OF SHORES & SAVANNAS:
EVOLUTIONARY ASPECTS OF ASF NUTRITION

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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)
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

• 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

- **Homo erectus**: 100%
- **Homo sapiens**: 9%
- **Agriculture**: 0.53%
- **Ultraprocessed foods**: 0.01%
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%)

Brain size increase through evolution

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

• 3.5 mya - 2.0 mya *Australopithicus* $\uparrow$20% compared to Miocene hominids

• 2 mya – 200,000 ya *Homo erectus* $\uparrow$3x compared to *Australopithicus* (Broadhurst et al. 1998)

Theories

– Expensive tissue hypothesis (% RMR): gut $\rightarrow$ brain (Aiello and Wheeler 1995)


– 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-Âjer-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/australopiths (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

The “Not-so-Glacial Pace of Evolutionary Change”
(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

“It has nothing to do with you, Bessie. It’s just that I’m lactose intolerant.”
EVIDENCE
Generating evidence – E3 Nutrition Lab

EVOLUTIONARY DIET ELEMENTS (ASF)

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

EVOLUTIONARY DIET WITHIN FOOD SYSTEMS

- 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)

<table>
<thead>
<tr>
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<th>Mean Z Scores (SD)</th>
<th>WHO Mean Percentiles (SD)</th>
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<tbody>
<tr>
<td></td>
<td>Male (n = 25)</td>
<td>Female (n = 20)</td>
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<tr>
<td>Biparietal Diameter</td>
<td>-0.65 (1.00)</td>
<td>-1.32 (1.19)</td>
</tr>
<tr>
<td>Head Circumference</td>
<td>0.45 (0.87)</td>
<td>-0.02 (1.07)</td>
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<tr>
<td>Abdominal Circumference</td>
<td>0.06 (0.86)</td>
<td>0.08 (1.00)</td>
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<tr>
<td>Femur Length</td>
<td>-0.21 (0.86)</td>
<td>-0.30 (1.39)</td>
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<tr>
<td>Humerus Length</td>
<td>41.82 (28.29)</td>
<td>34.84 (35.64)</td>
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<tr>
<td>Estimated Fetal Weight</td>
<td>39.90 (31.75)</td>
<td>45.25 (33.86)</td>
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<tr>
<td></td>
<td>Male (n = 25)</td>
<td>Female (n = 20)</td>
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<tr>
<td></td>
<td>35 (27.2)</td>
<td>19.75 (23.4)</td>
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<td></td>
<td>41 (33.4)</td>
<td>26.50 (24.6)</td>
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<tr>
<td></td>
<td>38 (30)</td>
<td>42.75 (27.3)</td>
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<tr>
<td></td>
<td>39 (29.25)</td>
<td>46.75 (34.75)</td>
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**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

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

Outcome variables
• 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

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

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