What I do

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University of Texas at Austin
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What I do

Ecology
- Competition
- Predation
- Parasitism
- Climate

Evolution
- Natural selection
- Sexual selection
- Population divergence
- Origin of new species

Traits
- Morphology
- Biomechanics
- Behavior
- Immunology

Adaptation

Genetics
- Genetic mapping
- Genomics
- Gene expression
- Quantitative genetics
- Population genetics

With a healthy dose of mathematics & computer programming
Why does among-individual variation persist within populations?
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Phenotype

Fitness: survival and reproductive success

Frequency

Directional selection
Why does among-individual variation persist within populations?

Phenotype

Frequency

Fitness

survival and reproductive success

Directional selection

Phenotype
Why does among-individual variation persist within populations?
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Stabilizing selection: purges variation, limiting future potential for adaptation

- Fitness (survival and reproductive success)
- Phenotype
- Frequency

Diagram shows a bell curve for fitness and a histogram for frequency, illustrating how stabilizing selection limits variation.
Why does among-individual variation persist within populations?

Phenotype

Frequency

Fitness

survival and reproductive success

Stabilizing selection:
purges variation, limiting future potential for adaptation

Phenotype
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Phenotype

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survival and reproductive success
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Three-spined stickleback

*Gasterosteus aculeatus*

Photo credit: Thor Veen
Stickleback Evolution Virtual Lab

THIS IS PART OF: The Making of the Fittest: Evolving Switches, Evolving Bodies

Summary
This virtual lab teaches skills of data collection and analysis to study evolutionary processes using stickleback fish and fossil specimens.

Start Virtual Lab

Recommend
179 other people found this useful

The Stickleback Evolution Virtual Lab will introduce you to the science and techniques used to analyze the forms and structures of organisms—in particular, the pelvic structures of the threespine stickleback fish (Gasterosteus aculeatus). The lab includes three experiments in which you will collect and analyze data using
Why does among-individual variation persist within populations?

Nobel Laureate, 1973

“Conditioned behavior” & Supernormal stimulus
Why does among-individual variation persist within populations?
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Male's nest depth (meters) vs. Red:Blue ratio of males' throat

- P-value = 0.016
- r = -0.372

Replicated in 3 additional years

Side-welling light gradient

More Blue

More Red
Why does among-individual variation persist within populations?
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Model color: $t = 5.9$, $P < 0.001$
Depth: $t = -1.14$, $P = 0.251$
Color*Depth: $t = -4.57$, $P < 0.001$

Model color: $t = 5.49$, $P < 0.001$
Depth: $t = 8.94$, $P < 0.001$
Color*Depth: $t = -6.82$, $P < 0.001$
Conclusions:

1. We see adaptation to local environment at shockingly small spatial scales
2. It is good to be atypical (enemies ignore you, and nobody eats your food)
3. Both 1&2 promote variation within populations

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You can do this at home or with students!

Materials:
- Go-Pro cameras in waterproof housing
- PVC stand
- 3D printed models
- Your local fish population
How repeatable / predictable is evolution?

Wind back the tape of life to the early days of the Burgess Shale; let it play again from an identical starting point, and the chance becomes vanishingly small that anything like human intelligence would grace the replay.

— Stephen Jay Gould —
How repeatable / predictable is evolution?

Threespine stickleback: many replicate “tapes of life”
How repeatable / predictable is evolution?

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Distance from Lake Gill raker number (PC3)

Morphology PC3 (gill raker number)

Distance downstream from lake (m)

Roberts Lake

Outlet stream

100 m
How repeatable / predictable is evolution?

Genome sequencing, ancestry score vs. Distance downstream from lake (m)

- SNP PC axis score
- Distance downstream (m)

Roberts Lake

Outlet stream

100 m
Phylogeny using 100,000 DNA fragments confirms that (most) adjacent lakes & streams are independent pairs.

Sampled 16 lake-stream pairs.

How repeatable / predictable is evolution?
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More Parallel (divergent in same direction) →

More Idiosyncratic (divergent, but inconsistently) →
How repeatable / predictable is evolution?

We use trigonometry & linear algebra to measure parallel evolution.
How repeatable / predictable is evolution?

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We use trigonometry & linear algebra to measure parallel evolution

Trait 1

Trait 2
How repeatable / predictable is evolution?

We use trigonometry & linear algebra to measure parallel evolution.
How repeatable / predictable is evolution?

We use trigonometry & linear algebra to measure parallel evolution.
How repeatable / predictable is evolution?

We use trigonometry & linear algebra to measure parallel evolution.
Lake/stream differences are sometimes parallel, often not.
How repeatable / predictable is evolution?

Genome resequencing of >800 individuals also shows variation in genetic parallelism
How repeatable / predictable is evolution?

Parallelism of lake-stream divergence vs Genomic location
Conclusions:

1. Lake and stream stickleback rapidly evolved genetic and phenotypic differences

2. This evolutionary divergence is repeatable... sometimes, for some traits or genes

3. Even the non-parallel evolution is predictable, it turns out...
How do hosts evolve to resist parasites?

Why me???
How do hosts evolve to resist parasites?

Threespine stickleback & friends

Common Stickleback Parasites

Image by Kim Ballare
How do hosts evolve to resist parasites?
Research vignette #3
How do vertebrates fight parasite infection?

![Graph showing the proportion of infected fish from 2004 to 2014 for Roberts Lake and Gosling Lake.]

Warning: parasite images coming up.
Research vignette # 3
How do vertebrates fight parasite infection?

Warning: parasite images coming up
Research vignette # 3
How do vertebrates fight parasite infection?

![Graph showing the proportion of infected fish over time for Roberts Lake and Gosling Lake. The graph indicates a decline in infection rates for Gosling Lake, while Roberts Lake remains consistently low.](image)
Research vignette # 3
How do vertebrates fight parasite infection?

Cestode mass log(mg)

Host genotype

Gosling
Gosling backcross
F2 hybrid
Roberts backcross
Roberts

15
17
35
27
9
NS
Research vignette # 3
How do vertebrates fight parasite infection?

Immunology

Transcriptomics

- Population
- Exposed
- Infected

- 3'23 prerniosome
- 3'93 small nuclear ribonucleoprotein complex
- 874 autosomal
- 126 small nuclear ribonucleoprotein complex
- 1375 spindles
- 2739 mitochondrial part
- 1677 mitochondrial matrix
- 5024 mitochondrial membrane
- 1762 plasma membrane protein complex
- 78436 plasma membrane part
- 4123 plasma membrane region
- 512 nucleus outer boundary
- 294/107 vacuolar part
- 59264 cytoskeleton
Parasite counter-adaptations: eliminating host B-cell germinal centers
How do vertebrates fight parasite infection?

B-cell immunosuppression is rapidly co-evolving
Why I do this

Practical applications:

- Determining how vertebrates suppress tapeworm growth
- Learning how tapeworms suppress host immunity could yield new drugs
- Maintenance of variation is crucial for conservation biology & agriculture
Why I do this

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- Determining how vertebrates suppress tapeworm growth
- Learning how tapeworms suppress host immunity could yield new drugs
- Maintenance of variation is crucial for conservation biology & agriculture

But really....
Diversity of form
and function
# 1: A love of & fascination with the natural world
If predators have a linear functional response, convert the consumed prey into offspring with efficiencies \(e_i\) and experience a per-capita mortality rate \(d\), then the fitness of a predator with phenotype \(x\) is

\[
W(x,N_1,N_2) = \sum_{i=1}^{2} e_i a_i(x) N_i - d
\]

and the mean fitness of the predator population is

\[
\overline{W}(\tilde{x},N_1,N_2) = \int_{-\infty}^{\infty} W(x,N_1,N_2) p(x,\tilde{x}) \, dx
\]

\[
= \sum_{i=1}^{2} e_i a_i(\tilde{x}) N_i - d.
\]

In the absence of the predator, each prey species exhibits logistic dynamics with intrinsic rates of growth \(r_i\) and carrying capacities \(K_i\). Under these assumptions, the ecological and evolutionary dynamics of our system are

### Results

**Pairwise predator-prey dynamics**

When there is only a single prey species, say species \(i\), in the system and \(\sigma_i > 0\), the mean predator phenotype evolves to \(\tilde{x} = \theta_i\), which maximizes \(\overline{W}\). The predator coexists with the prey species provided that it can invade when the predator’s reproductive number at the prey’s carrying capacity is greater than 1, i.e.,

\[
\frac{e_i K_i \sigma_i \tau_i}{d \sqrt{\sigma_i^2 + \gamma_i^2}} > 1.
\]

When this occurs, the predator-prey pair approaches a globally asymptotically stable equilibrium given by

\[
\hat{N}_i = \frac{d \sqrt{\sigma_i^2 + \gamma_i^2}}{e_i \sigma_i \tau_i}
\]

\[
\hat{P}_i = r_i \frac{\sqrt{\sigma_i^2 + \gamma_i^2}}{\sigma_i \tau_i}(1 - \hat{N}_i/K_i).
\]

Eq. 3 implies that increasing phenotypic variation of the predator reduces top-down control (i.e., \(\hat{N}_i\) increases with \(\sigma_i^2\)) and reduces the predator’s reproductive
I used to think correlation implied causation.

Then I took a statistics class. Now I don't.

Sounds like the class helped. Well, maybe.
Skills & knowledge

# 4: Computer programming
Skills & knowledge

# 5: Writing & Editing
Opportunities

Summer Research Experience For Teacher (RET) Internships

“DataNuggets” – data files for teaching statistics & graphics
Opportunities

College of Natural Sciences STEM outreach offerings include:

Science Under the Stars

Fun with Chemistry

Astronomy Star Parties

High School Summer Research Academy

College of Natural Sciences camps & podcasts

Explore UT – March 5

To learn more: https://cns.utexas.edu/outreach
We train PhD scientists to do cutting-edge integrative research in topics including:

- Biodiversity
- Conservation
- Genomics
- Computational Bio.
- Epidemiology

Our graduates achieve satisfying jobs such as:

- University Faculty
- College Faculty
- Museum Curators
- Science writers
- Data Analysts
- Research scientists for industry and government

We seek motivated young scientists who are interested in a diverse, challenging and supportive graduate training experience.

The University of Texas at Austin
College of Natural Sciences
Research vignette # 1
Adaptive variation WITHIN populations

Do males adjust their color to fit their nest depth?

Nesting males transferred to randomly assigned depth
Research vignette # 1
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Do males adjust their color to fit their nest depth?

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Research vignette # 1
Adaptive variation WITHIN populations

![Graph showing changes in red:blue ratio of males' throat before and after with time and depth effects.](image)

- Orange: UV ratio
  - Before: 1.5
  - After: 2.0
- Red: Blue ratio of males' throat
  - Before: 1.5
  - After: 2.0

- Time*Depth P = 0.004

- Deep (N=18)
- Shallow (N=17)
Career Path

Outdoor-oriented childhood
Career Path

Outdoor-oriented childhood
Collecting plants with botanists Janice and Ed Shwab
Northern Zambia, spring 1991
Career Path

Williams College, Williamstown MA
BA in Biology & Environmental Science
Organized the Williams College Natural History Club
Published a book on the geology & biology of the local research forest
Career Path

US Peace Corps Tanzania

Taught A-level Biology & Applied Maths
Same Secondary School
Kilimanjaro Region, Tanzania
Career Path

PhD, Population Biology
University of California at Davis
Career Path

PhD, Population Biology
University of California at Davis
Career Path

Professor at UT Austin
2004 - present
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2004 - present