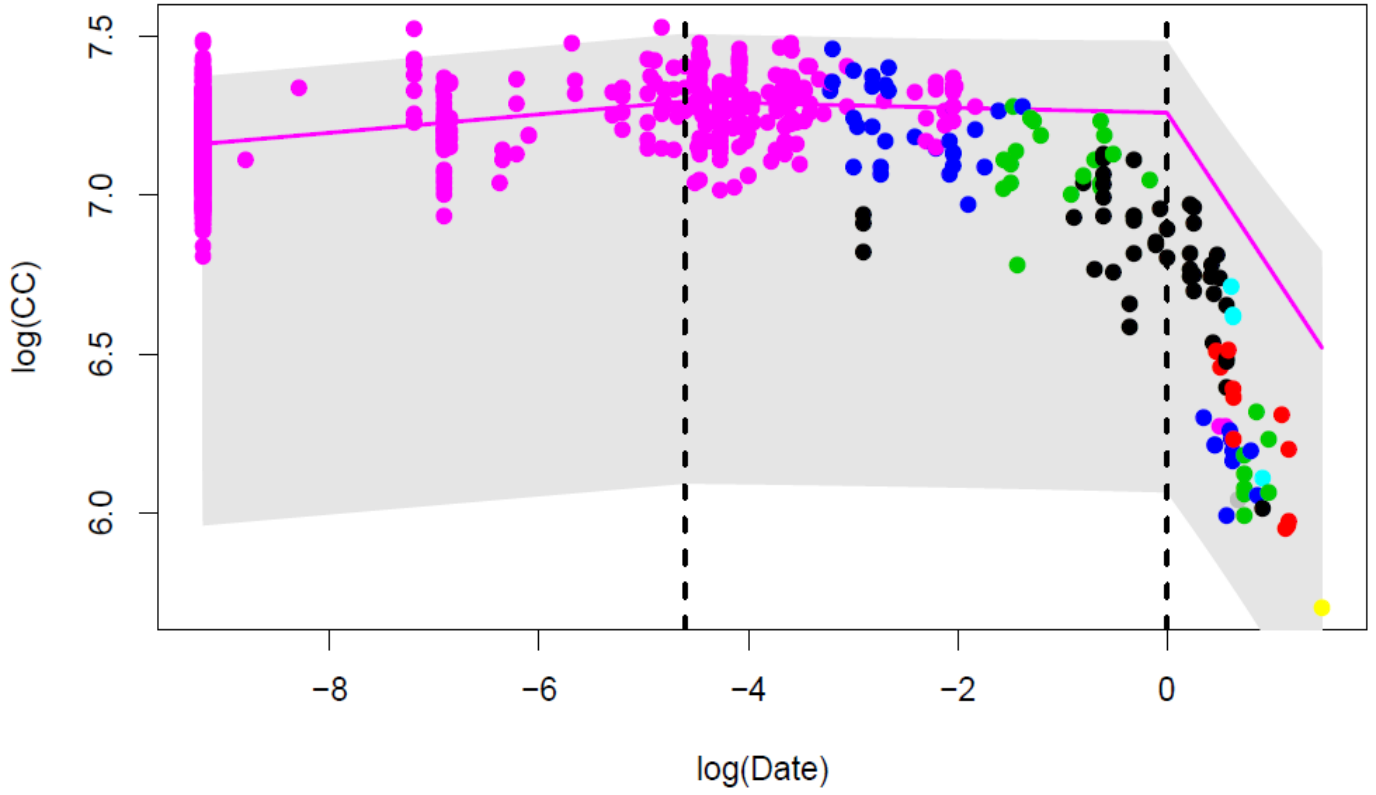


H. erectus (1.6 mya), *H. heidelbergensis* (300,000 ya), *H. sapiens Cro-Magnon* (30,000 ya;), modern *H. sapiens*

(DeSilva et al. unpublished)

Cranial capacity in evolution, by species (DeSilva et al. unpublished)

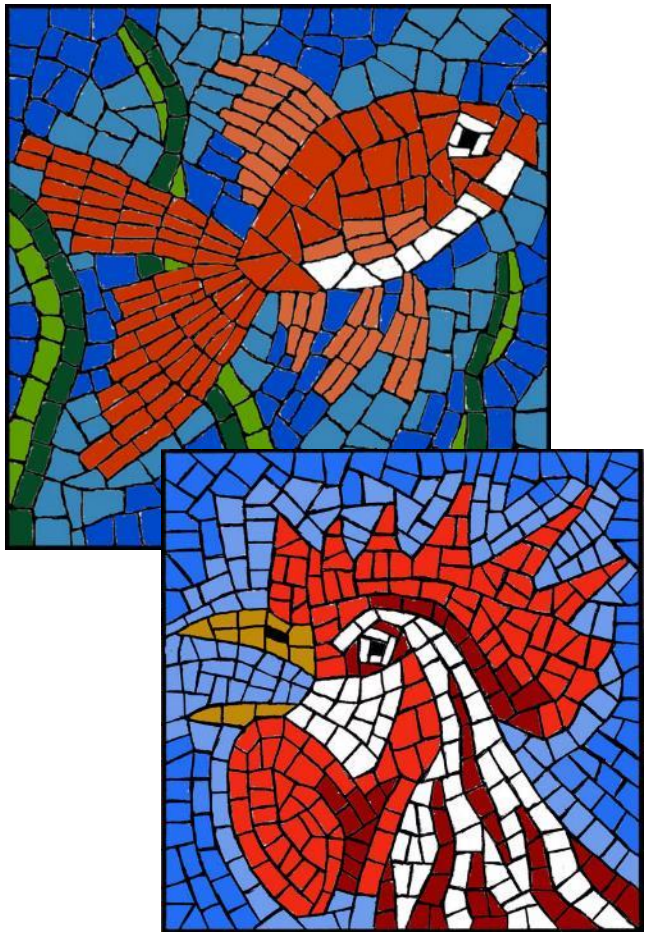
Modern humans (fucia)
Neanderthals (blue)
Heidelbergs (green)
H. erectus (black)
Early *Homo/autralopiths* (red, aquamarine, etc.)
Ardipithecus (yellow)



Mosaic Evolution & Evolutionary Life History

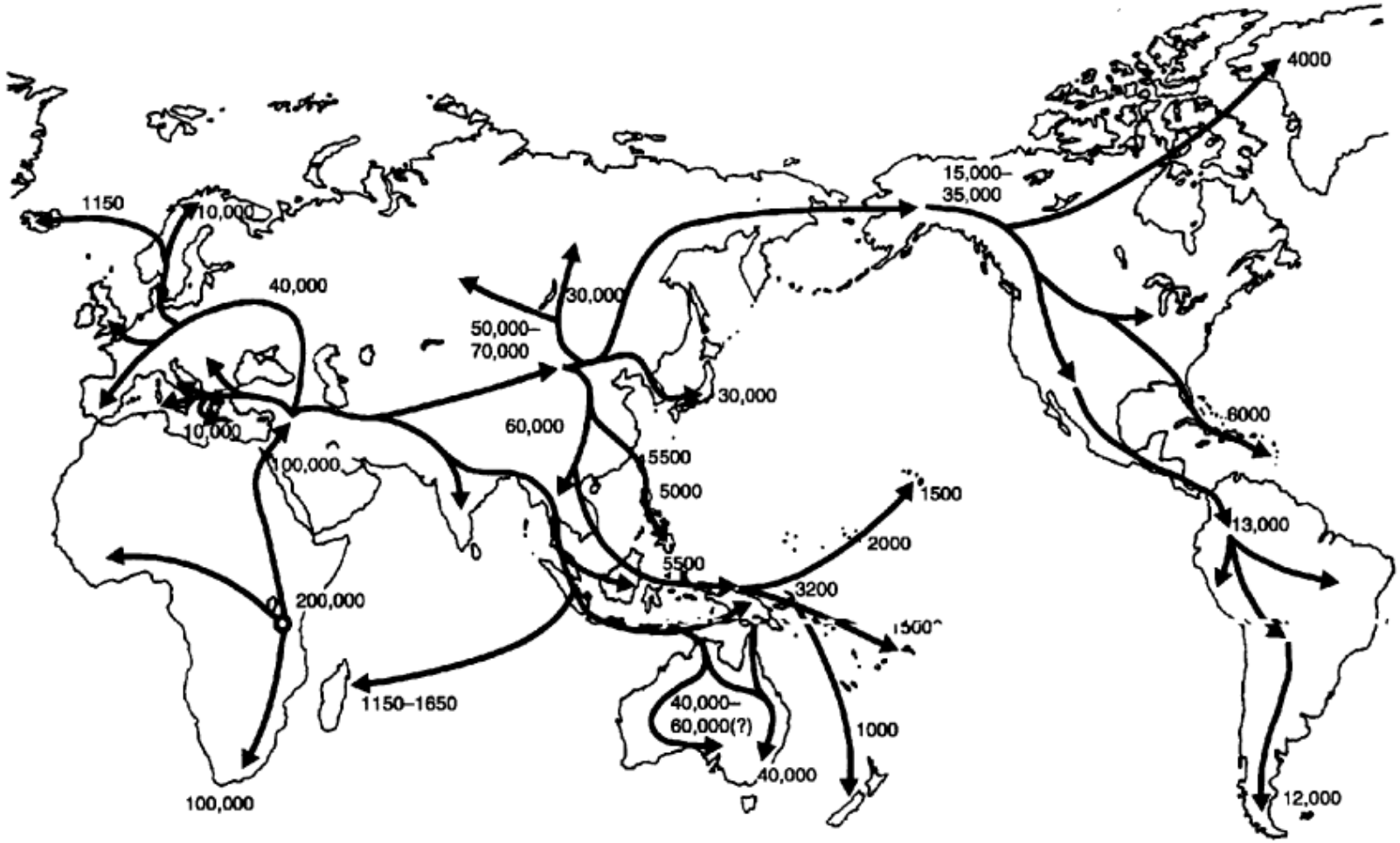
- Mosaic evolution refers to changes in particular body part size or function occurring at varying rates
  - Brain region allometries compared to Pleitocene humans, cerebellum ↑ (Weaver 2005) and parietal lobe ↑ (Holloway et al. 2003; Bruner et al. 2003)
  - Prefrontal and parietal cortices positive allometry, while somatosensory and auditory cortices have negative allometry

- Evolutionary developmental biology
  - Newer field that compares developmental processes in the life history of organisms
  - Diet-driven changes in breastfeeding & complementary feeding periods, birth spacing, age of fertility, and mortality

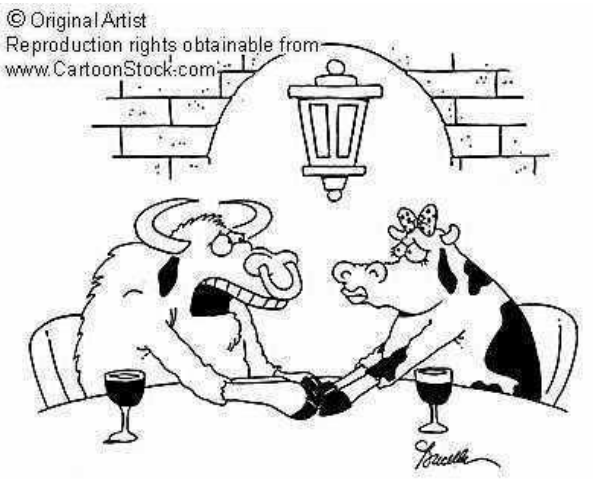


https://mosaicartsupply.com/shop/free-mosaic-pattern-crowing-rooster/

Geochronologic expansion of *Homo sapiens* (Strohle et al. 2010)



MILIEU MATTERS: adaptations



<u>The "Not-so-Glacial Pace of Evolutionary Change"</u>
(Losos, J., *Improbable Destinies* 2017)

- Moths
  - Peppered moth (*Biston betularia)* from speckled gray to black to speckled gray in 100 years, Industrial Revolution and Clean Air Act
- Tilapia
  - Tilapia farmed in Lake Malawi aquaculture now black for camouflage against nets?
- Milk
  - Lactase persistence became prevalent in populations relying on dairy (e.g. Europe) in ~2,000 years

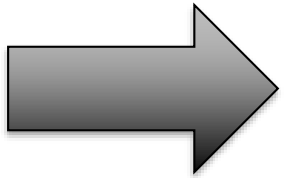
EVIDENCE

Generating evidence – E3 Nutrition Lab

EVOLUTIONARY DIET WITHIN FOOD SYSTEMS

EVOLUTIONARY DIET ELEMENTS (ASF)

- Eggs – Ecuador (Lulun Project); Malawi (Mazira)
- Fish – Haiti (environment), Kenya (small fisher households)
- Milk – Kenya (pastoralists)



- Indigenous food systems - Ecuador
- Macro-level analyses of food systems (FAO food balance sheet data)
- Future - trials to test evolutionary diets across contexts

Pilot study

- Pichincha Province, Ecuador: 4 health centers
- Eligibility criteria: 18+ yr; gestational age 19-28 wk, singleton pregnancy, no complications

- Methods
  - Mixed methods: focus groups, quantitative surveys (SES, pregnancy history, dietary intakes, morbidities)
  - Ultrasound measures by trained radiologists (portable Whale P-series)
    - Standard measures – head circumference, abdominal circumference, femur length, humerus length, biparietal diameter
    - Additional measures – corpus callosal length, thalamic measures, cerebellar diameter, gangliothalamic ovid
  - Z scores standard measures (Saloman et al. 2006), WHO percentiles

Pilot study – Ecuador (preliminary, unpublished results)

-	Mean Z Scores (SD)			WHO Mean Percentiles (SD)		
	Male (n = 25)	Female (n = 20)	All (n = 47)	Male (n = 25)	Female (n = 20)	All Mean (n = 47)
Biparietal Diameter	-0.65 (1.00)	-1.32 (1.19)	-0.95 (1.11)	35 (27.2)	19.75 (23.4)	28.05 (26.22)
Head Circumference	0.45 (0.87)	-0.02 (1.07)	0.26 (0.97)	41 (33.4)	26.50 (24.6)	35.32 (29.9)
Abdominal Circumference	0.06 (0.86)	0.08 (1.00)	0.08 (0.90)	38 (30)	42.75 (27.3)	40.32 (28.05)
Femur Length	-0.21 (0.86)	-0.30 (1.39)	-0.22 (1.10)	39 (29.25)	46.75 (34.75)	43.51 (31.96)
Humerus Length				41.82 (28.29)	34.84 (35.64)	38.44 (30.91)
Estimated Fetal Weight				39.90 (31.75)	45.25 (33.86)	42.61 (31.76)

Gangliothalamic ovoid diameter

Regression modeling:

- measures highly correlated
- head circumference, biparietal diameter, & cerebellar diameter associated with dietary intake of evolutionary nutrition foods (seafood, eggs, roots/tubers)

Evolutionary Nutrition Trial

CHILDREN'S DISCOVERY INSTITUTE℠
ST. LOUIS CHILDREN'S HOSPITAL
WASHINGTON UNIVERSITY SCHOOL OF MEDICINE

<u>RCT with mixed methods</u>

- Mixed indigenous community in peri-urban and rural regions
- Intervention: evolutionary diet 2nd & 3rd trimesters
- Social marketing components for all participants (engagement, compliance) and intervention participants (dietary diversity and no ultra-processed foods)

<u>Outcome variables</u>

- Primary: newborn length
- Secondary: brain regions at 21 wk, 37 wk, and birth; biomarkers of micronutrients and fatty acids at 12 & 37 wk; dietary intakes

<u>Team</u>

USFQ & Wash U → public health nutrition, radiology, neurology, psychology/marketing, engineering, metabolomics

KENYA

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

SecureFish Kenya

- 26% of children <5 yr stunted, but in coastal communities as high as 39%; 47% of population live below the poverty level (DHS 2014; WB 2015)
- Kenyan coastal fisheries overexploited; ↓4x in catch since 1980s (Samoilys et al. 2017)
- Fish Innovation Lab
  - The project seeks to promote natural resource conservation (IR1.1), mitigate risk of food safety (IR 1.2), and improve human outcomes, specifically nutrition (IR1.3). Cross-cutting themes of nutrition, gender, and resilience.

USAID
FROM THE AMERICAN PEOPLE

SecureFISH

- Sampling design
  - Site inclusion criteria: proximity to *Marine Protected Area*; rural vs. urban; and county
  - 6 sites (2 villages each): Beach Management Units divided by coastal highway
  - Fishers (n=100) and non-fishers (n=100)
- Mixed methods
  1) Quantitative survey – child diet/morbidities, child anthropometry measures
  2) Qualitative surveys – in depth interviews with key informants (card sorts, food matrix)
  3) Wildlife Conservation Society data
- Partners: Wash U, University of Rhode Island, Egerton University, Pwani University, MSU

CONCLUSIONS

Summary

- Long, long history of diets that were very different from present: 99.5% of hominin past
  - ↑ASF on shores & savannas (30-65% of kcal), but also dietary diversity
  - Capability to adapt to wide range of environments/foods

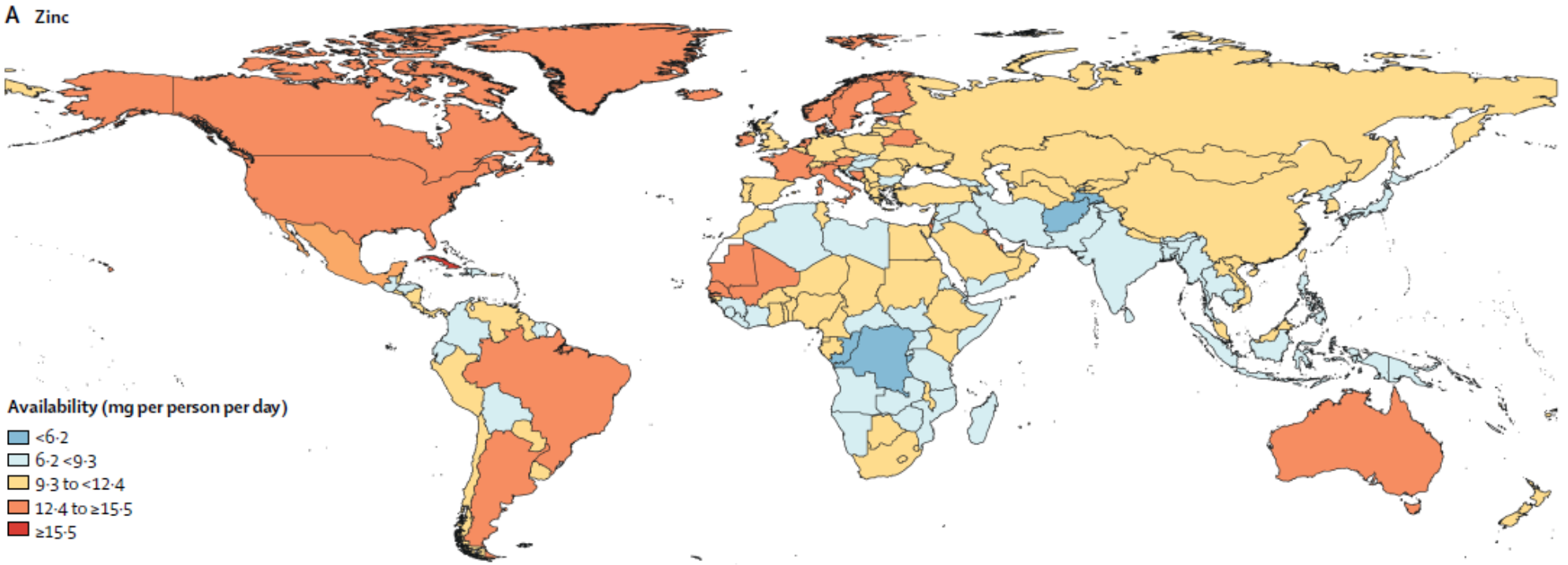
- ASF consumption likely contributor to anatomical differences in evolution
  - *H. erectus* taller, ↑ brain size (3x EQ), etc. attributable to ASF
  - Modern *H. sapien* ↓brain size due to decreases in ASF, seafoods?

- Generating evidence for EN
  - E3 Nutrition Lab & others testing limiting elements of evolutionary diet (eggs, fish, other ASF)
  - Intervention trials, epidemiology studies, transdisciplinary theory development

Scaling EN – other dimensions to consider

How do we feed 7.7 billion, sustainably and well?

Nutrition disparities: zinc availability (*Lancet* Planetary Health series 2018)



Fish consumption, by country strata (FAO 2013):
Industrialized 26 kg/capita, *Developing* (18.8 kg/capita), *Low-income, food-deficit* countries, 7.6 kg/capita

ASF & the environment

- Move away from Anthropocene
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Report
  - 1 million plant & animal species threatened
  - 75% land-based & 66% marine environments significantly altered by human actions
- Respectful adaption; biome-derived diets

https://en.wikipedia.org/wiki/One_Health_Model

Evolutionarily appropriate, Economically affordable, Environmentally sustainable