"Evolutionary Biology of Diet, Aging, and Mismatch"

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Keywords: Hamiltonian, Age-dependent Adaptation, Drosophila, Diet

Introduction

A variety of anthropologists and physicians claim that the health of present-day humans would be enhanced by reversion to "Paleo" diets [1-4]. Paleo-enthusiasts argue that our recent dependence on foods derived from grass species (e.g. wheat, corn, rice) and milk from ungulates exacerbates such chronic disorders as obesity, type two diabetes, and gut disorders such as Crohn's disease (e.g. [1,2]). On the other hand, Zuk [5] has proposed that there are no health benefits to be achieved from reverting to Paleolithic diets for most inhabitants of industrialized countries, because there has been sufficient time for human adaptation to agriculture.

Our hypothesis is that when adaptation to a novel environment is at least somewhat age-specific, then natural selection will produce more rapid adaptation at early ages compared to later ages, due to the weaker forces of natural selection at later ages [6, pp. 136-40]. Thus when humans with long-agricultural ancestry are young, they are well adapted to agricultural diets and activity patterns. But at later adult ages, with enough age-specificity of the alleles that established our adaptation to agriculture, humans may lose their ability to digest agricultural foods or to cope with the patterns of physical labor characteristic of agricultural life. We call this the "*Hamiltonian hypothesis*".

A Laboratory Paradigm for Testing our Hypothesis

Since the summer of 1981, we have maintained fruit fly (*Drosophila melanogaster)* populations exclusively on medium that contains banana and high-sugar syrups as the chief substrates [7]. The wild *Drosophila* population from which these laboratory populations were derived is that of Northeastern United States; the local agricultural setting is one that has featured apples as the chief cultivated fruit for centuries [8]. Thus we have a laboratory paradigm that features one long-standing dietary regime, dominated by apple rot, being replaced with another long-standing dietary regime, banana with live yeast. To further study patterns of adaptation to novel environments, we imposed a novel dietary regime on these flies. The entirely novel dietary regime features oranges as the chief substrate.

If our hypothesis is correct, then we expect our lab populations to fare as well or better on banana as on apple at early ages. But at much later ages, the flies should do better on apple medium, when adaptation to banana should fade. On the other hand, flies on banana should outperform flies on the evolutionarily novel orange food at early ages. Only at later ages should flies given the banana diet do as poorly as flies given the orange diet.

Experimental Results

Age-specific survivorship (p_x) and fecundity (m_x) were monitored in female flies exposed to the three diets. The product of these two variables ($p_x m_x$) gives an overall estimate of how cohorts of females are functioning at each age.

Banana versus apple diets: Flies performed roughly similarly on the banana and apple diets at ages up to ~26 days from egg (Figure 1; [9]). After that age, flies on the banana diet suffered reduced performance compared to flies on apple medium, with the difference growing with age.

Orange versus banana diets: Flies performed better on the banana diet compared to the orange diet at ages up to ~28 days from egg. After that age, flies on the two diets performed similarly (Figure 2; [9]).

https://jevohealth.com/journal/vol3/iss1/1
DOI: 10.15310/2334-3591.1103

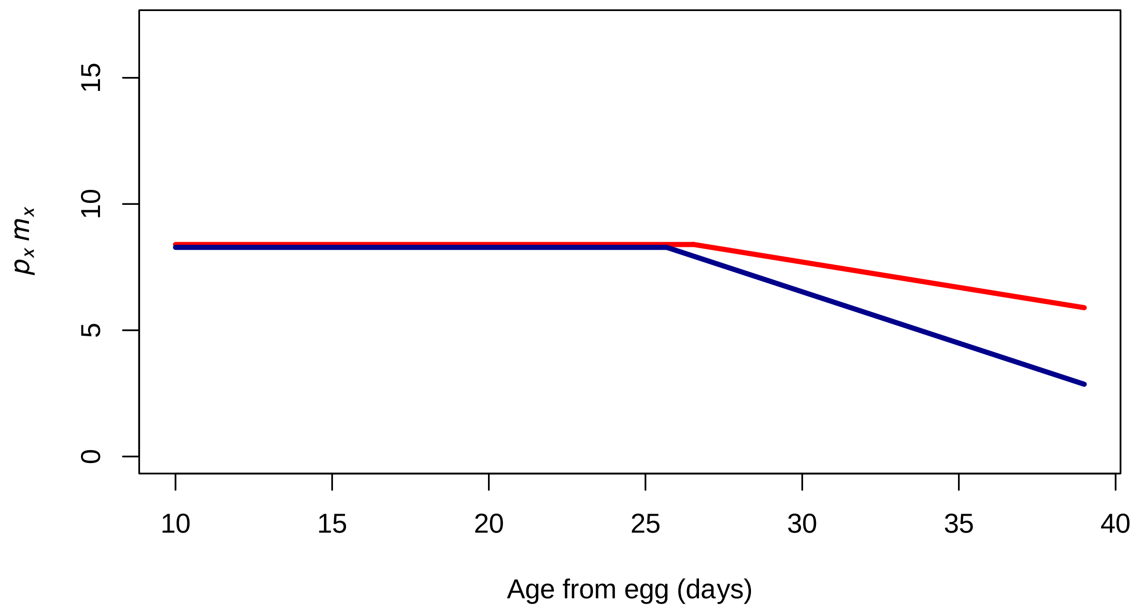

Figure 1. Fly performance (p_xm_x) on the apple and banana diets. Red lines represent linear regressions from the apple-fed flies. Blue lines represent linear regressions from the banana-fed flies. Flies given the apple diet perform similarly at early ages, but significantly better at later ages compared to flies given the banana diet.

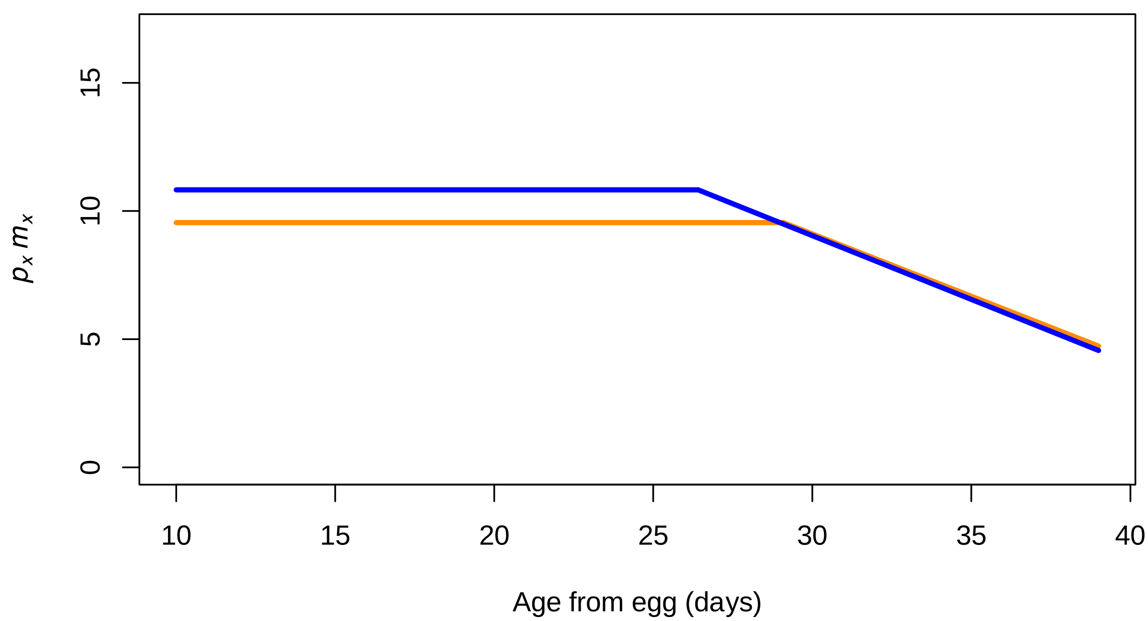

Figure 2. Fly performance (p_xm_x) on the banana and orange diets. Blue lines represent linear regressions from the banana-fed flies. Orange lines represent linear regressions from the orange-fed flies. Flies given the banana diet perform significantly better at early ages, but similarly at later ages compared to flies given the orange diet.

Discussion

The findings displayed in Figures 1 and 2 were obtained from fruit flies that had an inadvertent dietary transition during their evolution. But they still test whether populations show age-dependent adaptation to diet.

As we expected, younger flies fare well on their evolutionarily recent banana diet, while older adult flies fare better on medium that is relatively more like their evolutionarily ancestral apple diet. These experiments show that age-specific adaptation to a novel diet proceeds faster early in life compared to late in adult life.

Our results suggest that young people from populations with long histories of agriculture may be well adapted to agricultural diets. But at later ages, such adaptation to agricultural life may fail.

https://jevohealth.com/journal/vol3/iss1/1
DOI: 10.15310/2334-3591.1103

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