***79.6*** BIDDULPH, T.A.\*; HARRISON, J.F.; Arizona State

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***Oxygen Modulates Density Effects on Body Size in Drosophila***

***melanogaster***

Larval crowding has been shown to reduce body size in *Drosophila*

*melanogaster* but the mechanisms responsible for this effect remain

unclear. While nutritional limitation and larval competition are two

factors that likely play an important role in the determination of body

size, it may be possible that hypoxia occurs in the media at high

densities and this might be a factor in the density effect on body size.

To partially test this hypothesis, *Drosophila melanogaster* were

reared in 10, 21, or 30 kPa oxygen at three densities from egg to

adult. Adults were collected during the first two days after eclosion

began in each treatment and were starved for one day with agar gel to

prevent desiccation before their masses were recorded. There was a

significant interaction between oxygen and density on adult body

mass (two−factor ANOVA, N=146, p > 0.0000001). At low

densities, as seen in prior studies, hypoxia suppressed body size

while hyperoxia had no effect, but at high densities hyperoxia

increased body size and hypoxia had no effect. These results

demonstrate that oxygen needs to be considered as a potential major

factor in causing the reduction of body size in *Drosophila*

*melanogaster* at high densities, and suggest that larval crowding

causes hypoxia in the media. This study was funded by the SOLUR

Program at ASU as well as NSF IOS 1122157 and NSF 0938047.

***20.7*** BORCHERT, JB\*; ANGILLETTA, MJ; Arizona State

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***The games that flies play: laying eggs based on temperature and***

***competition***

We used game theory to predict how fruit flies, *Drosophila*

*melanogaster*, should compete for oviposition sites. Although flies

prefer to lay their eggs within a particular range of temperatures, the

potential for competition among offspring should cause females to

accept warmer or cooler sites when preferred sites become crowded.

To look at this problem, we observed where flies chose to lay eggs

under various densities of competing females. In each trial, 4 or 15

flies were placed within a thermal arena containing a choice of two

oviposition sites, one at a preferred temperature (25°C) and another

at a lower temperature (20°C). In a concurrent trial, 100 eggs were

added to the site with the optimal temperature and then 4 flies were

added to see if behavior depended on the presence of other females

or eggs. After 4 hours, we counted the eggs laid in each portion of

the gradient and analyzed how the distribution of eggs was affected

by the density of females. Flies at low density laid eggs almost

exclusively at 25°C, but those at high density laid a significantly

greater proportion of eggs at 20°C than did flies at low density.

Surprisingly, flies did not avoid laying at 25°C when eggs were

present, suggesting that flies responded to the presence of competing

females rather than cues associated with eggs. By drawing on game

theory to make quantitative predictions, this research builds on

previous empirical

***P2.75*** BORCHERT, JB\*; ANGILLETTA, MJ; Arizona State

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***The games that flies play: effects of temperature and density during***

***development on the fitness of Drosophila melanogaster***

Both temperature and competition can affect the fitness of an

organism. We examined how temperature and competition covary to

affect the fitness of *Drosophila melanogaster*. We transferred either

1, 5, 15, or 30 eggs to a petri dish and maintained them in an

incubator kept at either 16°, 21°, 25°, or 30°C. We then measured

developmental time, survival to adulthood, wing size, and fecundity

to approximate the fitness of drosophila under each treatment. These

data were used to parameterize a game theoretical model that predicts

where flies should

***24.2*** COMBES, S.A.\*; SALCEDO, M.K.; GAGLIARDI, S.F.;

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***Effects of environmental conditions on Drosophila flight***

***performance***

Wild insects inhabit a world of radically varying environmental

conditions, where temperature, humidity and light levels vary

substantially over multiple spatial and temporal scales. While we

understand how many of these factors affect development,

respiration, reproduction and other physiological traits, our

understanding of how environmental conditions affect insect flight

performance remains limited. Here, we examined the effects of

temperature, light intensity and wind speed on the free flight

behavior of fruit flies (*Drosophila melanogaster*), a model species

for laboratory−based flight studies, and also an insect that is likely to

encounter a range of variable microhabitats in the wild. We allowed

lab−reared flies to emerge spontaneously from a vial into a large,

open area (>2 m in each dimension) in either the laboratory or

outdoors. We quantified flight trajectories within a volume of

approximately 1 m3, while recording temperature, visible and UV

light intensity, and wind speed. A variety of locations and weather

conditions were sampled, and multiple flies were tracked during each

release to account for individual variability. We found that flight

velocity was strongly influenced by environmental factors, including

temperature and light intensity, and that saccade (turning) behavior

also varies with environmental conditions. Past studies have

demonstrated a positive relationship between temperature and flight

speed, but the strong influence of light intensity (~2.5−fold increase

in flight velocity from dim lab lighting to bright sunlight) has not

previously been shown. These results have important implications for

interpreting flight data collected in various settings, as well as for the

behavior and ecological interactions of wild insects, which may vary

in their sensitivity to environmental conditions.

***P1.189*** DAVIS, SM\*; ZACHARY, ED; JAMES, TA; LATHAM,

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***Using a sequential y−maze and selective breeding to create***

***Drosophila melanogaster strains with magnetic orientation***

***preferences***

There is some experimental evidence that the fruit fly, *Drosophila*

*melanogaster* uses the Earth's magnetic field as an orientation cue.

The ability to detect and orient using the Earth's magnetic field has

been shown in diverse species, including sea turtles, birds, lobsters,

newts, and sea slugs, yet the cellular basis for magnetosensory

behaviors has remained elusive. If *D. melanogaster* orients to

magnetic fields, the species offers an unprecedented opportunity to

study the genetic basis of magnetic orientation and navigation

because of their status as a model organism. We are going to attempt

to confirm that *D. melanogaster* can orient using the magnetic field

and will do this by creating populations with strong magnetic

orientation preferences using artificial selection. We developed a

maze that allowed us to isolate different individuals with north and

south orientation preferences. Two populations of *D. melanogaster*

were then created through selective breeding: a north−seeking

population and a south−seeking population. We will present the

preliminary results of this orientation and selection research. The

experiment will continue through 15 generations of selection. The

experiment was modeled after a study by Hadler (1964) which was

used to ascertain the genetic basis of phototaxis in *D. melanogaster*.

We are using this

***52.1*** DREYER, AP\*; SHINGLETON, AW; Michigan State

University; *dreyerau@gmail.com*

***Does Size Really Matter? The Effect of Genital Size on***

***Reproductive Success***

From flies to spiders and crabs to beetles, genital size remains near

constant among individuals in a population despite considerable

phenotypic plasticity in body size and the size of other organs.

Several competing hypotheses have been proposed to explain the

selective pressures underlying this commonly observed phenomenon,

however, a lack of experimental data has made it difficult to

distinguish between them. Any comprehensive test of these

hypotheses requires high levels of variation in genital size alone,

which does not exist in natural populations. We have designed a

method to circumvent this problem and test the hypotheses

experimentally. Our design uses targeted gene expression to up− or

down−regulate insulin−signaling in the developing genitalia of

*Drosophila melanogaster* and produce male flies with extreme

genital morphologies. Male flies with proportionally small,

wild−type or large genitalia are then paired with female flies in up to

three contexts; (1) no male competition, (2) direct male−male

competition, (3) indirect male−male competition. Specific aspects of

male reproductive success are measured to compare across the three

genital sizes: courtship and copulation latency, and duration;

post−mating egg production, proportion of fertilized eggs and egg

paternity. Our results suggest that females prefer males with

wild−type size genitalia even though they are physically able to mate

with, and fertilize eggs using sperm from, males that have

proportionally small or large genitalia.

***11.6*** EGGE, AR\*; ELLER, OC; MORGAN, TJ; Kansas State

University; *aegge@ksu.edu*

***Genotype−by−environment interactions of demographic values in***

***fluctuating thermal environments using Drosophila melanogaster***

Organisms often experience a wide range of temperatures in nature,

exhibited by daily and seasonal fluctuations. Ectotherms are

particularly susceptible to these fluctuations and must alter their

physiology in order to survive and reproduce in potentially stressful

conditions. Assessment of egg laying and survivorship at different

temperature regimes provides significant information on how

different genotypes are affected by thermal fluctuations. *Drosophila*

*melanogaster* have adapted to a range of thermal regimes and inhabit

much of the world. They also provide us with a large base of genetic

resources including the *Drosophila melanogaster* Genetic Reference

Panel (DGRP). We chose forty genotypes from the DGRP to assess

absolute lifetime fitness measures at two different fluctuating

environments: 18° ± 6° C and 25°± 6° C (average 18.3° C and 25.3°

C, respectively). Preliminary results indicate significant variation in

survival and egg laying rates among these forty genotypes, which

may lead to significant differences in demographic parameters such

as lambda, net reproductive rate, and generation time. These

parameters are important in assessing long−term population−wide,

genotype−specific survival under natural conditions. Association

mapping of these 40 genotypes will provide candidate genes involved

in these thermally sensitive reproductive values.

***P3.90*** ELLER, OC\*; EGGE, AR; MORGAN, TJ; Kansas State

University; *oceller@ksu.edu*

***Effect of Cooling Rate on the Rapid Cold Hardening Response in***

***Drosophila melanogaster***

Climate is a significant environmental factor that influences the

distribution and abundance of most organisms on Earth. One

constantly changing component of climate is temperature and we are

interested in how organisms respond to stress brought on by

temperature fluctuations coupled with cold stress. *Drosophila*

*melanogaster* is a cosmopolitan species that inhabits many different

environments throughout the world and exhibits a wide−range of

physiological thermal adaptations. Rapid cold hardening (RCH) is a

short−term acclimation response in which an organism is exposed to

a non−lethal cold temperature before being exposed to an extreme

cold temperature. This non−lethal pretreatment improves cold

survival for individuals that have the ability to acclimate over a short

period of time. Previous experiments investigating the RCH response

have directly transferred flies from rearing temperature to

pretreatment to extreme cold exposure. These direct shifts do not

translate to natural conditions where organisms are gradually

exposed to new temperatures. Our goal was to compare experimental

environments of a more natural context to see if or how the RCH

response changed in relation to direct transfer experiments. We used

thermal ramping to cool the experimental environment at two

ecologically natural but different rates and then compared

survivorship after an extreme cold shock between flies that received

a ramping pretreatment and flies that received a direct transfer

pretreatment. Our results indicate that neither the speed of cooling

nor direct transfer pretreatment have a significant effect on an

individual's ability to acclimate and survive extreme cold

temperatures. These results are significant as they demonstrate that

direct and ramping RCH pretreatments are both ecologically relevant

measures of thermal performance.

***P3.89*** EVERMAN, ER\*; MORGAN, TJ; Kansas State University;

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***Age−related change in cold stress tolerance in Drosophila***

***melanogaster***

Organisms occur in environments that vary spatially and temporally

throughout their lifespans. Resistance to cold stress is one important

fitness trait that is expected to decline through ontogeny; however

this general expectation is based on the response of a small number

of genotypes of *Drosophila melanogaster*. To further characterize

this change in cold stress resistance, we performed Rapid−Cold

Hardening (RCH) screens on 49 genetically distinct lines of the

*Drosophila melanogaster* Genetic Reference Panel (DGRP) at early

(5−7 days) and late (20−22 days) age. Consistent with previous

investigations of RCH and the DGRP lines, we observed a wide

range of variation between lines at each age point. In addition, cold

stress resistance differs significantly (p < 0.05) between early and

late aged flies. However, we observed that the direction of the change

in expression of cold stress resistance varies among lines as well,

with several lines increasing in cold stress resistance as they age. The

difference in cold resistance between ages combined with the

difference in direction of the change between lines suggests that cold

stress resistance as characterized by RCH screens is influenced by a

number of complex genetic interactions. To fully characterize these

interactions, we will continue screening the remaining 143 lines in

the DGRP and use association mapping to isolate regions of the

genome that are likely tied to the age−related change in cold stress

tolerance.

***120.1*** FRANKINO, W. A.\*; STILLWELL, R. C.; DWORKIN, I. M.;

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***Tipping the scales: Evolution of the allometric slope independently***

***of average trait size***

The scaling of body parts is central to the expression of morphology

across body sizes and to the generation of morphological diversity

within and among species. Although patterns of scaling relationship

evolution have been documented for over one hundred years, little is

known regarding how selection acts to alter these patterns. In part,

this is because the degree to which the elements of scaling

relationships, mean trait size and the slope, can evolve independently

is not known. Here, using the wing:body size scaling relationship in

Drosophila as an empirical model, we demonstrate that the slope of a

morphological scaling relationship can evolve independently of mean

trait size. Our success is likely due to in part to our employment of a

developmentally−timed diet manipulation to isolate the nutritional

static allometry from the genetic static allometry and to our

application of selection over many (17) generations. We discuss our

findings in the context of how selection likely operates on scaling in

nature, the developmental basis of the integration of mean trait size

and the scaling relationship slope, and the general approach of using

individual−based selection experiments to study the expression and

evolution of morphological scaling.

***129.6*** HATEM, N.E.\*; SUZUKI, Y.; Wellesley College;

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***Regulation of critical weight in the tobacco hornworm, Manduca***

***sexta.***

The regulation of the timing metamorphosis is a critical event in

many organisms. In insects, a size assessment point called the critical

weight marks the time at which metamorphosis is no longer delayed

even when animals are starved. The timing of metamorphosis in the

tobacco hornworm, *Manduca sexta*, is primarily regulated by

juvenile hormone (JH). During the final instar, metamorphosis is

inhibited by JH until the larva reaches the critical weight when JH

titers drop. In contrast, studies have shown that in the fruit fly

*Drosophila melanogaster*, the critical weight is regulated by

nutrition−dependent insulin signaling in the prothoracic gland, the

major site of ecdysteroid biosynthesis. Alterations of prothoracic

gland size through the manipulation of insulin signaling lead to shifts

in the critical weight. In this study, we examined the role of

insulin/TOR signaling in the determination of the critical weight in

*Manduca*. By feeding *Manduca* rapamycin treated diets, we inhibited

TOR signaling in final instar larvae, and the effect on the critical

weight was examined. In wildtype larvae, the peak size was

unaffected when fed rapamycin although the growth rate was

reduced. Critical weight was also unaffected when fed rapamycin.

However, the size of the prothoracic gland at the critical weight was

disproportionately smaller in larvae fed rapamycin. These results

indicate that insulin/TOR signaling does not play a major role in the

determination of critical weight in wildtype *Manduca*. Thus, JH

overrides the nutritionally dependent critical weight regulation in this

species. Our study shows that the critical weight is regulated by two

distinct mechanisms, one that senses body size (mediated by JH) and

another that senses nutritional input (mediated by insulin/TOR

signaling). The relative contribution of these two mechanisms

therefore determines whether body size or nutritional availability

determines the timing of metamorphosis.

***108.5*** LANE, S.J.\*; FRANKINO, W.A.; ELEKONICH, M.M.;

ROBERTS, S.P.; Central Michigan Univ., Mount Pleasant, Univ. of

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***The Effects of Age and Lifetime Flight Behavior on Flight***

***Capacity in Drosophila melanogaster***

The effects of flight behavior on physiology and senescence may be

profound in insects due to the extremely high metabolic costs of

flight. Previous studies have shown that flight capacity decreases

with age, and that flies prohibited from flying had longer lives and

slower age−related loss of antioxidant capacity and accumulation of

oxidative damage in flight muscles. Using *Drosophila melanogaster*,

we tested the effects of age and lifetime flight behavior on wingbeat

frequency, metabolic rate, and the ability to fly in a hypo−dense gas

mixture. Specifically, 5−day old adult flies were separated into three

life−long treatments: (A) those not allowed to fly (no flight), (B)

those allowed − but not forced − to fly (voluntary flight), and (C)

those mechanically stimulated to fly (induced flight). Flight capacity

senesced earliest in flies from the no−flight treatment, followed by

the induced−flight group and then the voluntary flight group.

Wingbeat frequency senesced with age in all treatment groups but

was greatest in the voluntary and induced flight groups. Metabolic

rate during agitated flight senesced earliest and most rapidly in the

induced flight group, and was low and uniform across ages in the

no−flight group. Early senescence in the induced flight group was

likely due to the acceleration of effects such as the rapid

accumulation of damage at the cellular level, while the early loss of

flight capacity and low metabolic rates in the no−flight group

demonstrate that disuse effects can also significantly alter senescence

patterns of whole−insect performance.

***75.3*** LOCKWOOD, B.L.\*; MONTOOTH, K.L.; Indiana University;

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***The consequences of thermal stress on early embryonic***

***development: from cells to the whole−organism***

For ectothermic organisms like *Drosophila*, changes in

environmental temperature alter cellular processes. During early

development, a rapid series of mitotic divisions bring an embryo

from having a single nucleus to having thousands of nuclei, before

gastrulation occurs and cell differentiation begins to take place.

These early mitotic divisions are driven by the cytoskeleton, and

previous work in cell culture has shown the cytoskeleton to be

sensitive to thermal stress. Does thermal variability disrupt

developmental progression by adversely affecting the cytoskeleton?

Here we use confocal fluorescence microscopy to investigate the

effects of thermal stress on the cytoskeleton in vivo in early stage

embryos of *Drosophila melanogaster*. We find that exposure of eggs

to heat stress causes gross defects in cytoskeletal arrangement and

leads to the disruption of mitosis and cellularization of the

blastoderm, both key developmental events. Moreover, brief heat

stress events experienced in early embryogenesis lead to a decrease

in survival to adulthood. These findings suggest that the thermal

sensitivity of the cytoskeleton plays a key role in determining

thermal tolerance at both the cellular and whole−organism levels.

***P2.149*** MCKEE, A\*; NEWTON, S; CARTER, A; California State

University, Long Beach; *biologymajor8@gmail.com*

***Influence of Inbreeding on Female Mate Choice in Two Species of***

***Drosophila***

Many organisms have been reported to choose their mates in order to

increase the heterozygosity of their offspring by avoiding mating

with relatives or homozygous individuals. Most previous studies

using *Drosophila melanogaster* have used artificial chromosomes or

extreme inbreeding treatments, situations unlikely to be matched in

nature. Additionally, few studies have examined the interaction

between female inbreeding status and her choice of mate. Using

females and males from populations that had experienced either

random mating or one generation of sib−sib inbreeding, we measured

the preferences of females for males. Our results indicate that outbred

males were chosen more often than inbred males and that this

preference may be more pronounced in outbred females than in

inbred ones.

***16.1*** RUSSEY, WA\*; FRANKINO, WA; Univ. of Houston;

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***Do clines in Drosophila flight morphology result from adaptive***

***environment−phenotype matching?***

*Drosophila* exhibit convergent genetically−based clines and

phenotypic plasticity in absolute and relative wing size; relative to

warm environments, cooler environments produce large flies with

disproportionately large wings. Although this pattern has been

documented for many insect species on several continents, the

reasons for the pattern remains unknown. The leading hypothesis is

that selection on flight performance across thermal environments

favors the observed patterns in morphology, although data addressing

this hypothesis are scant and the importance of phenotypic plasticity

in producing and maintaining these patterns remains unknown.

Discussed here is a two−part study to (I) impose natural selection on

flight performance in warm and cool environments to create

experimentally derived populations of flies possessing morphology

suited to flight at each temperature, and (II) assess the adaptive

nature of the derived morphologies in ecologically relevant flight

assays. Two experimental evolution studies were performed. In the

first, warm and cool−selected populations were both reared at an

intermediate temperature, removing effects of thermally−induced

phenotypic plasticity. In the second experiment, warm and

cool−flight selected lines were reared such that temperature of

rearing was the same as the temperature of adult flight, providing a

reliable cue during development. The experiments discussed here

rigorously test the hypothesis that selection on ecological

performance has produced a biogeographic morphological pattern

frequently cited as one of the most compelling cases of adaptation

known. In addition, the proposed work will offer general

understanding into how developmentally and functionally integrated

suites of traits might change rapidly under different thermal

***57.3*** SALEEM, S\*; CARNEY, G.E.; Texas A&M University;

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***Sexual experience enhances mating behavior and success of male***

***Drosophila melanogaster***

Competition for mates is a wide−spread phenomenon affecting

individual reproductive success. The ability of animals to adjust their

behaviors in response to changing social environment is important

and well documented. *Drosophila melanogaster* males compete with

one another for matings with females and modify their reproductive

behaviors based on prior social interactions. However, it remains to

be determined how male social experience that culminates in mating

with a female impacts subsequent male reproductive behaviors and

mating success. Here we show that sexual experience enhances

future mating success. Previously mated *D. melanogaster* males

adjust their component courtship behaviors and are able to

out−compete sexually inexperienced males for copulations, when

placed in the same mating arena. Interestingly, courtship experience

alone was not sufficient in providing this competitive advantage,

indicating that copulation plays a role in reinforcing this social

learning. We also show that females use their sense of hearing to

preferentially mate with experienced males when given a choice. Our

results demonstrate the ability of previously mated males to learn

from their positive sexual experiences and adjust their behaviors to

gain a mating advantage. These experienced−based changes in

behavior reveal strategies that animals likely use to increase their

fecundity in natural competitive environments.

***85.4*** SAXENA, N.\*; NATESAN, D.; SANE, S.P.; National Centre

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***Odor tracking behavior of fruit flies in the presence of landmark***

***cues***

Flying insects rely heavily on visual cues for flight. For example,

during pheromone tracking, moths are known to utilize surrounding

visual patterns to maintain upwind heading. Similarly, fruit flies also

require wide−field visual cues to reach the vicinity of the odor source

location. Whereas odor cues in combination with far−field visual

cues may serve to attract a fly towards the general area of odor

source, landmark cues may be important to pinpoint the location of

an odor source. Thus, we hypothesized that the presence of multiple

landmarks or landmarks that are dissociated from odor sources will

elicit a search behavior that is dependent on the distribution of visual

objects. We studied the behavior of the fruit flies, *Drosophila*

*melanogaster* as they honed in on the odor source within a wind

tunnel. Our results show that in presence of multiple closely−spaced

but identical visual cues, flies often make errors in identifying the

exact location of the odor source. Moreover, in experiments where

the odor cues are dissociated from visual cues, flies are often likely to

be attracted to high−contrast visual cues in the vicinity of the odor

cues. Thus, these experiments highlight the importance of landmark

cues in the odor tracking behavior.

***P3.48*** SCHULTZHAUS, JN\*; MOEHLMAN, AT; CARNEY, GE;

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***The role of fit in Drosophila melanogaster starvation response,***

***eating behavior, and lipid storage***

*female specific independent of transformer* (*fit*) expression increases

in *D. melanogaster* courting males and in both sexes after mating. In

contrast, *fit* expression decreases during starvation in males and

females. *fit* expression is enriched in the fat body, an insect tissue

that is analogous to vertebrate fat. The fat body stores excess

nutrients that are mobilized during starvation. This information led us

to investigate how *fit* mutants respond to starvation. We found that

both *fit* mutant males and females are starvation resistant, a

phenotype that is reversed in males by *fit* expression in the fat body.

*fit* mutants may be starvation resistant because they consume more

food than controls prior to starvation. To test this, we monitored the

total amount of food consumed from eclosion until starvation using

the CAFE assay. Another possible explanation for starvation

resistance is either increased storage before or slower use of lipids in

the fat body during starvation. We used Nile Red and Oil Red O to

stain lipids in the fat bodies of fed *fit* mutants and controls to

examine whether the absence of *fit* leads to altered lipid storage. We

also examined the fat bodies of *fit* mutants and controls throughout

starvation to determine when lipid stores are depleted.

***S9.1−5*** WILLIAMS, C.M.\*; SUNNY, N.; EDISON, A.S. ;

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***Nutrient flux through glycolysis and gluconeogenesis and the***

***evolution of cold−stress tolerance in Drosophila melanogaster.***

Ectotherms must maintain energy homeostasis in rapidly changing

thermal conditions; a considerable challenge given that metabolism

comprises a complex suite of processes that differ in their thermal

sensitivities. Cold−adaptation on a broad phylogenetic scale involves

changes to enzymes and pathways that allow them to function more

effectively at low temperatures, but we lack an understanding of the

microevolutionary variation in energy metabolism segregating within

populations that may contribute to cold−stress tolerance. Without an

integrative understanding of this naturally segregating variation, from

the genomic through the physiological to the organismal levels, we

cannot predict the evolvability of cold−stress tolerance, an important

component of predicting the impacts of global climate change. We

hypothesize that susceptibility to cold stress is set by an imbalance

between energy supply and demand incurred at low temperatures,

and that resistance may be conferred by reorganizing metabolic

networks to maintain energy balance more effectively at low

temperatures. Using complementary resources of the *Drosophila*

*melanogaster* Genetic Reference Panel (192 fully−genotyped

isogenic lines), and *Drosophila* lines selected in the laboratory for

fast or slow recovery from a cold−induced coma, we show that

tolerant flies have higher metabolic rates, maintain metabolic

homeostasis more effectively during cold exposure, and show

considerable restructuring of metabolic networks. Using stable

isotopes, we demonstrate a reallocation of nutrients among core

energetic pathways. These alterations to nutrient flux may rebalance

energy supply and demand in the cold, and assist in maintaining

energy balance in the face of changing temperatures.

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