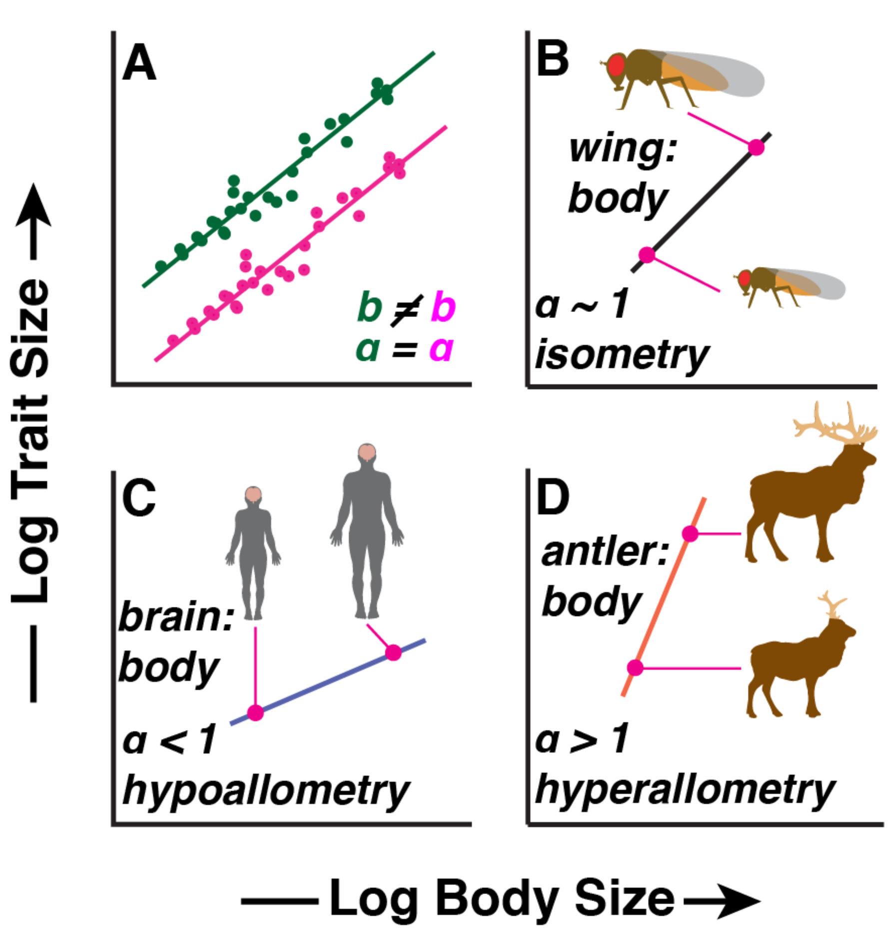
Inter- and intraindividual variation in morphological scaling relationships

Sarah Mai & W. A. Frankino
Biology & Biochemistry

Background

Morphological scaling relationships describe how the size of individual traits (e.g., legs, wings) increase with body size within a species, population, sex, or similar biological group (Figure 1). Scaling is central to ecological function and morphological diversity – in fact, most of the morphological variation among biological groups results from changes in how traits scale with body size. While our group has documented variation among individuals in the same morphological scaling relationships (e.g., variation in the slopes of leg-body size scaling) no study has looked for correlations among slopes of different traits *within* individuals. Such correlations are expected because the same mechanisms control and integrate growth throughout the body. Importantly, if present, such correlations would constrain the independent evolution of scaling among traits.



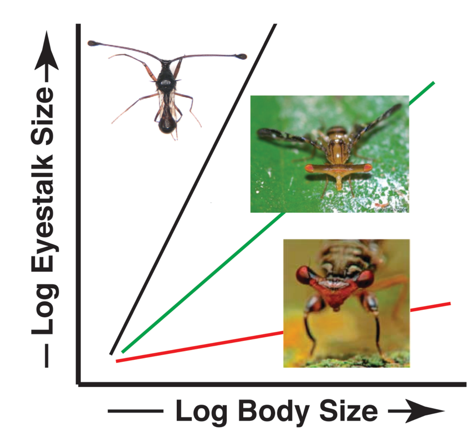


Figure 1. Scaling relationships fit to populations of individuals are described by the equation: log(y) = log(*b*) + α log(x), where y is trait size, x is body size and *b* and α are the intercept and slope, respectively. (**A**) Variation in *b* between populations. (**B**) Large individuals are proportionally magnified versions of small individuals when α ~1, maintaining shape across sizes. (**C&D**) Traits scale disproportionally with the body when $\alpha \neq 1$ and thus shape changes with size. (**E**) Variation in scaling accounts for much morphological diversity.

Results & Discussion

Our diet treatment allowed us to fit a scaling relationship between wing and body size across the full range of size expressed by each genotype (Figure 3). The scaling relationships ranged in slope from hypoallometry (0.82) to strong hyperallometry (1.40) - an impressive difference. Interestingly, these relationships vary even more widely in intercept. Our findings are important because they demonstrate scaling variation among genotypes on which selection could act. However, the degree to which these can evolve is dependent on the correlation in the pattern of scaling among disparate traits; if hypo- or hyperallometric scaling is correlated among traits within genotypes, then these traits will be constrained to evolve as a unit. We are currently measuring different traits (genitalia, legs, palps) to assess this possibility.

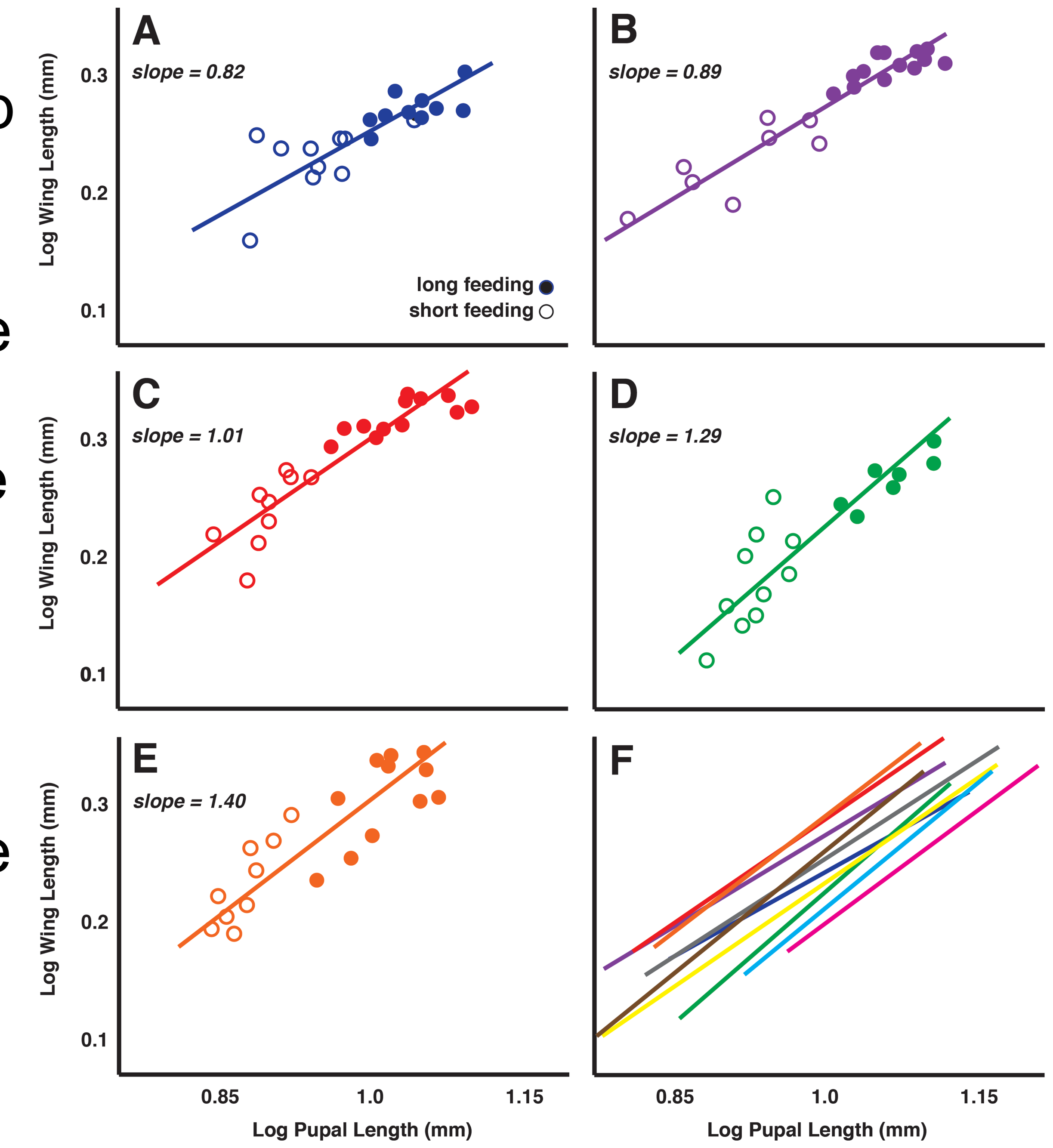


Figure 3. Genetic variation in scaling. (**A-E**) Males differ among genotypes (colors) in how wing size scales with body size. (**F**) Intercepts and slopes vary considerably among 10 genotypes.

Methods

Scaling relationships typically cannot be observed for an individual, as adults express only one size phenotype. We circumvented this problem by rearing flies from populations of genetically identical individuals on food at standard density until late in larval ontogeny, and then removed them from the food at one of two developmental time points to create variation in wing and body size. We then imaged the pupal case (a proxy for body size), wing, and male genitalia using a computer-connected microscope. Size was quantified as shown in Figure 2. Size data were pooled within genotypes across food treatments, log-log transformed, and scaling relationship parameters estimated using major-axis regression.

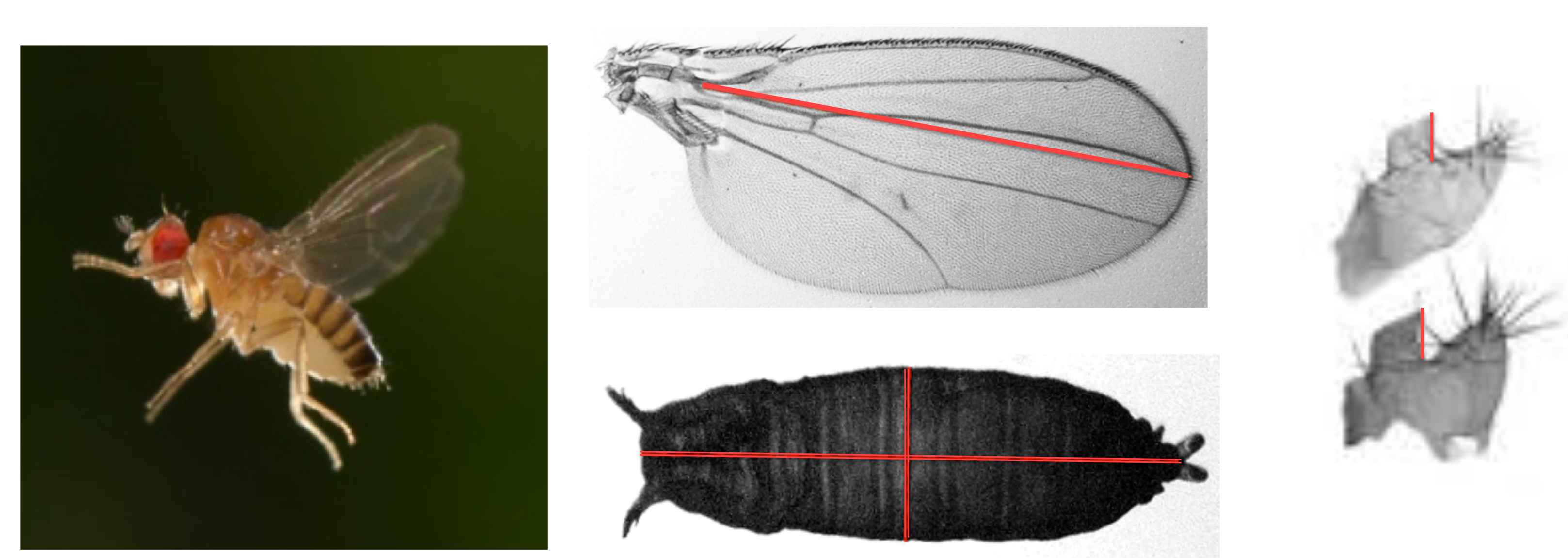


Figure 2. *Drosophila melanogaster* morphology. Pupal (body), wing, and genital arch size were estimated as the distance between landmarks (red lines).