Macroevolution by the Generation of Variation with application to culture

Julian Z. Xue

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Presentation overview

Long term evolutionary trends by mutation bias

Cultural Evolution
Presentation overview

- A theory of long term evolutionary trends
Presentation overview

• A theory of long term evolutionary trends
• Applied to culture
Macroevolution
by the
Generation of
Variation

The Modern Synthesis

Evolution has two phases:
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- Generation of heritable phenotypic variation
The Modern Synthesis

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- Differential reproduction among different variants
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The Modern Synthesis

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- Generation of heritable phenotypic variation
- Differential reproduction among different variants

The Modern Synthesis:
- Natural selection is the major driver of evolution
- Drift is important in small population
- Macroevolution is the extension of many microevolutionary events
- Similar assumptions underly memetics and related theories
We might conclude that...

The generation of variation is unimportant in evolution
We might conclude that...

The generation of variation is unimportant in evolution
- Determines rate of population response to natural selection
We might conclude that...

The generation of variation is unimportant in evolution
  • Determines rate of population response to natural selection
    • Fisher’s Fundamental Theorem
    • Price Equation
Thesis:

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Thesis:

Generation of variation can direct long term trends in evolution
Modeling framework is borrowed from Adaptive Dynamics [Metz et al., 1996]
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- Large, finite, homogeneous, clonal population
Modeling framework is borrowed from Adaptive Dynamics [Metz et al., 1996]

- Large, finite, homogeneous, clonal population
- At rare intervals, introduce a mutant

Modeling framework:

- Large, homogenous population
- Introduction of rare mutant
- Mutant either goes extinct or drives previous population to extinction
- At rare intervals, introduce another mutant
Modeling framework is borrowed from Adaptive Dynamics [Metz et al., 1996]

- Large, finite, homogeneous, clonal population
- At rare intervals, introduce a mutant
- Wait until mutant goes extinct or drives previous population to extinction
Modeling framework is borrowed from Adaptive Dynamics [Metz et al., 1996]

- Large, finite, homogeneous, clonal population
- At rare intervals, introduce a mutant
- Wait until mutant goes extinct or drives previous population to extinction
- Introduce another mutant
Long term trends in evolution
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Can we explain this trend non-teleologically, without recoursing to “complex is better”? 
Question and answers

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2. McShea and Brandon: complexity does not affect fitness, growth in complexity is a drift upwards [McShea and Brandon, 2010]
Can we explain this trend non-teleologically, without recoursing to “complex is better”?


2. McShea and Brandon: complexity does not affect fitness, growth in complexity is a drift upwards [McShea and Brandon, 2010]

Long term evolutionary trends without need for neutrality

I propose a mechanism for long term evolutionary trends for traits that
Long term evolutionary trends without need for neutrality

I propose a mechanism for long term evolutionary trends for traits that

- Affects fitness
Long term evolutionary trends without need for neutrality

I propose a mechanism for long term evolutionary trends for traits that

- Affects fitness
- May explain trends in complexity (however measured)
I propose a mechanism for long term evolutionary trends for traits that

• Affects fitness
• May explain trends in complexity (however measured)
• Not limited to complexity
Traits in a complex organism

Standard theory
Traits in a complex organism
Traits in a complex organism
Traits in a complex organism
Traits in a complex organism

Many other traits
Traits in a complex organism

- Many other traits

![Fitness distribution](image1)

- Marginal fitness $\phi=9$

- Fitness distribution $\phi=9$

- Marginal fitness $\phi=8$

- Fitness distribution $\phi=8$

- Density

- Marginal fitness $\phi=9$

- Fitness distribution $\phi=9$

- Marginal fitness $\phi=8$

- Fitness distribution $\phi=8$
Traits in a complex organism

- Long term evolutionary trends by mutation bias
- Cultural Evolution
What trait value will sweep next?

- Marginal fitness \( \phi=9 \)
- Marginal fitness \( \phi=6 \)
- Fitness distribution \( \phi=9 \)
- Fitness distribution \( \phi=6 \)
What trait value will sweep next?

From which distribution will the organism with maximum fitness come from?
What trait value will sweep next?

From which distribution will the organism with maximum fitness come from?

Choose 1000 times
What trait value will sweep next?

From which distribution will the organism with maximum fitness come from?

Choose 1000 times

Choose 10 times
What trait value will sweep next?

Standard theory
- $\phi = 6$, with higher fitness will invariably sweep next
What trait value will sweep next?

Standard theory

- $\phi = 6$, with higher fitness will invariably sweep next

This theory

- It depends on how many times each trait value is drawn
What trait value will sweep next?

Standard theory

• $\phi = 6$, with higher fitness will invariably sweep next

This theory

• It depends on how many times each trait value is drawn
• 1000 draws from $\phi = 9$ may draw a larger fitness than 10 draws from $\phi = 6$
What trait value will sweep next?

Standard theory

• $\phi = 6$, with higher fitness will invariably sweep next

This theory

• It depends on how many times each trait value is drawn
• 1000 draws from $\phi = 9$ may draw a larger fitness than 10 draws from $\phi = 6$
• Analyze with extreme-value theory
Long term consequences for population fitness
Long term consequences for population fitness

- If environment did not change, fitness steadily increases until no more sweeps
Long term consequences for population fitness

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- If environment change, model by reverting back to mean fitness
Long term consequences for population fitness

- If environment did not change, fitness steadily increases until no more sweeps
- If environment change, model by reverting back to mean fitness
- Long term fitness may decrease
Numerical simulations
Numerical simulations
Numerical simulations

Choose 10,000 times

Choose 100 times
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Numerical simulations

Choose 10 times (mutation bias)
Choose 100 times (no mutation bias)
Choose 10000 times
Choose 100 times
Numerical simulations

Choose 10 times (mutation bias)

Choose 100 times (no mutation bias)

Choose 10000 times

Choose 100 times

Mutation bias (10x)
Numerical simulations results

Create evolutionary trends

Crash fitness
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Presentation overview

Long term evolutionary trends by mutation bias

Cultural Evolution

Trend is nearly independent of pattern of environmental change
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Standard theory

• How a trait changes over time depends on the history of how environment (selective pressure) changed
Trend is nearly independent of pattern of environmental change

Standard theory

- How a trait changes over time depends on the history of how environment (selective pressure) changed

This theory

- In almost every new environmental challenge, the trait value that draws more phenotypes is likely to win, even if it has lower marginal fitness
Trend is nearly independent of pattern of environmental change

Standard theory

- How a trait changes over time depends on the history of how environment (selective pressure) changed

This theory

- In almost every new environmental challenge, the trait value that draws more phenotypes is likely to win, even if it has lower marginal fitness

*Fitness over time does not have to decrease, it simply does not very much matter...*
Irreversible division of labor
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- Rare event: a group of identical individuals come together and form a “super-organism”
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Irreversible division of labor

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```
5 1 6 2 9 -> 0 0 0 0 0
```

- Far more mutations to super-organisms with diverse components than mutations to super-organisms with identical components
- Diversity increases even if decreases fitness
- Very different organisms can have the same internal diversity
Agent-based simulation
Other applications

Appliable to any trait that we have reason to suspect mutation bias
Other applications

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- Number of traits in an organism
Other applications

Appliable to any trait that we have reason to suspect mutation bias

- Number of traits in an organism
- Many more ways to add a trait than to subtract a trait
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- Number of traits in an organism
  - Many more ways to add a trait than to subtract a trait
  - Imagine a lineage of organisms with 10 traits...
Other applications

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  - Only 10 ways to remove a trait!
Other applications

Appliable to any trait that we have reason to suspect mutation bias

- Number of traits in an organism
  - Many more ways to add a trait than to subtract a trait
  - Imagine a lineage of organisms with 10 traits...
  - Only 10 ways to remove a trait!

- Things that are necessary to an organisms will “diffuse” throughout organism, making them harder to remove
Relation to existing theory
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Observers of evolution would notice:

• Every evolutionary event is due to natural selection
• There is a long term trend in some evolutionary traits

Observe may conclude that the trend is driven by natural selection

• This conclusion would be wrong

Right now we deny this conclusion by denying the existence of trends...
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Answers to objections
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- This is not “just” hitchhiking (traits are only good or bad in some context!)
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Answers to objections

- This is not "just" hitchhiking (traits are only good or bad in some context!)
- This mechanism DOES breakdown in sexual reproduction (unless strong assortive mating)
  - But mechanism WILL work across speciation events and over lineages
What does this have to do with culture?
What does this have to do with culture?
Alexis de Tocqueville

*Everywhere we look, the various events of people’s lives have turned to the advantage of democracy; all men have helped its progress with their efforts... ...some despite themselves, some unwittingly, like blind instruments in the hand of God.*
Great historical trends
Great historical trends

...exist
Great historical trends

...exist

Would be expected if this mechanism operated for culture (beliefs, ideas, practices)
Great historical trends

...exist

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Would proceed in the way Tocqueville described it (all men have helped its progress...)
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Great historical trends

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The great driver will be

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- But how ideas are created
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*The Spirit of the Age*
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An application
An application

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- How many "good" theories are there?
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- If many – then I finding a good theory of evolution not driven by natural selection means little
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- Saving grace: unlike fitness, the “goodness” of a scientific theory does not (usually) decay
- Theory can continue to get better while being ideologically driven
- But at least they get better... (Khun vs. Popper)
Open questions

For both biology and culture:
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- Biology: we know how mutations act genetically, no idea of genotype to phenotype map (that’s why evo-devo is so important!)
Open questions

For both biology and culture: How is novelty generated?

- Biology: we know how mutations act genetically, no idea of genotype to phenotype map (that’s why evo-devo is so important!)
- Culture: mostly no clue (increased division of labor?)
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